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# ABSTRACTS

## SICB 2025 Annual Meeting Abstracts

### Effects of perchlorate on mice behavior

*Carly Abelson, Michael Minicozzi*

Perchlorate is a common pollutant found in surface and ground water of industrialized countries because of its oxidative properties. This chemical inhibits the body's ability to make thyroid hormone which can lead to hypothyroidism. Hypothyroidism is associated with developmental, behavioral, and metabolic abnormalities in humans and other animals. We aimed to study the effects of perchlorate on mouse behavior with an elevated plus-maze. This maze has two arms enclosed by walls and two open tracks raised high above the ground. At weaning, mice were exposed to 100 parts per million (ppm) perchlorate via drinking water or not exposed to perchlorate (0ppm), for 50 days. After exposure, mice were transferred to a filming room, acclimated for 30 minutes, placed in the middle of the elevated plus-maze, and recorded from above for ten minutes while they explored the maze without external stimuli. These recordings were analyzed with EthoVision for the time spent in each arm, how far they traveled in the open arms, as well as the latency to the open arms. Perchlorate exposed mice tended to spend more time in the closed arms and were hesitant to explore the open arms. Additionally, exposed mice moved slower and less often than control mice. These results indicate perchlorate affects mice behavior by reducing their exploratory behaviors despite a short and developmentally late exposure regime.

### Cholinergic regulation of sleep in the jellyfish *Cassiopea*

*Michael Abrams*

Perhaps nothing is stronger evidence of the importance of sleep than its conservation across animals. Even cnidarians, gelatinous aquatic animals such as the jellyfish Cassiopea and the polyp Hydra, exhibit the hallmark features of sleep observed in animals with centralized nervous systems: reversible quiescence, increased latency to arousal, and homeostatic regulation. Cassiopea behavior is controlled by radially-spaced marginal ganglia. We compared gene expression profiles of ganglia from sleep deprived animals to that of controls and found differential expression in many sleep-related genes but focused on a gene encoding a nicotinic acetylcholine receptor alpha subunit-like (Charnl-E) that increased expression 3.8-fold in sleep deprived animals. Using electric field recordings, we found that cholinergic neuromodulators regulate pacemaker activity, supporting an intact cholinergic system is in place in Cassiopea. Quantitative PCR and in situ hybridization support an increase in expression within the ganglia due to sleep deprivation, so we developed RNAi for use in Cassiopea. We determined that Chrnal-E is required for proper sleep patterns and is important for responding to nighttime sleep deprivation. Our finding that Cassiopea sleep is regulated by the deeply conserved cholinergic system underscores the importance of studying early branching animal lineages to gain insight into the evolutionary origins and basic mechanisms of sleep.

### Hop, Swim, and Jump: Station-holding Behavior of Marine Sculpins in a Turbulent Wave Channel

*Emalie Abshire, Shubham Vijay Kumar Yadav, Austin Garner, Emily Kane*

The intertidal zone in a nearshore ecosystem faces turbulent waters because of strong waves that crash into the rocks as the tide rises and lowers. Tide-pools that form in these areas are often home to sculpins, a benthic fish which has fins designed for both negative lift and gripping. We studied station-holding behavior in these fish on San Juan Island, WA in the summer of 2024. Most studies involving sculpins reacting to their environment use swim tunnels, which provide a laminar flow. We used a wave channel, which has much more unpredictable flow, and gives a more accurate representation of their environment. We tested 6 species, representing 3 intertidal sculpins and 3 comparative outgroups, to determine differences in behavioral responses to wave energy. We recorded behavior at controlled levels of wave action, noting the levels that fish no longer maintain position on the bottom. Intertidal sculpins had a better ability to keep still on the substrate than the outgroups. At higher wave action, fish tended to try to escape the flow by hiding in corners, swimming, or even jumping out of the water. This supports the idea that turbulent intertidal habitats are a significant challenge for sculpins that require a suite of traits for survival.

## Apple snails: looking at regeneration with a new pair of eyes

*Alice Accorsi, Brenda Pardo, Eric Ross, Timothy Corbin, Melainia McClain, Mol Mir, Kyle Weaver, Stephanie Nowotarski, Sean McKinney, Alejandro Sánchez Alvarado*

Vertebrate camera-type eyes allow for high image-resolution, but their regenerative capacities are either limited or absent. Mechanisms to tackle their repair are difficult to study due to the lack of models that can completely regenerate their adult camera-type eyes. We discovered that the invertebrate golden apple snail (Pomacea canaliculata) has camera-type eyes that can fully regenerate, even in adults. We characterized apple snail eyes using light and electron microscopy and analyzing their transcriptome. We found several morphological and molecular distinct cell types in their retina. We showed that regeneration occurs through the formation of a blastema, and that most morphological and transcriptomic features recover one month after amputation. To mechanistically investigate gene function, we developed protocols to microinject and culture zygotes, and used CRISPR/Cas9 to establish – for the first time – stable mutant lines in P. canaliculata. After defining the main stages of P. canaliculata direct development and gaining an understanding of the embryonic gene expression through bulk RNA-seq and HCR in situ hybridization, we knocked out the gene pax6. Pax6 isa transcription factor necessary for eye development in vertebrates and flies. Excitingly, pax6 mutant snails completely lacked eyes, revealing a conserved role for this gene in apple snail eye ontogeny. This work establishes P. canaliculata as a genetically tractable organism for mechanistically exploring the complete regeneration and the evolutionary history of camera-type eyes.

## Variations in antioxidative activity between latitudinally different populations of Astrangia poculata

*Jaime Acero, Anabel Martinez, Isabella Changsut, Lauren Fuess*

Corals are the chief ecosystem engineers within tropical reef ecosystems, promoting the biodiversity seen within those environments. With the rise of ocean temperatures, corals become more susceptible to disease and bleaching, placing those ecosystems under threat. It has been observed that disease susceptibility within coral is increased with the stress of warming ocean temperatures, which in conjunction with bleaching, has been theorized to exacerbate that susceptibility. Astrangia poculata, while not a tropical coral, can be found all along the East Coast of the United States in varying environmental conditions. A. poculata is also a facultatively symbiotic coral, meaning that it can have a relationship with algal symbionts, but it does not require them to survive. These characteristics make it a great model organism for investigating potential variations in constitutive immunity across different natural conditions. In this study, the specific immune metrics we observed were antimicrobial activity and antioxidant activity (peroxidase and catalase), and we measured them in several individuals across three populations of different latitudinal locations (RI, VA, and TX). These key immune metrics were found to be significantly different between populations, meaning that varying conditions likely play a role in the immune activity of A. poculata. This information contributes to the growing breadth of knowledge on coral immunity within the context of climate change and may one day be applied to other coral populations.

## Hard-head-hitting questions: Multi-level brain analysis in wild woodpeckers and experimental goats.

*Nicole Ackermans, Rana Adam, Ayodele Oyadeyi*

Little is known about how brain injury develops into chronic neurodegenerative disease in humans. Experimental rodent models have contributed to our understanding of these diseases on the molecular scale, but any treatment for patients has been restricted by species-translation difficulties. To better understand brain injury pathogenesis, studying a wider variety of model species is necessary. Many animal species sustain high-intensity head impacts in the wild. Head-butting goats, and woodpeckers are some of the most charismatic representatives in this category. For centuries head-hitting animal behavior has spawned various theories attempting to answer the question, 'why don't they get headaches?', to little avail.

We conducted multi-level brain analysis on experimental domestic goats and wild woodpeckers to definitively determine whether and how they sustain neurodegeneration. We analyzed fluid biomarkers of neurodegeneration in blood and cerebrospinal fluid (CSF), performed immunohistochemistry on brain tissue targeting markers for traumatic brain injury and Alzheimer's disease (AD), and performed behavioral analysis focusing on impact force and frequency, as well as memory and aggression. Our initial findings in experimental goats showed one of the main AD markers, amyloid beta, had an Ab42/Ab40 CSF ratio that decreased over six months within the expected range for human AD diagnosis. Further investigation in these unconventional species will provide insight into their evolutionary life history and advance our understanding of neurodegenerative disease development.

## Low salinity tolerance and recovery of the invasive tunicate, *Botrylloides* violaceus

*McCaela Acord, Carolyn Tepolt, Zachary Tobias, Gareth Miller*

The colonial tunicate, Botrylloides violaceus, is an invasive fouling species found on both coasts of North America, where it threatens marine structures and native species. Climate change is increasing the frequency and intensity of storms, introducing freshwater into marine environments where B. violaceus lives. To better understand the potential spread of B. violaceus, I tested its ability to respond and recover from periods of exposure to low salinity. Oozoids, or newly-settled larvae, were collected from adult colonies from Eel Pond, MA. Oozoids were exposed to various salinity levels (10, 12.5, 15, 17.5, 20, 25, or 35 ppt) for 20 hours. Oozooids were then censused for heartbeats, returned to 35 ppt, and assessed for heartbeats and growth at multiple timepoints until 15 days post-exposure. The median lethal salinity (LS50) was $15.07 \pm 0.27$ ppt. Although oozooids in salinities under 15 ppt had no recognizable heartbeat, some recovered after being moved to 35 ppt. Additionally, post-exposure growth was higher for oozoids exposed to higher salinities. These results suggest that changes in salinity from storm events can have a prolonged effect on the growth and reproduction of B. violaceus. However, the ability of oozoids to pause physiological processes when stressed, followed by recovery when salinity returns to normal, could indicate potential resiliency to brief, periodic low salinity events.

## A phylogenetic investigation into the material properties of the skull of cetaceans and artiodactyls

*Danielle Adams, Brad Boyce, Kevin Garber, Benjamin Klitsner, Daniel Hooks, Lisa Cooper, Joy Reidenberg, Samantha Price, Richard Blob*

Returning to the aquatic realm involved drastic evolutionary changes in whales and dolphins (Cetacea) compared to their terrestrial relatives (Artiodactyla). Material properties of the skull and mandible are critical for understanding evolution of feeding mechanics and sound reception in cetaceans. We sampled bone from dried museum specimens at five locations across the skull and mandible of 14 cetacean and 10 artiodactyl species and measured elastic modulus using nanoindentation. Values obtained were consistent with previously measured values for mammalian bone. However, there were significant differences in elastic modulus in bone locations between cetaceans and artiodactyls. In artiodactyls, modulus varied along the anterior-posterior axis of the skull, with the anterior rostrum and mandible showing lower values than the posterior bones. Cetaceans exhibited more consistent values across the skull, with the nasal bone having a higher modulus value than most other locations, while the maxilla had a relatively low value. Phylogenetic ANOVAs revealed that, when considering relatedness, cetaceans have a higher modulus for the nasal and lower for the posterior mandible compared to their terrestrial relatives, likely reflecting functional differences between these elements. This study highlights the importance of a phylogenetic perspective when investigating material properties, and enhances the understanding of the evolution of bone within and between taxa. Specifically, how variation in this trait might contribute to functional specialization for different habitats and life habits within Cetartiodactyla.

## Influence of thermoregulatory posture on predictions of lizard activity and body temperature

*David Adams, Matthew Gifford*

Many ectotherms thermoregulate to maintain body temperatures that maximize physiological function. As temperatures increase globally, the ability of ectotherms to thermoregulate may become compromised, resulting in local extirpation. However, to accurately predict the impact of climate change on ectotherms populations, we need a well-developed understanding of how organisms regulate heat exchange with their environment. Because organisms have thermal properties distinct from their surroundings, operative temperatures are often used to estimate body temperatures. Operative temperatures represent equilibrium body temperatures by simulating radiative exchange with the environment and are measured using physical models that resemble the size, shape, and radiative properties of a focal organism. Most measurements, though, ignore the potential impacts of thermoregulatory posture. Here, we used 3D printed operative temperature models combined with thermal drone imagery to examine how thermoregulatory posture impacts estimates of surface activity and body temperatures of Eastern Collared Lizards (Crotaphytus collaris). Fine-scale operative temperature maps were generated for each posture from model and drone temperature measurements. These maps were used to estimate the activity and body temperatures of lizards with known home ranges, either including all postures or only the standard posture. Predictions were compared to empirical observations of activity, body temperature, and body posture using linear regressions. The results of these analyses and their implications for the future of ectotherm populations will be discussed.

## Indications of short- and long-term urbanization stress in deer mice

*Elizabeth Addis, Lauren Acuff, Louis Nipp, Eva Guzman, Brooke Robertson, Sydney Suggs, Ashley Beck, Laurie Dizney*

The footprint of urban areas increases each year. The impacts of the environmental changes that result from increased urban development are experienced at all levels of a community. However, some organisms have more adverse responses than others, including local extirpation. These absences make it difficult to investigate the mechanisms underlying responses to urbanization. One approach to deal with this difficulty is to evaluate the physiological responses of a single species capable of inhabiting a wide range of anthropogenic disturbance. Western deer mice, Peromyscus sonoriensis, are a good model organism for such comparisons because they are found extensively in both urban and rural environments. Here we use a dual approach to examine the impact of urbanized habitats on deer mouse physiology by assessing glucocorticoid levels as an indicator of stress. We used the non-invasive approaches of measuring glucocorticoids in hair and feces. Corticosterone, the primary glucocorticoid in deer mice, was measured in the hair, where its accumulation gives an integrative measure of long-term stress. Concomitantly, we quantified fecal glucocorticoid metabolites, which are an integrative indicator of recent stressors that occurred in the previous several hours. We show the impact of living in an urban environment on short- and long-term stress in deer mice and elucidate the nuanced relationship between the two levels.

## Low nutrient availability alters myostatin 2b expression in rainbow trout (Oncorhynchus mykiss)

*Michael Addo, Peggy Biga*

Myostatin negatively regulates skeletal muscle tissue growth in most studied vertebrates. Myostatin expression is predominately expressed in muscle tissue, heart, and mammary glands in mammals. Fish species, like salmonids, express myostatin in almost all tissue types, likely due to two whole genome duplication (WGD) events resulting in salmonids expressing multiple gene copies/paralogs of myostatin.

In rainbow trout, myostatin 1a, 1b, and 2a are functional paralogs, while myostatin 2b is considered nonfunctional due to its truncated gene, considered a pseudogene. Despite myostatin 2b being nonfunctional, the spleen and ovaries in female rainbow trout show high expression. Additionally, its gene promoter houses multiple serum response factor (SRF) putative regulatory elements. SRF, a transcription factor, regulates myogenic genes and myogenic regulatory factors like MyoD and myogenin, which could play a role in myostatin 2b expression and overall cellular growth. Current literature shows SRF expression is sensitive to nutritional/dietary changes and nutrient availability influences most transcription factors' expression levels.

This project will identify how nutrient availability modulates myostatin 2b expression in rainbow trout spleen. Additionally, this study will determine how transcription factor-dependent expression, with a focus on SRF, affects myostatin 2b expression. The results will provide insight into how low nutrient availability affects myostatin 2b expression through an SRF-dependent gene program.

## Close entanglements: behavioral dynamics of Penpoint Gunnels (*Apodichthys flavidus*)

*Sarah Adelson, Kassandra Ford*

Studies in teleost behavior and social structures have, for the most part, been relegated to freshwater and reef systems, while ignoring inter- and subtidal fishes. Our study examined the social behavior of the penpoint gunnel (Apodichthys flavidus), a sub-tidal fish commonly found along the West Coast of the United States. We quantified location preference and behavioral reactivity based on factors such as predator presence (Myoxocephalus polyacanthocephalus), conspecific presence, and availability of a structural hide. We observed a lack of reaction when in the vicinity of a predator species and significant differences in quadrant preference based on the previously mentioned factors. There were significantly fewer aggressive social behaviors (i.e., striking and pursuing) when a similar-sized conspecific was present compared to a larger conspecific. Interestingly, focal individuals were also likely to share a rock shelter with both similar-sized and larger conspecifics despite previous negative interactions. There also appeared to be social preference between focal fish pairs, with one pair exhibiting predominately non-aggressive behaviors (i.e., tangling and bumping) and frequent physical contact, whereas the other focal pair exhibited more aggressive behavior towards one another. Our results suggest that A. flavidus exhibit advanced social behavior that may be influenced by their ecology and habitat preferences, as well as behaviors that are likely beneficial to their survival.

## Optimizing the isolation and storage of *Medaka* brain cells

*Addesyn Aderogba, Peggy Biga*

Across the animal kingdom, sex-specific aging differences show females outliving males in humans and the reverse in bats. As organisms age, cellular processes like DNA replication support multiple rounds of cellular division. Organismal aging alters DNA repair efficiency as it is associated with accretion DNA damage. This study focuses on the differences in DNA repair efficiency between young and old males and females. To analyze this, an alkaline COMET assay will identify and compare single and double DNA strand breaks between young and old male and female cells that have experienced DNA damage and controls.

The target organism for this study is Medaka (Oryzia latipes) fish. Medaka are novel model organisms due to their non-live bearing, naturally translucent, and relatively minimal husbandry requirements. However, their novelty has left gaps in standardized methods to obtain viable cells for use in the COMET assay. This study describes the procedure used to navigate this. Preliminarily, resazurin assay will validate optimum isolation media volumes, final isolation media, and storage techniques to establish cellular viability after isolation using cellular respiration as a proxy. The results have shown cells isolated in half of the volume of the reagents denoted in known literature and slowly frozen for storage had higher respiration levels than others.

## Metatranscriptomic analysis of the microbiome of octocoral *Swiftia exserta* after a year in captivity

*Alvaro Aguayo, Demi Carballosa, Sheila Kitchen*

Anthropogenic stressors threaten coral habitats worldwide, in some areas outpacing their natural recovery rates. Restoration interventions to achieve ecosystem stability have benefited shallow tropical reefs, however, sparse work has taken place in the deeper, cold water reefs that are also impacted by these stressors. For example, the 2010 Deepwater Horizon oil spill had lasting impacts on mesophotic and deep coral habitats in the Gulf of Mexico, leading to extensive injury of vulnerable species like the gorgonian species Swiftia exserta. In an effort to restore these impacted populations, colonies of S. exserta have been fragmented and reared in captivity over several years. Prior studies using the 16S rRNA gene indicate that the microbiome of S. exserta in the northern Gulf of Mexico is dominated by one to two bacterial taxa, and that these microbial associates may vary along environmental and geographic gradients. In order to understand how laboratory rearing may alter the holobiont function of S. exserta, we compared expression profiles of the microbial communities of captive year-old fragments to freshly isolated fragments of 12 S. exserta colonies spanning several reefs. Our study hopes to identify the influence of captivity on the structure and function of the microbiome of S. exserta to enhance husbandry efforts as well as provide insights on potentially symbiotic relationships with the dominant microbes.

## Population dynamics & genetic connectivity of established and newly colonized bull shark nurseries

*Iliza Aguiar, Alyssa Andres*

Bull sharks (Carcharhinus leucas) are a coastal species that use freshwater habitats for parturition and nursery refuge for their offspring. Female bull sharks are known to be philopatric, leading to traditionally low mitochondrial DNA diversity compared to nuclear DNA within nursery locales. Such evidence has suggested gene flow between nurseries is male-dependent. However, recent studies suggest nursery site fidelity in females may be shifting, with tropicalization under climate change driving colonization of more northern nursery habitats. Kings Bay/Crystal River, FL is one such location, but to date no genetic information exists on the population in this anecdotally growing nursery. Genetic analysis will reveal environmentally-driven population dynamics and genetic connectivity within and between nursery locales. Fin clip samples (n>50) were obtained for neonate, young-of-year, and juvenile bull sharks in Kings Bay/Crystal River, FL between 2023-2026. A suite of mitochondrial DNA control regions and nuclear microsatellite loci will be sequenced to identify relatedness between samples and cohorts. Results will be compared with cataloged samples from known bull shark nurseries across US Gulf of Mexico and Atlantic coasts to provide insight into maternal and paternal contributions to genetic flow and shark site fidelity across distinct mating seasons. Furthermore, the work informs population dynamics such as immigration and emigration of individuals between nursery locations and the degree of diversity in genetic expression and regulation between cohorts and populations.

## Evolutionary morphometrics in marine angelfishes: body shape, fin geometry and defensive spines

*Hannah Aguinis, Linnea Lungstrom, Mark Westneat*

Evolutionary morphometrics of body, fin, and defensive structure shape can advance our understanding of evolution and ecomorphology in diverse fish groups. The marine angelfishes (Pomacanthidae), united by a sharp pre-opercular defensive spine, are diverse in their body and fin shapes as well as ecology. Here, we combine a new molecular phylogeny for the family with morphometric analyses of body, fin, and pre-opercular spine shapes, to test for rapid divergence and unexplored convergence in this diverse and economically important reef fish family. We placed over 40 fixed landmarks and a set of curves defined by sliding semilandmarks on the body, fins, and pre-opercular spine on over 180 images across the revised phylogeny (75 species, 11 genes) to perform phylogenetic geometric morphometric analyses. Results show that the major axes of shape variation are body elongation and head shape, with Genicanthus exhibiting long bodies, narrow heads, larger pectoral fins, and long spines and Pomacanthus exhibiting deep bodies, large heads, smaller pectoral fins, and short spines. While elongate, slender body shapes or deep, nearly circular profiles often characterize these genera, we found multiple examples of convergence between genera in body shape, forehead profile, and fin geometry. The defensive weapon of the preopercular spine is also highly variable and convergent. In conclusion, far-reaching, rapid divergence in many traits leads to high levels of morphometric and functional convergence within the angelfishes.

## Hemodynamic changes during the onset of cardiac innervation

*Ainsley Ahmadian, Luis Hernandez-Nunez*

The development of neurocardiac relationships in vertebrates remains a largely unexplored area of study. In most mammals and birds, the first nerve to reach the heart is the motor vagus nerve; however, the developmental and physiological implications of this event are not well understood. In this project, we leveraged the optical and genetic accessibility of larval zebrafish to use laser ablations, all-optical cardiac physiology, and long-term live imaging techniques to investigate the early stages of cardiac innervation and the onset of neural control of heart function. We mapped the anatomical progression of this first innervation event and observed stimulus-induced physiological changes in cardiac function as indicators of the beginning of autonomic modulation. Our findings provide insights into the hemodynamic changes that occur immediately before, during, and after cardiac innervation, as well as into the role of cardiac innervation in physiological responses to environmental threats. Our work sets the stage for studying the developmental origins of cardiac dysautonomias and the role of the autonomic nervous system in congenital heart disease.

## Binary search for generating multi-segment kinematic models from fish midlines

*Otar Akanyeti, Theodore Castro-Santos, Robert Sterling, Maxim Buzdalov, Elsa Goerig*

Current kinematic models describing body caudal fin (BCF) swimming using travelling wave equation cannot generalize to unsteady gaits such as C-starts and burst and coast swimming. Multi-segment models, which approximate continuous body midlines using a series of linear segments, offer an alternative framework to compare quantitatively BCF kinematics across different behaviours. Here, we present a new algorithm for efficient calculation of multi-segment models from fish midlines. The algorithm uses binary search which iteratively halves the search space to find favourable segment lengths so that the approximation error between a segment and a midline is kept below a user-defined threshold. We demonstrate empirically using one biological and one artificial dataset that the binary search algorithm can be four times faster than the segment growing algorithm, which employs linear search to generate its multi-segment models. We also present a theoretical analysis of both binary search and segment growing algorithms to determine the relationship between runtime and input variables (number of midline points, number of frames and number of segments). Multi-segment models are useful for a wide range of applications in fundamental and applied research from studying how muscle recruitment and morphology relate to locomotor performance to designing small scale underwater robots and improving fishways at hydroelectric dams. Algorithms which can quickly translate fish midlines into multi-segment models are valuable for reducing computational cost especially while analysing large datasets.

## Spiders of the spiny forest: the Dictynidae s.l. spider diversity of Madagascar (Araneae)

*Amin Al-Jamal, Lauren Esposito*

Spiders are amongst the planet's most ubiquitous and diverse arthropod predators, but their diversity remains poorly understood. Despite the historical murkiness of spider systematics, a new vision is emerging that preserves many of the broader classifications within order Araneae, whilst also revealing new clades in which multiple families are nested. One such group is the Marronoid clade first identified in Wheeler et al. (2017). One family within this group, the mesh-web weavers (Dictynidae O. Pickard-Cambridge, 1871), are of particular interest for their diverse, and sometimes extreme, life histories and cosmopolitan distribution. One major challenge for this group's taxonomy has been the overrepresentation of species documented from the Northern Hemisphere and South America, and the underrepresentation of documentation from Sub-Saharan Africa, Australia, and much of the rest of the Southern Hemisphere. For example, presently there is only a single fossil species described from the entire island of Madagascar. This research aims to tackle that issue by describing numerous new species from Madagascar, leveraging the island's magnificent biodiversity and propensity for endemism to test our emerging framework of dictynid phylogeny. We will use molecular phylogenetic methods alongside morphology to fit the new taxa into the larger phylogeny proposed by Montana et al. (in review) and create a family-level key to all known Madagascan taxa.

## Introduction to the symposium: Cities as a natural experiment

*Valentina Alaasam, Anthony Snead, Kristin Winchell*

Urbanization is one of the most significant global changes of the Anthropocene. Understanding how organisms evolutionarily respond to this drastic and rapid environmental transformation is crucial for preserving biodiversity and ensuring ecosystem resilience. Moreover, cities provide unparalleled opportunities for studying contemporary evolution due to their distinct and replicated environmental conditions. Research has shown that some species can adapt to urban pressures, however the mechanisms underlying these adaptations remain largely unexplored. To date, much of the research in urban evolutionary ecology has focused on quantifying phenotypic shifts and correlated environmental changes without explicitly interrogating trait-environment connections to the selective landscape. Our symposium aims to fill this knowledge gap by: 1) showcasing cities as natural experiments that can elucidate evolutionary constraints underlying variation in adaptation, 2) promoting inclusive and comparative research across diverse taxa, and 3) developing strategies to standardize research approaches to facilitate study of evolutionary convergence. Our speakers employ integrative approaches to link trait and environmental variation from an eco-evolutionary perspective across diverse taxa. Finding commonalities in urban evolutionary research will enable us to leverage the power of cities as globally replicated natural experiments to advance our mechanistic understanding of adaptive and convergent evolution to novel conditions.

## Adaptive mechanisms in coastal anurans: proteomic insights into salinity tolerance

*Molly Albecker, Camryn Kritzell, Micheal McCoy*

Coastal wetlands often exhibit highly variable salinity, typically favoring salt-tolerant taxa. Amphibians generally inhabit only freshwater habitats because of their limited salt tolerance and are thus rarely found in saline environments. However, Hyla cinerea, the American green tree frog, frequently inhabits brackish coastal marshes in the U.S., challenging this expectation. To unveil the physiological mechanisms that enable coastal populations of H. cinerea to thrive in coastal, brackish environments, we conducted a common garden experiment in which we exposed embryos and larvae from coastal and inland populations to varying salinities and collected samples at early (whole body, Gosner stage 26) and late developmental stages (gill baskets only, Gosner stage 38). We used liquid chromatography-mass spectrometry (LC-MS) for proteomic analysis. Early stage protein profiles differed based on population origin and embryonic salinity exposure, but the larval environment did not significantly affect protein expression at this early time point. In late-developing gill baskets, the interaction between location, embryonic salinity, and tadpole salinity best explained the variation in protein profiles. Further analysis revealed the differential abundance of certain proteins involved in osmotic regulation between the coastal and inland locations. These findings provide initial insights into the divergent mechanisms that enable coastal H. cinerea populations to persist in brackish environments and expand our understanding of amphibian resilience to salinity stress.

## Kinematics and flow quantification of shell-less pteropods at intermediate Reynolds number

*abdullah Aldaddi, Ferhat Karakas, Evan Williams, Amy Maas, David Murphy*

Sea angels are tiny marine snails (gymnosomatous pteropods) without shells that live in the upper water layers. They are planktonic throughout their life cycle and navigate in water by flapping their highly flexible wings to generate thrust. Sea angels swim for feeding, avoiding predators, reproduction, and ascending to the surface. However, the flow generated by the animal has not been well studied. This work investigates the kinematics and fluid dynamics of a subtropical speciesP-neumoderma atlantica captured in Bermuda. The collected individuals can reach up to 8 mm long and up to 4.5 mm in wingspan and flap its parapodia at frequencies close to 5 Hz, which creates a sawtooth trajectory in upward swimming. This places the animal in the intermediate Reynolds number around 100. Using a high-speed camera setup, we kinematically characterized the body and wings in 3D for hovering and upward swimming modes. We compared the results with a morphologically similar species Clione antarctica, which is up to twice as large and swims in water twice as viscous. Furthermore, we measured the fluid dynamics around the wings through a time-resolved 2D micro-PIV technique. The flow analysis revealed that P.atlantica wraps its muscular wings close to the body at the end of the power stroke to form a cylindrical shape. The new mechanism is named cylindrical "near clap-and-fling," similar to the known clap-and-fling mechanism.

## Exploring the context-dependency of macroevolutionary patterns in squamate viviparity

*Laura Alencar, Saúl Domínguez Guerrero, Gustavo Burin, Josef Uyeda, Martha Muñoz*

The evolution of key innovations can profoundly alter how a lineage interacts with its environment, unlocking new ecological opportunities and driving diversification. Viviparity, or live birth, is widely recognized as a key innovation among vertebrates, providing enhanced maternal control over embryonic development. This trait has traditionally been linked to cold climates, with viviparous species exhibiting specialized thermal physiology and behavior that enable them to thrive in such environments. However, viviparity has evolved independently over 110 times in lizards and snakes across different regions worldwide. While most viviparous lizards and snakes are indeed found in cold habitats, the presence of viviparous species in warmer environments raises an intriguing question: Did viviparity consistently evolve in cold habitats, or do different environmental conditions drive its evolution? This study aims to address this by investigating: (1) the environmental conditions most closely associated with the origins of viviparity in squamates; (2) whether viviparity alters the relationship between body temperature and environmental conditions across different climates; and (3) how these distinct evolutionary scenarios influence the evolution of their morphological, ecological, and physiological traits, as well as rates of lineage and phenotypic diversification. By exploring these questions, we aim to deepen our understanding of how this pivotal physiological trait has shaped the evolutionary trajectories of squamates.

## Minimal radial oxygen loss from tropical seagrasses: a counter paradigm

*Nicole Alexiou, Alex Hoey*

Tropical seagrasses live in anoxic sediment high in phytotoxic sulfides, such as H2S, and utilize Radial Oxygen Loss (ROL) from the roots to avoid tissue hypoxia and oxidize H2S. We examined the process of ROL, wherein O2 is diffused from the roots into the rhizophspere, in three dominant tropical seagrass species, Halodule wrightii, Thalassia testudinum, and Syringodium filiforme, from Florida Bay (FB) using two methods. 2-D O2 planar optode trials in FB sediment showed no ROL, and methylene blue staining trials showed a maximum of only 33% staining in response to ROL, with more staining in new roots and root tips. Older roots and slower-growing species had lower ROL, possibly due to more time in which to develop barriers to gas exchange. Our results from tropical seagrass species, with high microbial O2 demand and carbonate sediments high in H2S, counter the current paradigm that all seagrasses sustain a highly oxidized root environment and may explain large-scale seagrass die-offs.

## Genomic Analysis of Positive Selection on the Evolution of Cooperative Display Behavior in Manakins

*Camilo Alfonso, Peri Bolton, Ignacio Moore*

Social behavior in the manakin clade (Pipridae) is diverse, evolving from species in which males display alone to lek-based systems. Within lekking manakins, two distantly related genera, Pipra and Chiroxiphia, independently evolved male-male cooperative courtship displays. However, the genomic mechanisms underlying the evolution of these cooperative behaviors remain unclear. Here, we used brain transcriptomes to analyze the rates of amino acid nonsynonymous and synonymous divergent substitutions, as well as nonsynonymous and synonymous polymorphic substitutions, to detect signs of selection associated with the convergence of cooperative behavior. Specifically, we applied the McDonald-Kreitman test with group permutation comparisons across four manakin species. The black manakin (Xenopipo atronitens), which exhibits solitary display and lacks lekking, served as the outgroup. We compared it to the golden-collared manakin (Manacus vitellinus), which exhibits lekking behavior without male-male cooperation, and to two species with cooperative displays: the wire-tailed manakin (Pipra filicauda) and the blue manakin (Chiroxiphia pareola). Our goal was to identify shared genes under positive selection in the cooperative lineages, potentially explaining the convergent evolution of this trait. The transcriptome data included 17,319 unique genes, of which 285 showed significant signs of positive selection across all species comparisons, and four shared genes were under positive selection in the cooperative lineages. We discuss the functions of the TMEM69, XK, QSER1, and PTCH1 genes in the evolution of cooperative display behavior in manakins.

## Ground truthing 3D muscle reconstructions: a comparison between myogenerator and segmented muscles

*Evan Alger-Meyer, Baker Cerise, Casey Holliday*

3D reconstructions of jaw muscles based on attachment sites have become increasingly popular as a way to estimate the volumes of muscles in extinct animals. However, the accuracy of sculpted muscle volumes is underexplored. Using the Myogenerator Blender add-on, we reconstructed jaw muscles from muscle maps of skulls of seven extant vertebrates, including reptiles, mammals, and birds. Volumes of the resulting muscle reconstructions were then compared against segmented DiceCT muscles from the same specimens. The DiceCT data were regarded as 'truth.'

As expected, the accuracy of reconstructed muscle volumes varied considerably between taxa and muscle type. The reconstructions of Didelphis jaw muscles were the closest to the segmented muscles, ranging from 93–160% of true muscle volume with a median of 111%. Reconstructions of Varanus muscles were the least accurate, ranging from 9–1012%, with a median of 69%. Reconstructions of adult alligator muscles were less accurate than those of the juvenile, partly because of the morphology of pterygoideus ventralis. The least accurate reconstructions tended to be depressor mandibulae and the pterygoideus muscles, while the most accurate were pseudotemporalis superficialis and the adductor mandibulae group.

Based on these results, muscles reconstructed with Myogenerator can produce relatively accurate volumes. However, some reconstructions will have a wider margin of error based on the accuracy of the muscle attachment estimations and how the muscles are bounded by bony structures.

## Ontogenetic differences of sensory pores in bonnethead sharks (*Sphyrna tiburo*)

*Sonia Ali, Ingrid Reyes Patron, Grace Solevilla-Moreno, Jennifer Hodge, Kathy Liu, Lauren Simonitis*

Sharks rely on multiple sensory systems, including the pores of the lateral line and the electrosensory Ampullae of Lorenzini, to navigate, hunt, and interact with their environments. This study focuses on the bonnethead shark (Sphyrna tiburo), a distinctive species within the hammerhead family, noted for its role as an omnivorous secondary consumer. Our primary objective is to investigate the differences in pore field morphometrics throughout ontogeny in bonnethead sharks. While there has been a recent increase in bonnethead developmental studies, there is little research on their relative sensory capabilities. We analyzed photographs of bonnethead sharks of varying life stages using ImageJ to quantify head morphometrics and ampullary density. We applied the same methods to fetal bonnethead specimens with the addition of contrast-enhanced micro CT scanning to aid in the visualization of their lateral line and ampullary systems. By evaluating whether bonnethead sharks are born with fully developed sensory pore systems or if they develop these structures progressively over time, we can gain a better understanding of their overall neurodevelopment, and potentially identify periods of increased neuroplasticity. Moreover, this research will contribute valuable insights into sensory-motor integration and the development of complex behaviors, learning processes, and cognition in bonnethead sharks.

## Adapting flow cytometry methods for studying immune tradeoffs in migratory bats

*Meagan Allira, Kristin Dyer, Bret Demory, Kaylee Norman, Mark Lang, Daniel Becker*

Flow cytometry has traditionally been used in immunology to identify specific cellular subsets (e.g., T-cells/neutrophils) from mouse and human samples. However, owing to a lack of reagents, studies of cellular immunity in wildlife have been limited to methods of analysis that can be held at room temperature, like differential white blood cell counts (dWBC) from blood smears, which lack specificity. Recent interest in bat immunology has led to developments of some flow cytometry reagents for bats, a technique rarely applied to wildlife. This study aimed to adapt flow cytometry methods to field-based studies and investigate seasonal immune trends in wild bats. Specifically, our goal was to identify immune strategies of Mexican free-tailed bats (Tadarida brasiliensis) between migratory periods. Aligning with preliminary dWBC data, we predict adaptive immune cells (e.g., B, & T-cells) to proliferate during periods of low physiological costs, with innate immune cells (e.g., macrophages, & neutrophils) proliferating during physiologically costly periods. We collected blood samples from bats between March and September and processed them in the field before transport to a flow cytometry core laboratory for analysis. Using generalized additive models, we identified time points where bats experience shifts in favor of one immune branch over the other. As ecosystems continue to undergo anthropogenic change, understanding the interplay between stress, infection, and immune cell fluctuations in bats will be key for conservation efforts.

## Early life wheel exercise and anxiety behaviors in laboratory mice

*Jeremy Almazan, Ramiro Barajas, EmilyGrace Pineda, Yesenia Avalos, Apolo Ibanez Rincon, Angela Horner*

Exercise can reduce the effects of chronic stress, including decreasing anxious behaviors. Although studies in a variety of rodent models have shown that wheel running can reduce anxiety, studies on the effects of early-life exercise are more varied. Here we investigate the impacts of early-life exercise on adult anxiety behaviors in an outbred wild-type strain of mouse model. A total of 36 female mice were used, with half (Wheel) of the mice exposed to a loaded running wheel for a period of 10 weeks beginning at the weanling phase (3 weeks), and the other half (Control) housed in cages with no exercise wheel. After this 10-week training phase all mice were housed in standard rodent cages for at least 15 weeks until behavioral assays were performed. We used three standardized assessments to evaluate anxiety in the mice: a light/dark field test, an open field test, and forelimb grip strength test. In our study, there were no significant differences between mice exposed to exercise earlier in their lives and those housed in standard cages for their entire life. There were significant interactions of body mass and exercise in force grip tests such that larger Wheel mice were stronger, but larger Control mice were weaker. Our study suggests that the positive behavioral effects of exercise have a washout date, even for mice who exercised intensely during maturation.

## Hidden dimensions of diversity in woodland salamanders

*Nathalie Alomar, Henry Camarillo, Edward Burress, Isabella Burger, Meaghan Gade, Julia Laterza Barbosa, Saúl Domínguez Guerrero, Eric Riddell, Martha Muñoz*

Adaptive radiation typically follows ecological opportunity, which species exploit by diversifying morphologically to occupy new niches. By contrast, non-adaptive radiation is often characterized by limited morphological diversification, with speciation driven by primarily geographic isolation and niche conservatism. Nevertheless, adaptive diversification can involve trait evolution along multiple phenotypic axes, not just morphology. Woodland salamanders (genus: Plethodon), a diverse clade of lungless salamanders, are a classic example of non-adaptive radiation and offer an ideal system to test for adaptive divergence in physiological traits, an unexplored possibility for this group. By investigating Plethodon ecophysiology and their varying microhabitat preferences, we aim to uncover adaptive specializations related to microclimate specialization. To achieve this, we measured water loss rates, metabolic rates, thermal preference, cold tolerance, and heat tolerance across 30 species of Plethodon salamanders. We then conducted a multivariate rate analysis to estimate the rate of evolution for each trait. Our findings reveal hydric and metabolic traits exhibited the most diversity, reflecting a key trade-off between skin resistance and metabolic rate due to their reliance on cutaneous respiration. Notably, physiological traits evolved at a faster rate than morphological traits, indicating that even in clades classically viewed as a non-adaptive radiation, significant adaptive divergence can occur. This study highlights the ecophysiological complexity of Plethodon salamanders and the need to consider multiple phenotypic axes in understanding species radiations and evolutionary processes.

## The use of multidimensional endocrine panels in navigating curious complexities of pseudopregnancy

*Mattina Alonge, Creagh Breuner, Helen Chmura*

Information embedded in ecological and environmental variables are translated by the endocrine system into molecular signals regulating behavior and physiology. Within modern conservation and management contexts, endocrine measures are increasingly used to help characterize individual's health or reproductive state. Data produced, however, are often one-dimensional with regard to the animals we study and may not capture information that reflects complex ecological interactions, potential for life history trade-offs, and curious physiological adaptations. Here, I use two species of management concern – wolverine and Canada lynx – to demonstrate the benefit of using a multidimensional endocrine approach in characterizing an individual's physiological status, with particular focus on reproductive activity and investment. While progesterone concentrations are a reliable marker of pregnancy across many taxa, wolverine and lynx exhibit pseudopregnancy which is indistinguishable from "true" pregnancy via progesterone concentrations alone. Through an extensive collaborative network, we are generating longitudinal endocrine reference profiles, for each of these species, shaped by multiple hormone targets, including progesterone (P4) and prostaglandin fecal metabolites (PGFM), that have to power to reflect known reproductive status. Multidimensional endocrine profiles not only provide a powerful tool for mapping physiological information from wild, free-roaming individuals, but also strengthens our ability to ask questions about the selective pressures that have shaped reproductive and life history traits, including the evolution of pseudopregnancy.

## Effects of Acoustic Disturbance on the Auditory System of Atlantic Croaker (Micropogonias undulatus)

*Ariel Alonso, Kelly Boyle*

Anthropogenic noise pollution is a growing threat to sound-producing fishes and other marine animals that rely on hearing. Sensory hair cell proliferation (addition of hair cells during growth) and regeneration (addition following noise damage) in the ear is documented from relatively few teleosts. In this study, we aim to determine if Atlantic Croaker (Micropogonias undulatus) saccular hair cells proliferate and regenerate after noise exposure. We conducted laboratory experiments to test for hair cell proliferation and regeneration after 36 hours of white noise (150 dB re: 1μPa). We used in vivo injections of Bromodeoxyuridine (BrdU) and immunohistochemistry to assess cell proliferation rates among a control group and four recovery treatments (0, 2, 4, and 6 days) following noise exposure. A 2-factor linear model was used to determine if proliferation differed among treatments after accounting for body size. Hair cell proliferation was highest in spring (non-reproductive season), but proliferation did not increase following noise exposure (i.e., no regeneration). To verify that damage occurred following noise exposure, a second experiment was conducted to determine if hair cell bundle loss and apoptosis was higher in noise-exposed fish compared to a control group (analysis in progress). Atlantic Croaker hair cell addition following noise damage does not exceed normal hair cell proliferation rates and thus epithelial damage following acoustic trauma may persist longer than expected from studies in other fishes.

## Exoskeleton influence on primary afferent feedback in-vivo

*Amro Alshareef, Paul Nardelli, Lena Ting, Timothy Cope, Gregory Sawicki*

With significant advancement in wearable technologies for assisting locomotion and augmenting balance, there is a growing need to understand how such devices affect sensorimotor control of movement. Exoskeletons act mechanically in parallel to a joint and have been shown to affect muscle dynamics and kinematics in significant ways, in turn affecting overall muscle stiffness and activation and the proprioceptive organs within.

Here, we directly measured how muscle spindle 1a Instantaneous Firing Rate (IFR) is influenced by added exoskeletal assistance in a sedated, acute rat preparation. IFR is measured through the dorsal root while imparting a length change to the gastrocnemius MTU. Various springs are attached in parallel to the MTU simulate a passive exoskeleton and muscle activation is adjusted through the ventral root during stretch, for a resulting length clamped, force-matched eccentric contraction resembling perturbed standing.

We observed a qualitative decrease in 1a IFR metrics during ramp stretch as the exoskeleton stiffness was increased and muscle stiffness, via activation, was decreased, suggesting an inhibition of sensory feedback.

This work provides insights into how assistive exoskeletons affect sensory feedback, which can help us develop exoskeletons more adept at addressing clinical challenges in motor learning and rehabilitation.

## The thermal physiology of a diurnal omnivorous lizard, the giant day gecko

*Infinity Alvarez, Angela Roth, Charles Watson*

Ectotherms rely on their environment to regulate and maintain their body temperature. For this reason, environmental fluctuations have a strong impact on their biology. Lizards are ectotherms that have historically served as suitable models to investigate thermal physiology. However, a large proportion of this research has been studied using new world Anolis and Sceloporus lizards. In this study, the giant day gecko, (Phelsuma grandis), native to Madagascar but invasive in Florida, was selected as a model for comparison. This species may exhibit physiological differences from other species because their most recent ancestors are nocturnal and they (Phelsuma) secondarily evolved durnality. Additionally, we are using a standardized methodology to document the physiology of this species as a means to demonstrate the utility of standardization for more direct comparisons. This “thermal physiotype” includes measurements of metabolic rate and performance (sprint speed) at standard temperatures as well as thermal preference and critical thermal maximum and minimum. This research provides an additional set of data to evaluate the sensitivity of ectotherms to a changing climate, while also providing insights into the thermal biology of a species that has secondarily evolved diurnality.

## Transcriptome Data Analysis of Parrotfish Beak Evolution

*Sebastian Alvarez Luna, Kory Evans*

Parrotfishes are key stone species in coral reef ecosystems, known for their unique tendency to feed on coral and other hard substrates in search of algae and other microscopic organisms, which many species achieve using their specialized beaks that are formed from hundreds of small teeth fused together into a coalesced tooth plate. Their beaks, one of the strongest biomaterials in the world, allow them to feed with minimal wear and abrasion. Interestingly, parrotfishes have convergently evolved beaked morphologies multiple times independently. However, the genomic mechanisms that underly this convergence remain poorly understood. Here we will use transcriptomic analyses and long read genome sequencing to identify genetic factors that underly beak development and convergent evolution in parrotfishes. Differential gene expression will be assessed between muscle and dental plate tissue to identify significantly expressed genes. This comparative approach will allow us to identify genes of interest from four dental development pathways which will go through further analyses for selection pressure and evidence of convergent evolution. We hypothesize that we will find distinct genetic mechanisms that underly the convergent evolution of beaked morphology in parrotfishes, suggesting that there are multiple genetic pathways that lead to beak formation.

## Early-life social regulation of size, growth, and sex steroid hormones in developing cichlid fish

*Alyssa (Aly) Alvey, Cameron Hamson, June Lee, Samuel Chan, Cristi Cruz, Kiren Kanazawa, Blake Migden, Emma Thompson, Tessa Solomon-Lane*

For many social species, development has a bidirectional relationship with social environments. In Burton's Mouthbrooders (Astatotilapia burtoni), a highly social cichlid, grouping fish of different body sizes can be used to engineer status, and adult status also regulates growth. We investigate growth, and roles for estrogen and testosterone, in juveniles. In the first experiment, we socially engineered conditions with fish differing in body size. We reared juveniles with their siblings, or with two older, larger juveniles for different time periods (4-days to 12-weeks).We found that juveniles reared without the larger fish were bigger than their siblings, suggesting that the larger fish suppress growth. Estrogen and testosterone were measurable at all ages. Age and environment influenced estrogen, but not testosterone. Estrogen positively correlated with size for juveniles with siblings only. In the second experiment, we socially engineered conditions with similarly sized fish. By 2-mo old, size varies dramatically, and groups were formed with same-sized juveniles across the size-spectrum. Growth was surprisingly similar across groups, showing their capacity, despite slow early growth. Most groups also had 1-2 fish with accelerated growth. Testosterone and estrogen were positively associated with growth later in development, and fish that developed male nuptial coloration had higher estrogen and testosterone. Together, this suggests that early-life social regulation of growth may exert powerful influence over development, neuroendocrine mechanisms, and future phenotype.

## Evolutionary Influence on Marine Actinopterygian Hearts: Chamber Landmark Morphometrics

*Kyra Amacker, Stacy Farina*

Actinopterygii are arguably the most morphologically diverse class of vertebrates, exhibiting immense variation in the form and function of the circulatory system. The simplistic single-circuit teleost circulatory system addresses the specific demands of the varying conditions of oceanic environments for 34,000+ species. Our research seeks to establish the role of habitat and evolution in shaping the heart morphology of teleost species across the clade. Using Micro-CT scans of contrast-stained specimens, we studied fifteen ecologically distinct species from across the Actinopterygii clade (pelagic, benthic and intermediate) via size and volume landmarking analysis. We used 3D Slicer to landmark heart chambers and converted those landmarks into hull meshes using a custom R script. We generated and analyzed three-dimensional heart meshes in MeshLab for size, shape, and relative chamber volume measurements for interspecies comparison. To study interspecies variations and confirm heart function specificity, we performed phylogenetic ANOVA analysis in similar zone species. Our study reveals discernible diversification in heart morphology across clade species, revealing intricate interactions between evolution and ecology in soft tissues. We further generated a phylogenetic tree based on relative species ecology and morphology. Implications of the resulting phylogeny will be further discussed.

## Mechanisms of genetic accommodation of a polyphenism in the tobacco hornworm, *Manduca Sexta*

*stephanie Amaya, Yuichiro Suzuki, Daniela Becerril, Paula Gonzalez, Elizabeth Chou*

Genetic accommodation is an adaptive process by which natural selection acts on developmental plasticity to generate novel phenotypes. In this study, we explored the molecular basis of genetic accommodation using two genetically accommodated strains of the tobacco hornworm, Manduca sexta, which change color to different degrees in response to temperature. RNA-seq and quantitative PCR revealed changes in the expression of genes associated with juvenile hormone (JH) and epigenetic regulation. We demonstrate that JH is responsible for the strain-specific response to temperature, while epigenetic regulation impacts the process of genetic assimilation and phenotypic robustness. Thus, genetic accommodation may rely upon a complex interplay of endocrine and epigenetic changes.

## A View to a Keel: the form and function of ventral keels in fishes

*Charles Amazon, Matthew Kolmann, Cassandra Donatelli, Spencer Truman, Charbel El Khoury*

Ventral keels, defined here as rigid, bony structures that create a "V"-like taper along the abdomen, are found across Actinopterygian fishes. There are competing hypotheses for keel function in fishes. Classically, keels are thought to reduce roll during swimming, like the keel of a boat. Alternatively, we propose that keels add passive stiffness to the body, increasing the fish's ability to accelerate quickly. Our study set out to assess the multifunctional role of ventral keels, across a variety of fish body shapes. We made nine different soft-bodied fish models, which included both a flexible backbone and rigid skull. These models allowed us to test the effect of adding a second source of passive stiffness in the form of a flexible ventral keel at different ratios of standard length. Models were actuated in an oscillatory motion across multiple frequencies and at different water flow speeds to measure the thrust produced by the model and its rotational stability (i.e., resistance to roll). Torque and thrust did not vary in a predictable way across frequencies, and did not vary significantly across models at low flow speeds (10 m/s). However, at higher flow speeds (30 m/s), elongate-bodied fish models had lower thrust production and lower rotational stability as keel length increased, while deeper bodies produced more thrust and resisted roll as keel length increased.

## Evaluating behaviors of mobile organisms in seagrass beds via baited remote underwater video (BRUV)

*Georgia Ambrose, William Love, Emily Rose, Heather Mason*

Seagrasses are highly productive coastal ecosystems under threat from anthropogenic activities, and traditional survey methods are limited in monitoring this complex habitat. This study focused on surveying seagrass ecosystems in Tampa Bay, Florida using baited remote underwater video (BRUV) as a non-destructive, non-extractive sampling method. To examine seagrass ecosystem ecology, we collected data on depth, water chemistry, season, proximity to seagrass beds and anthropogenic activities in Tampa Bay to evaluate species richness, species diversity, and behavioral interactions. Each month between February 2022 and January 2023, we deployed BRUV units equally into varying depth profiles: shallow (1.8 to 3m), mid-depth (3 to 4.8m), and deep depth (4.8 to 6.7m) resulting in 200 hours of video footage. Preliminary results indicate that the species richness and abundance varied across the depth profiles. The shallow depth profile displayed higher abundance of a few species while deep and mid-depth profiles indicate more richness but less abundance. We captured footage of inter- and intra-species interactions which include competition and predator-prey interactions. The Hardhead Catfish (Ariopsis felis) is the most common species seen across all three depth profiles. Ongoing analyses are being conducted to identify any environmental, temporal, and spatial relationships, in addition to functional diversity measures, that could influence the species observed. The findings of this study will help inform conservation measures for the threatened seagrass ecosystem in Tampa Bay.

## The metabolic response of constant growth versus simulated cold dormancy in gopher tortoises

*Ali Amer, Chelsea Cochran, Tonia Schwartz, Anet Filipova, Jeff Goessling, Ericha Shelton-Nix*

Ectothermic species are facing precipitous population declines as a direct consequence of anthropogenic disturbances due to human-related activities. Variation in temperature during critical developmental phases may alter the physiological phenotype that may persist into later life stages. Gopher tortoises (Gopherus polyphemus), a keystone species with high juvenile mortality and a slow life-history trajectory, are increasingly vulnerable to population threats. Head-starting, a promising approach in conservation biology seeks to increase the survivability of threatened species by captive rearing hatchlings in a "constant growth" environment during vulnerable developmental periods. However, the long-term consequences of "constant growth" on ectotherm physiology have not been fully explored. Here, we use a laboratory experiment to investigate the long-term physiological impacts of head-starting under constant growth at 28oC versus simulated cold dormancy (2 months of decreasing temperature down to 13oC). We hypothesize that individuals in simulated cold dormancy will suppress metabolic phenotypes during dormancy and will persist 2 weeks and 3 months after dormancy relative to the constant growth treatment. We found that tortoises in simulated cold dormancy had lower plasma glucose with no effect of treatment at 2 weeks and 3 months post dormancy. Results of LS-MS plasma metabolic profiles are forthcoming and will be presented. This study will provide insights into long-term impacts of head-starting on ectotherm physiological phenotype to help improve long-term viability of head-starting as a conservation technique.

## Effects of antidepressant drug on tissue morphology and body fluid conditions of American oyster

*MD Faisal Amin, MD Rahman*

The rapid growth of pharmaceutical usage over the past few decades has brought significant benefits to human health. Studies have shown that a wide array of pharmaceutical compounds such as antibiotics and antidepressant drugs, are commonly detected in surface waters, groundwater, and even drinking water. Pharmaceuticals in aquatic environments pose a serious threat to a diverse range of aquatic organisms. Marine bivalves are an important and wide source of seafood for people worldwide. In this study, we determined the effect of short-term exposure to fluoxetine, an antidepressant drug used for depression (low dose: 0.5 $\mu$g/L and high dose: 5 $\mu$g/L for one week) on American oyster (Crassostrea virginica, an important shellfish and seafood species) under controlled laboratory conditions. Histological analysis showed atrophy in the gills and digestive glands of oysters exposed to fluoxetine. The pH levels of extrapallial fluid significantly increased in the high-dose treatment groups. However, antidepressant treatments significantly decreased the amount of mucous in the gills and digestive glands. Our results suggest that oysters can experience impaired physiological functions through morphological changes in tissues and alterations in body fluid conditions due to antidepressant drug exposure.

## Transcriptomic patterns of behavioral cross-sexual transfer in a biparental cichlid, Julidochromis

*Andrew Anderson, Susan Renn*

Cross-sexual transfer, or the acquirement of phenotypic values associated with another sex is proposed to occur by accessing hormonal signal pathways that are sex-biased. Previous work in our lab has shown that female Julidochromis transcriptus, a biparental cichlid, increases circulating levels of a male-biased hormone, 11KT, to take on male-biased behaviors under certain social conditions (a smaller male partner). Following on these findings we took brain-punches from regions associated with these behaviors and test the following: 1) are females and males using the same gene suites to generate the same behavioral suites, 2) are females altering expression patterns of genes associated with hormonal signaling. Using the framework we have developed, the Ancestral Modulation Hypothesis, we predict that females are using the same genes and have increased sensitivity to androgen signaling in these brain regions. Here, we present our preliminary findings as well as findings in a congener, J. marlieri, where females typically engage in behaviors observed in male J. transcriptus.

## Evoked neural activity in chorus frogs reveals candidate mechanisms of species recognition

*Carlie Anderson, Linda Rinaman, Emily Lemmon*

Species recognition and courtship behaviors are powerful drivers of speciation. Here, we investigate the neural basis of species recognition in Upland chorus frogs (Pseudacris feriarum). Some populations of this species have evolved divergent male mating calls and enhanced acoustic discrimination by females due to costly hybridization with local heterospecifics. Frogs in derived populations show specific responses towards the local conspecific call (LC) and reject both the heterospecific call (H) and foreign conspecific calls (FC). We hypothesized that patterns of neural activity mirror these behavioral patterns of species recognition, specifically in brain regions associated with audition and social behavior, to reveal which brain regions contribute to species recognition. We collected wild frogs from breeding aggregations and examined evoked neural activity in response to either LC, FC, H calls, or silence via phospho-S6 immunofluorescence. We found that the LC call specifically evokes neural activity in the auditory midbrain and some forebrain areas known to regulate social decision-making, whereas the other stimuli do not. Our results indicate that, at a neural level, this population of P. feriarum cannot discriminate between the FC and H calls, while the LC call evokes a pattern of neural activity associated with species recognition. This work represents one of the first attempts to provide candidate mechanisms of species recognition during one of the earliest stages in the speciation process.

## Impacts of premature birth and nipple type on Suck-swallow-breath coordination in infant feeding

*Dylan Anderson, Elska Kaczmarek, Ani Smith, Thomas Stroud, Emily Volpe, Maressa Kennedy, Harlow Smith, Skyler Wallace, Hannah Shideler, Holly Sabato, Shanique Yazzie, Christopher Mayerl*

Infancy is a period of rapid anatomical growth and physiological maturation, including neural coordination. During feeding, infants must coordinate sucking, swallowing, and breathing to acquire milk without aspirating. However, the ability to coordinate these behaviors can be impacted by several factors, including gestational age at birth (ie prematurity) and nipple design. For example, breastfed babies typically exhibit different suck-swallow-breathe dynamics than bottle-fed babies, potentially due to differences in nipple structure: breasts are ducted whereas bottles are hollow cisterns. We raised term and premature infant pigs on either a ducted, biomimetic nipple or a standard cisternic nipple and evaluated suck-swallow-breathe coordination in each group, on each nipple type, across infancy. We synchronously recorded high-speed biplanar videofluoroscopy and respiratory data while infants fed on both nipple types at 7 and 17 days of age (∼1 and ∼8 month old human equivalent). We found an impact of nipple type on suck-swallow function in both full-term and preterm pigs. Preterm pigs raised on biomimetic nipples swallowed at a significantly faster rate when feeding on cisternic nipples, as compared to other preterm infants. Unlike terms, preterm infants did not coordinate swallow-breath cycles, and swallow-breath coordination was not affected by nipple type. These data indicate that infants can adjust suck-swallow dynamics in response to variation in nipple properties, but that the challenges associated with swallow-breathe coordination, especially in preterm infants, remain.

## Microbiome of chained catsharks throughout development

*Emma Grace Anderson, Katelyn Mika, Elizabeth Parsons, Cody Neal*

Little is known about how the microbiome of chondrichthyans changes throughout development, particularly because this field is one of recent exploration. Previous work on little skates (Leucoraja erinacea) done by members of our lab has shown that specific bacteria and bacterial populations correspond to developmental stages and specific tissues within each developmental point. The chained catshark (Scyliorhinus retifer) lives in the same waters as the little skate and shares many similar life history traits, making them ideal for comparison. We can compare the microbiome across the development of the chained catshark with the data from the little skate to begin to disentangle the role of the environment versus the host in microbiome acquisition. Microbial samples from the chained catshark were collected by swabbing the internal surface of catshark eggs, as well as collecting a sample of the internal liquid of the egg, a gill tissue sample, and a skin sample from the tail of developing embryos at different developmental time points (stages 0, 17, 28, 33, 37). After extracting 16S DNA, samples were sent to the Marine Biological Laboratory for sequencing. After receiving the sequencing datathe sequencing data back, QIIME is being used to identify times point and tissue specific microbial distribution. Over time, this research aims to further uncover the importance of the microbiome in a marine species' adaptation to changing environmental factors.

## Do semi-arboreal snakes feed differently between arboreal vs. terrestrial environments?

*Jeffery Anderson, Joshua Pulliam, Joshua Taylor, Yohan Sequeira, Kamau Braxton-Hall, Kelly Fangyen, Amalia Moore, Pranav Khandelwal, Ignacio Moore, Jake Socha*

Semi-arboreal snakes are known to feed both terrestrially and arboreally. Although each environment has its mechanical challenges related to maintaining a grip on both the substrate and the prey item, the arboreal environment can be more restrictive due to additional considerations of balance, suggesting that semi-arboreal snakes may adapt their feeding behavior to their specific circumstance. Here, we examined the prey-handling abilities of Eastern black rat snakes (Pantherophis alleghaniensis) in both terrestrial and arboreal arenas. Snakes were fed pre-killed small and large quail to present varying mechanical challenges. We quantified prey-handling performance and behavior using recordings from GoPro Hero4 cameras. Preliminary results suggest that in arboreal trials, snakes used a segment of their body to support prey during ingestion, but never in terrestrial trials. However, in terrestrial trials, snakes used body-pinning behaviors, which were not observed in arboreal trials. Arboreal feedings of large prey lasted approximately 4x longer than other trial types, and generally, prey was orally released less often compared to terrestrial trials. In summary, these snakes use different behaviors to ingest the same prey items in different environments, supporting the hypothesis that the arboreal environment imposes additional physical constraints on feeding behaviors in snakes.

## Elevated [$CO_2$] and temperature increase gas exchange and alter fitness in a montane forb

*Jill Anderson, Derek Denney*

Climate change is simultaneously increasing atmospheric carbon dioxide concentrations ([CO2]) and temperatures. Elevated [CO2] could offset costs associated with increased temperatures. We conducted a multi-factorial growth chamber experiment to examine the interactive effects of temperature and [CO2] on fitness and ecophysiology of diverse accessions of Boechera stricta (Brassicaceae) sourced from a broad elevational gradient in Colorado. This experiment revealed that elevated [CO2] increased photosynthesis and intrinsic water use efficiency across all accessions. However, these instantaneous responses to treatments did not scale up to fitness. Instead, increased temperatures reduced the probability of reproduction for all accessions. Elevated [CO2] and increased temperatures shifted the adaptive landscape, such that low elevation accessions had higher survival and fecundity under future [CO2] and warming temperatures than their higher elevation counterparts. Thus, contrary to expectations, increased photosynthesis from elevated [CO2] does not compensate for fitness costs associated with increased temperatures. Our results suggest that elevated temperatures and [CO2] associated with climate change could have especially severe negative consequences for high elevation populations. Follow-up research maps loci associated with traits and fitness under four combinations of [CO2] and temperatures using a genome-wide association study.

## Combined effects of temperature and food on ribbed mussel (*Geukensia demissa*) larvae

*Nicolas Anderson, Dianna Padilla, Julia Dovi*

Ribbed mussels are a key species, increasing salt marsh resilience along the Atlantic coast of North America. Like other marine bivalves, they have planktonic larvae, facilitating broad dispersal. Across their geographic distribution, larvae can experience a wide range of ocean temperatures and food abundance. Climate change is likely to alter local temperature and food availability, which may impact larval survival, growth, and development. Understanding the consequences of climate change driven temperature and food availability will be especially important as they can impact mussel distributions and population dynamics. But, we do not presently understand how these factors impact early life stages. Therefore, we tested the combined effects of temperature and food quantity on survival, growth, and time to metamorphosis in larval ribbed mussels.

We found highest survival at 20°C, but larvae were slow to metamorphose, and lowest survival (no metamorphosis) at 15°C. In general, higher food availability improved survivorship at most temperatures. Larvae developed fastest at 30°C and food availability did not affect development time. Food availability increased larval growth except at the coldest temperature and larvae were larger with increasing temperature. These data suggest tradeoffs between survivorship, growth, and development at different temperatures and will be used to parameterize systems models to understand the impacts of combined factors (including temperature and food availability) during the larval stage on ribbed mussel populations in salt marshes.

## Testing the effects of variation in avian thermal window size on territory defense behavior

*Rindy Anderson, William Abbott*

Thermoregulation requires time and energy. During elevated sublethal temperatures, animals are forced to make behavioral and physiological tradeoffs. Temperature increases can lead to decreased effectiveness of foraging and reproductive behaviors, which can have fitness costs. In birds, radiative cooling occurs through thermal windows including the legs and bill. Larger thermal windows are thought to allow more heat loss. We asked how bill size relates to territory defense behavior in a South Florida population of Bachman's sparrow (Peucea aestivallis). Using simulated territorial intrusions during peak heat and humidity, we asked if differences in bill size or tarsus length predicted differences in territorial defense. Birds with the largest bills relative to their body size responded with more flights and songs and persisted in these behaviors longer than birds with smaller bills. Understanding how organisms are affected by a hot and humid climate, and how morphological traits may play a role, is paramount to understanding how animals will respond to challenging climate patterns.

## Exploring the role of epigenetics in shaping stress responses in chestnut-crowned babblers

*Susan Anderson, Makayla Busskohl, Andrea Liebl*

Developmental environments have lifelong phenotypic consequences (e.g. how they respond to external stimuli). Such plasticity is of interest as it involves the interactions between the genome and the environment, both current and developmental. For example, environments such as parental care, food availability, and sociality lead to variations in stress responses and associated behaviors later in life, which can have lasting impacts on spatial and cognitive learning, as well as on an individual's sensitivity to glucocorticoids. While it is well-supported that environmental conditions can alter an individual's stress response, the mechanisms behind this response are less understood. Interestingly, epigenetics—specifically DNA methylation, a biochemical interaction between the environment and DNA—may drive variation in stress responses by altering the expression of glucocorticoid receptor and metabolic genes. In this study, chestnut-crowned babblers, a cooperatively breeding species that vary in the number of carers contributing to offspring care, were used to analyze how levels of DNA methylation influence corticosterone levels in fledglings. Corticosterone was extracted using ELISA from blood samples after a 30-minute stressor and a dexamethasone injection (to simulate negative feedback) and compared with DNA methylation determined using EM-seq from blood samples. We expect to find that methylation of the promoters of genes related to stress signaling and metabolism will predict corticosterone levels in this species, illustrating the impact of epigenetic signals and the environments that lead to them.

## Tide and seek: *Oligocottus maculosus* and the role of refuge in the rocky intertidal

*Kaelin Andruss, Amy Cook*

Although the intertidal zone is a stressful environment, many resident species have physiological and behavioral adaptations that allow them to tolerate rapid fluctuations in temperature, salinity, and oxygen availability. As marine ecosystems continue to be affected by severe temperatures and rising sea levels caused by climate change, exploration of how intertidal species respond to extreme environmental variability may provide insight into the future adaptability of marine organisms. This observational study focused on juvenile tidepool sculpin (Oligocottus maculosus) in the upper tidal pools of Deadman Bay, San Juan Island to investigate the functionality of refuges for mitigating environmental stressors. Behavioral scans were conducted across five tidal pools over the span of five weeks to assess general and refuge-specific activity. Physical characteristics of pools were measured to create depth profiles and to determine area and rugosity. A Thermal Relief Score (TRS) was developed to quantify temperature differences between refuges and surrounding pool environments. Results indicated there was no correlation between thermal relief and population density. Findings suggest that while refuges are utilized by juvenile tidepool sculpin, their primary function is not conclusively related to thermoregulation or foraging opportunity. Further research is necessary to determine the potential benefits of refuge use by marine fishes in the intertidal.

## Assessing anthropogenic chemical bioaccumulation in blue crab tissues in the Cape Fear region

*Nicholas Angeli, Joseph Covi*

The blue crab, Callinectes sapidus, is a keystone species in the Cape Fear River (CFR) and serves a vital economic role in North Carolina. From 2012-2022, the NC blue crab industry annual revenue was approximately 23.4 million dollars with 16-30 million pounds harvested. However, the harvest dramatically dropped to 9 million pounds in 2022. This decline could be attributed to pollution. A large body of literature demonstrates that anthropogenic chemicals bioaccumulate in blue crabs and negatively impact the organism. However, despite their economic and ecological significance, almost no research exists on blue crab populations near the CFR. This study tested the hypothesis that chemicals from the CFR are bioaccumulating in blue crab tissues. Blue crabs were collected from one site on the CFR and one site on the Intercoastal Waterway north of the CFR. Animals were dissected, and tissues were tested for anthropogenic chemicals present in the CFR. I anticipate finding pesticides, including Atrazine, Metolachlor, Alachlor, Carbaryl, Diazinon, and Prometon, because peer-reviewed literature demonstrates that these chemicals are present in the Cape Fear Watershed. Levels of anthropogenic chemicals are expected to be higher in the CFR due to the dilution of river pollutants by the gulf stream current at the Intercoastal Waterway site. The results of this comparison will be presented.

## Linking Western diet with cardiovascular health: μCT imaging of perivascular adipose tissue in mice

*Abdullah Ansari, Meredith Taylor, Akinobu Watanabe, Maria Sepulveda*

Obesity is a well-established risk factor for the development of various diseases and conditions, including coronary heart disease, stroke, type 2 diabetes, and various cancers. In obese individuals, adipose tissue expands, becomes dysfunctional and releases adipokines that induce harmful inflammatory responses in the cardiovascular system. More recently, a specific fat tissue located surrounding blood vessels called perivascular adipose tissue (PVAT) has drawn great attention from researchers. To further expand our understanding of the relationship between PVAT and cardiovascular health, it's crucial to examine how this fat deposit changes due to diet. In this project, we aimed to quantify PVAT mass surrounding the thoracic aorta using mice as a model system. Male specimens were split into a control and a "Western-diet" group and were euthanized at 32 weeks of age. Specimens were then dissected, stained with Lugol's iodine, and scanned using a μCT scanner, then three-dimensionally reconstructed. Aorta and PVAT volumes were measured at T3–T10 levels. Our results show that PVAT volume is greater in the "Western-diet" group. As such, our study links consumption of 'Western' diet with the formation of larger PVAT that are known to cause vascular dysfunction through harmful inflammatory response.

## Tag-based estimates of full-body swimming kinematics for bottlenose dolphins (Tursiops truncatus)

*Gabriel Antoniak, Enric Xargay, Tyson Lin, Kira Barton, Bogdan-Ioan Popa, Kenneth Shorter*

Dolphins are highly maneuverable and efficient swimmers. However, due to the aquatic environment, it is difficult to make in vivo measurements of swimming kinematics. Camera based systems (both single and multi-camera arrays) have been used to estimate the swimming kinematics of cetaceans, but they are limited in the number of consecutive stroke cycles they can capture since this approach requires the animal to be in the field of view of the cameras. In this work, we use an array of biologging tags to quantify the animal kinematics (speed, depth, acceleration, and body pose). Four tags were placed on the animal using suction cups: one was placed between the dorsal fin and blowhole, one was placed on the side of the torso below the dorsal fin, and two more tags were placed along the side of the peduncle. Measurements were made from six dolphins during both prescribed swimming tasks over a range of speeds and during self-selected swimming. Data from the tags were used to generate continuous estimates of dolphin kinematics and body pose for hundreds of fluke strokes across a range of swimming speeds. We compare our results to the literature, and use the measured body kinematics to drive a hydrodynamic model of dolphin swimming to estimate propulsive forces during locomotion.

## Allele Frequencies of Loggerhead Sea Turtles on Florida Gulf of Mexico Beaches

*Aniela Anuszczyk, Andrew Maurer, Jake Lasala*

Loggerhead sea turtles (Caretta caretta) are globally listed as an endangered species by the IUCN, but their nesting population on Florida's Gulf of Mexico coastline is rapidly growing - counter to other regional rookeries. Loggerheads return to their natal region to nest and show nesting site fidelity (average 15 - 28 km). But less is known about interconnectivity over multiple nesting seasons or between multiple regional beaches, especially in the Gulf of Mexico. Blood samples were taken from nesting loggerhead females in Sarasota County, Florida from 2020 - 2024. Samples were collected on three beaches: Siesta Key, Casey Key, and Venice (∼16 km). These samples were genotyped using eight polymorphic tetranucleotide microsatellite loci. Allelic frequencies between yearly nesting cohorts were compared to determine if there was evidence of genetic differentiation between nesting seasons. Genetic variation was also compared between regional nesting beaches within the study period. Historical tag returns show that turtles from Sanibel Island (80 km south of the study region) occasionally nest in Sarasota County. A subset of loci were compared to previously published genotypes to determine connectivity. Through genetic analysis, we hope to gain a deeper understanding of this subpopulation of loggerhead sea turtles.

## A non-invasive technique for metabolic rates of free-swimming jellyfish

*Simon Anuszczyk, John Dabiri*

Measuring metabolic rates of marine animals often requires enclosing the animal in a sealed vessel on the order of the volume of the animal such that changes in oxygen concentration are quantifiable above background noise. These apparatus constrain the ability to achieve measurements of free-swimming organisms that are free of wall effects. We present a non-invasive technique to infer metabolic rates of free-swimming jellyfish based on 3D morphological reconstructions of the animal and the process of autophagy. We utilized a 6-meter-tall water tank for swimming experiments without food present in the water column. In order to study continuous swimming, we implemented a microelectronic swim controller that externally stimulated jellyfish swimming for 30 hours. This apparatus used computer vision to provide a flow current that opposed the animal and enabled this continuous swimming without encountering the vertical limits of the tank. Using a 3D laser scanning system, we created a volumetric reconstruction of the live jellyfish before and after swimming experiments. The change in animal tissue volume was converted to energy consumption through the known chemical composition of Aurelia aurita. In addition to enabling measurement of metabolic efficiency in marine invertebrates, the developed technique can also be used to compare natural and externally stimulated swimming. This technique can help us understand the energetics of freely swimming animals and the physiological endurance of jellyfish for long-duration swimming.

## The larger the cetaceans, the more stationary they sleep

*Kodai Aota, Yuske Sekiguchi, Hiroshi Katsumata, Seiki Konno, Daiki Inamori, Haruka Hiramatsu, Dale Kikuchi*

Due to the high thermal conductivity of water, maintaining body temperature in aquatic environments is challenging for endothermic mammals, making adaptation to aquatic life difficult. This challenge may be particularly significant during sleep, as decreased activity reduces thermogenesis compared to the wake state, making these animals more susceptible to heat loss. Cetaceans, however, can sleep underwater regardless of this constraint. They exhibit various sleeping behaviors, dividing into two types: "swim-sleep" and "stationary-sleep." We hypothesized that cetaceans use swim-sleep to prevent drops in body temperature during sleep. Here, we test this hypothesis through inter- and intra-specific comparisons by examining the relationship between heat loss (indirectly indicated by body size and ambient temperature) and sleeping behavior. Our results show that as body size decreases, they reduce stationary-sleep and increase swim-sleep, while as body size increases, they do the opposite. Furthermore, in lower ambient temperatures, cetaceans exhibit more swim-sleep, whereas higher temperatures result in more stationary-sleep. Given that the rate of heat loss varies inversely with body size and directly with the difference between body and ambient temperatures, our findings indicate that cetaceans employ behavioral thermoregulation by adjusting their sleeping behaviors in response to heat loss to maintain body temperature. We propose that this behavioral thermoregulation is a key factor in enabling cetaceans to sleep underwater.

## Spatial relationships between insect prey and *Anolis* lizards in an island community

*Miles Appleton, James Stroud*

The spatial distribution of predators is often influenced by the distribution of their prey. We investigate the relationship between the spatial distribution of 800 lizards from five Anolis species and the distribution of their insect prey in an island community. Lizards were classified as either terrestrial or arboreal based on their ecomorph. Insect biomass and diversity were quantified separately for terrestrial and arboreal habitats. We hypothesize that terrestrial lizard density will be highest in areas with the greatest terrestrial insect biomass, while arboreal lizard density will be highest in areas with the greatest arboreal insect biomass. This study explores how the spatial distribution of prey resources influences the distribution of predators in a complex multi-species community, providing insights into the role of trophic interactions in structuring ecological communities.

## Identification and characterization of neuropeptides in the earthworm Dendrobaena veneta

*Folashaye Araromi, Ameena Mohassib, Rebeca Rodriguez, Ahad Shabazz-Henry, Ellis Butler, Abigail Davis, Olivia Laun, Lily Silverman, Matthew Niepielko, Michael Rizzo, Cecil "Jake" Saunders*

Earthworm digestion is critical for establishing soil's biological properties and is modulated by signaling molecules within the earthworm. Neuropeptides are short protein signaling molecules that orchestrate many vital biological functions across metazoa, like reproduction, metabolism, and digestion. While many neuropeptides are highly conserved throughout evolutionary history, uncharacterized modifications or entirely novel signaling molecules are often discovered in under-explored genomes. Thus, we chose to investigate neuropeptide signaling in the European Nightcrawler, Dendrobaena veneta. To identify neuropeptide genes, we conducted Pacbio RNA-sequencing on neural tissue and two digestive tract structures, the crop and gizzard. We identified many transcripts that contained a sequence indicative of neuropeptides. Several myomodulin homologs and one novel peptide were selected from our candidate list for physiological and anatomical characterization. To determine if these peptides would modulate digestive tract smooth muscle contraction, we examined their ability to alter the rhythmic contractions of an explanted earthworm crop-gizzard. While one myomodulin variant significantly increased both the contraction rate and force of the crop gizzard, another myomodulin variant and the novel peptide had the opposite effect. Finally, to determine the anatomical source of Myomodulin, we employed single-molecule fluorescent in situ hybridization, which labeled clusters of cell bodies in the segmental and suboesophageal ganglion. Characterizing these novel neuropeptides offers a powerful lens for examining the evolution of the neural control of the digestive system.

## It's a team effort… sometimes: drivers of joint territorial defense in songbirds

*Shreyas Arashanapalli, Benjamin Freeman*

The way that species defend territories varies across environments. In particular, both defense by a single individual (typically a male) and joint defense by a mated pair are common strategies, with other cases where a family group may jointly defend the territory. Here we test the hypotheses that joint territorial defense is explained by geography (latitudinal zone), ecology (territoriality, migration, cooperative breeding), or sexual selection (social bonding, sexual selection score, duetting). We tested these hypotheses by conducting 3169 playback experiments to measure joint territorial defense in 266 species of birds across the Americas. We used phylogenetic regressions to evaluate the importance of predictor variables and report evidence that a combination of geographic, sexual selection, and ecological traits all contribute to joint territorial defense. Joint territorial defense was more common in tropical species, cooperative breeders, and duetters. Taken together, our results provide strong evidence of the factors that explain the observed variation in joint territorial defense.

## Architectural gear ratio and muscle-tendon function improves during pregnancy and lactation in rats

*Adrien A. Arias, M. Lauren Delargy, Nicole Danos*

Changes in limb muscle-tendon morphology during pregnancy suggest that mammals may decrease the energetic cost of locomotion to mitigate the increased metabolic demand of gestation and lactation. Muscles with series elastic elements may improve force economy by decoupling whole muscle-tendon unit length from fascicle length during dynamic muscle contractions. Previous work shows that the medial gastrocnemius of rats (Rattus norvegicus) increases in proportion of Type IIa muscle fibers that insert into more compliant tendons during lactation. However, it remains unclear whether these changes lead to any functional differences at the muscle level that directly show more efficient force generation or increased elastic energy storage capacity. Here we used in situ muscle preparations on isolated medial gastrocnemius muscle-tendon units in non-pregnant, pregnant, and lactating rats to characterize architectural gear ratio (AGR = whole muscle/fascicle velocity) and maximum capacity for elastic energy storage. Preliminary results show increased AGR values (across most isotonic conditions) and elastic storage capacity (during optimal fixed-end contraction) in pregnant and lactating rats, relative to non-pregnant controls. These results suggest that pregnancy and lactation cause an increased range of gear ratios and elastic energy storage capacity in the lower limb of rats, consistent with more efficient force generation potentially reducing the energetic cost of locomotion in pregnant and lactating mammals.

## The biogeography of avian abundance along elevational gradients

*Maria Jose (Majo) Arias, Abhimanyu Lele, Jacob Drucker, Benjamin Freeman, Elisa Bonaccorso*

The "abundant-centre hypothesis" predicts that species tend to be most abundant at the center of their distribution, and scarcer towards the edges, reflecting the distribution of optimal conditions and resources. We used data from mist-net and point count surveys to study the shape and the drivers of abundance of 25 passerine bird species along a 3000-m elevational gradient on the northwestern slope of the Ecuadorian Andes, where the Tropical Andes and Chocó biodiversity hotspots converge. We modeled the shape of the abundance distributions of species across the elevational gradient, and used N-mixture models to ask questions about the biotic and abiotic parameters that shape abundance. We show that the elevational distribution of bird abundance in these tropical mountain forests varies among species, and that no single parameter predicts local spatial patterns throughout the gradient. Our results point towards the complex and multifaceted system of ecological factors that shape species' distributions in the Andes, and they reinforce the need to develop more effective conservation strategies that are imperative to preserve mountain habitats in the face of climate change and persistent anthropogenic pressure.

## Clinging for shear life: modulation of suction performance in the northern clingfish

*Sarah Arnette, Cassandra Donatelli, Olivia Hawkins, Jack Rosen, Jonathan Huie*

Northern clingfish (Gobiesox maendricus) have evolved an abdominal suctorial disc that is used to adhere to rocks and resist the dynamic waves of the intertidal. Even deceased clingfish generate impressive forces that have inspired the design of novel adhesive technologies. However, little is known about the role of behavioral modulation in the suction performance of living clingfish. In this study, we 1) compared the suction performance between live and dead clingfish ($n = 5$), and 2) explored the musculoskeletal structures supporting the adhesive disc using micro-computed tomography (micro-CT) and iodine contrast-enhancing stain. We exposed live clingfish to increasing flow speeds in a high speed flume until they detached and measured suction force using a custom platform fitted with pressure transducers. Following live trials, animals were euthanized and the experiments were repeated. We found that live clingfish generate higher suction forces and could withstand higher flow speeds before detachment. However, suction performance increased passively in dead clingfish as flow speed increased, indicating that suction performance is a combination of passive mechanics and behavioral modulation. The disc is made of modified pectoral and pelvic girdle bones and is actuated by several muscles that we predict allow for fine-scale changes which enhance substrate contact. Together, our data suggest that existing adhesion technologies may be advanced by generating actuated models based on the functional anatomy of clingfish muscles.

## Early ontogenetic allometry and shifting modularity in skull development of the red sea anemonefish

*Kaleigh Arnold, HoWan Chan, Mayara Neves, John Majoris, Kory Evans*

Fishes experience dramatic morphological and ecological changes during early development, particularly after flexion, when many species begin feeding actively in the water column. Trait covariation is believed to shift significantly during this period due to changes in cell migration, differentiation, and larval behaviors. We investigated the early ontogenetic allometry and modularity of the skull in the Red Sea anemonefish, Amphiprion bicinctus, from hatching through day 14 post-hatch, covering critical life history transitions including benthic hatching, pelagic stages, and reef settlement. Using micro-CT scans and 3D geometric morphometrics, we quantified the allometric growth of cranial structures across key developmental stages. The primary axis of shape variation during development was driven by growth in the premaxilla, maxilla, and mandible, characterized by positive allometric growth in feeding-related structures during early larval stages, supporting rapid adaptation to environmental demands. This growth transitioned to more isometric patterns as the fish approached reef settlement. Our modularity analysis revealed shifting patterns between pre- and post-flexion stages, where the upper and lower jaws, initially decoupled, became integrated during postflexion. This shift coincides with the transition to suction-feeding in larvae, providing strong evidence for changes in modularity at key developmental points. These findings enhance our understanding of morphological adaptations in A. bicinctus and offer a basis for comparative analyses across fish families, contributing to evolutionary developmental biology and functional morphology.

## Investigation of stinging cell development in the coral, *Astrangia poculata*

*Sarah Arnold, Leslie Babonis*

Stinging cells are present in all cnidarian species and have become specialized for many different functions, making them an excellent system to study the diversification of cell identity across species. Previous work has identified key genes involved in stinging cell development in the sea anemone, Nematostella vectensis, but this process has not been studied in any other Anthozoan species. To better understand the development and diversification of stinging cells across Anthozoan species, we have established the stony coral, Astrangia poculata, as a tractable model. We have characterized the morphologically distinct types of stinging cells present in A. poculata, showing that they have a greater diversity than those present in N. vectensis. Preliminary analysis using in situ hybridization and shRNA knockdown techniques suggest that known regulators of stinging cell differentiation in N. vectensis (SoxB2 and ZNF845) may also regulate their development in A. poculata. In addition, we wanted to identify genes regulating the stinging cell types in A. poculata not found in N. vectensis to understand how this diversity arises. To do so, we generated a developmental scRNAseq time-course every 12 hours for the first four days of development to capture stinging cell differentiation. With this comparative system, we aim to understand how new genes are integrated into conserved gene regulatory networks to facilitate cell type diversification across species.

## Boulevard of broken frogs: patterns of local (mal)adaptation in polluted ponds

*Santi Arounsack-Colon, Steven Brady*

Road networks and their pollutants are widespread across the landscape, especially in urban settings. These features of the built environment degrade aquatic habitats and reshape natural selection across much of the planet. Two species of amphibians have shown contrasting patterns of local population divergence in response to the effects of roads and pollution. Spotted salamanders show classic local adaptation to road-adjacent breeding ponds despite high costs to survival in roadside habitats and local maladaptation to road salt exposure. Wood frogs on the other hand present a complex suite of outcomes with contrasting impacts on different components of fitness, suggesting either a suite of trade-offs or persistent local maladaptation. Here, we present gene expression findings that might help explain the presence of maladaptive traits in road-adjacent wood frog populations and discuss the implications of alternative splicing in the context of rapid, (mal)adaptive responses to pollution. We also draw upon estimates of quantitative genetic parameters and countergradient osmoregulatory variation in embryos to discuss a suite of mechanisms that might constrain or facilitate adaptation to these stressful road-adjacent environments.

## Life in Flux: Investigating Species Adaptations in Dynamic Estuaries

*Tiffany Arpi*

The Chesapeake Bay's dynamic conditions create a challenging habitat for native species to survive within. This study aims to investigate the adaptations that enable the formation of specialists under estuarine conditions. Water quality analyses and species data collected at different points of the Bay at the Smithsonian Environmental Research Center (SERC) were examined to explore abiotic factors and their effect on common species' diversity and abundance. Findings reveal that dissolved oxygen, temperature, and salinity play a major role in shaping the species profile and environmental suitability of the Chesapeake Bay. These results are substantiated by research highlighting the importance of physical factors on estuarine species, including environmental factors such as habitat heterogeneity, competition, and resource availability. Species-specific morphological and physiological adaptations also shape organisms' varied tolerances. Human activity can further destabilize these volatile ecosystems, resulting in detrimental outcomes (i.e., eutrophication, mass species death) that inhibit organisms' abilities to thrive. The significance of alleviating anthropogenic stressors to preserve estuarine biodiversity is made evident. Further research into the adaptations allowing species to inhabit the Chesapeake Bay successfully may lead to the implementation of effective conservation strategies.

## Mechanisms driving behavioral responses to invasive species in threespined stickleback

*Eric Arredondo, Laura Stein, Brendon Byrd*

Parents often juggle competing demands, such as protecting themselves versus their offspring from predators. Invasive predators are increasingly prevalent across ecosystems, presenting challenges to parental decision-making. Parents might respond inappropriately to novel predators, leading to severe consequences for their fitness. However, little is known about the behavioral and neural mechanisms by which parents make decisions when encountering unfamiliar predators. Threespine stickleback (Gasterosteus aculeatus) are small teleost fish found throughout the northern hemisphere. In Alaska, stickleback encounter various predators, including native rainbow trout (Oncorhynchus mykiss) and invasive northern pike (Esox lucius). We tested the hypotheses that the introduction of invasive pike alters average parenting behavior, and responses to invasive and native predators show different neural activity in the amygdala. Across two lake types (pike/no pike), we assigned parenting males to one of three treatments (native predator: trout; invasive predator: pike; non-predatory native fish: Arctic char). Baseline behavior was measured, followed by exposure to one of the three model stimuli. Brain tissue was processed for immunohistochemistry to assess neural activity. Our results will elucidate behavioral and neural mechanisms governing parenting decisions amidst different types of predation risk, providing insights into species interactions in changing environments.

## From pause to play: how temperature affects dormant zooplankton development

*Hunter Arrington, Joseph Covi*

Understanding the dynamics of thermal tolerance in organisms that are responsible for a significant amount of global biomass in aquatic systems is critical for proper management of natural resources. Freshwater zooplankton can experience dormancy lasting days to centuries as embryos residing in lake sediments. These dormant embryos create an "egg bank" that enhances genetic diversity within populations and provides a buffer against extinction in variable environments. We examined the effects of short-term temperature elevation on post-dormancy development and survival of Boeckella poppei, a naturally occurring monoculture of copepod in Maritime Antarctica. Experiments show different developmental patterns for embryos exposed to 7 days of elevated temperature at 20°C and 25°C to the 4°C control groups. All copepods were monitored for a total of 8 weeks and not fed for the duration of experiments. Nauplii hatched in both 20°C and 25°C groups, suggesting B. poppei are tolerant to increasing temperatures. However, increased failed embryonic development and death by week 8 in groups exposed to 25°C, further suggesting thermal tolerance, not resistance. Data show increased development around 4 weeks to the pre-nauplius embryonic stage and decreased nauplius (hatched) stage in both 20°C and 25°C groups compared to 4°C groups. The increase in embryonic development and nauplius death suggest depletion of yolk during embryonic development under thermal stress. Additionally, stored sediment samples are unique environments as control groups varied.

## Chillin with urchins: how temperature influences larval development in *Strongylocentrotus purpuratus*

*Ivanna Arrizon Elizarraras, Douglas Pace, Sarah Kasem, Ethan Nguyen, Alanna Ha*

While there are many studies comparing larval development of different species at different habitat temperatures, there is little information comparing the same species at different temperatures. This study assessed how temperature influences development, growth, and physiological energetics in larvae of the purple sea urchin, Strongylocentrotus purpuratus, which has an estimated thermal range from 5°C-20°C (Alaska to Baja California). Larvae were reared at 9°C and 16°C and fed 10,000 algal cells ml-1 daily. We hypothesized that larval rearing temperature would have broadscale consequences on larval phenotype, resulting in different cumulative energetic costs of development. Larvae cultured at 9°C had lower respiration rates and smaller post-oral arms throughout development compared to larvae reared at 16°C. Both time-to and size-at metamorphic competency were significantly influenced by rearing temperature. Larvae at 9°C achieved 70% competency at 62 days post-fertilization (DPF) with a protein biomass of 2,818 ng ind-1, whereas at 16°C, 70% competency was achieved at 30 DPF with a biomass of 4,732 ng ind-1. Despite having 40% less biomass, larvae reared at 9°C had a cumulative cost of development 2.5-times higher than larvae reared at 16°C (341 and 135 mJ for 9°C and 16°C larvae, respectively). Our results demonstrate how temperature influences more than just the rate of development and may involve substantial tradeoffs between size at metamorphosis and the energetic cost to achieve it.

## Tax the rich (bees): Individual-level niche dynamics of bumble bee pollen loads

*Kaysee Arrowsmith, Madeleine Strait, Manogya Chandar, Berry Brosi, Shalene Jha*

In this study, we integrated molecular and network ecological approaches to examine potential drivers of intra-specific heterogeneity in bumble bee (Bombus spp.) foraging niches. We conducted our study in five subalpine meadows in the Colorado Rocky Mountains in 2023 and 2024. During this time, we collected pollen from the corbiculae of over 800 individual bumble bees and used DNA metabarcoding to identify the plant species that made up these pollen loads. We then connected the diversity of pollen found in these individual pollen loads to variation in genetic markers, body size measurements, and temperatures at the time of foraging, with the expectation that all three potential drivers would influence the composition of pollen species in our pollen loads. We found that bumble bee species identity mediated the effects of temperature and body length on the proportion of the population-level niche width utilized by individual bees. These findings suggest that different bee taxa have different relationships between individual-level and population-level foraging patterns, which has broad-scale implications for biodiversity persistence and ecosystem function.

## Three-dimensional immunofluorescence brain atlas of the hackled orb weaver spider, *Uloborus diversus*

*Gregory Artiushin, Abel Corver, Andrew Gordus*

Spider orb-web building is a striking example of animal construction, performed by an animal with a relatively small nervous system – but little is known about the neural basis of this complex, innate behavior. A majority of our knowledge of spider brain anatomy stems from studies of cursorial species, which do not build webs for the purpose of prey capture. A foundational mapping of an orb-web building spider brain will be valuable for advancing and grounding future investigations into the circuit mechanisms controlling this behavior. We have created a three-dimensional atlas of the brain of the hackled orb-weaver spider, Uloborus diversus through confocal imaging of whole-mounted synganglia. Using immunostaining against synapsin to reveal neuropil structures and serve as a common reference channel, we have registered image volumes of expression patterns for many of the canonical neurotransmitter- and neuromodulator-, as well as a subset of neuropeptide-expressing populations, to create a cohesive atlas which is the first of its kind for a spider species. This initial view into the neuroanatomy of U. diversus comprehensively details immunoreactivity throughout the synganglion of an orb-web building spider, revealing co-expression patterns in established structures, as well as novel neuropils not hitherto recognized in other study species.

## Do carnivorous bladderworts funnel prey into their traps - reexamining trap entrance structures

*Celia Arzola, Lukyon Mendrin, Ulrike Muller, Luz Gonzalez Ponce, Otto Berg*

Bladderworts (Utricularia) are a genus of carnivorous plants comprising more than 200 species and occur in a wide range of wet habitats from terrestrial to fully aquatic. Trap morphology varies widely, in particular at the entrance region. Those entrance structures range from flat wings and robust horns, over dense bundles of bristles, to elongate antennae. Few hypotheses have been formulated about their function, and only one has been tested experimentally. The long antennae in aquatic species have been shown to funnel zooplankton prey toward the trap entrance. A previous study tested this hypothesis by comparing capture success of traps with intact and removed antennae on one aquatic bladderwort species (Utricularia vulgaris) and one species of zooplankton prey, and found that complete removal reduced capture success.We conducted experiments with additional species and prey types using the same overall protocol, testing whether this finding applies across bladderwort and prey species. We used lab experiments and a mesocosm approach using four bladderwort species. We found that removing the antennae did not significantly reduce capture rate in Utricularia australis, gibba, bremi, and inflata, in neither the lab experiments using a single prey species nor the mesocosm experiments using a prey spectrum. These findings raise questions for further research of antennae's true function, which could offer deeper insight into understanding bladderwort trap morphology.

## Do dispersive larvae of highly fecund species facilitate rapid adaptation?

*Alexander Ascher, Carolyn Tepolt*

The rapid rate of climate change in the modern era necessitates an equally rapid rate of adaptation to maintain population stability. The common life-history strategy of producing a large quantity of dispersive larvae may be one way in which marine taxa facilitate rapid adaptation, both selective and plastic. High fecundity generates a large gene pool for selective forces to act upon at the larval stage. In addition, environmental heterogeneity encountered during dispersal may increase the likelihood of a beneficial plastic response. Overall, high fecundity and dispersal across a heterogeneous environment may interact to enhance phenotypic variation at a crucial life-history stage, allowing species to persist in a changing environment. Here, we use laboratory experiments to measure variation in fitness traits, such as body size and respiratory rate, of a wild copepod population and their offspring, in order to investigate the potential role of larvae as facilitators of adaptation. Nauplii of the common model organism Acartia clausi were raised under different temperature regimes, simulating a heterogeneous environment. Fitness traits were recorded at each developmental stage from nauplius to adult in order to assess stage-specific phenotypic variation and plasticity. This research serves to underline the impact a dominant life-history strategy may have on adaptability.

## An Open Educational Resource for introductory/intermediate courses in eukaryotic biodiversity

*Neil Aschliman*

Essential Biodiversity is an Open Educational Resource (OER) textbook in support of a one-semester lecture plus lab course in eukaryotic biodiversity at the 100/200 level. This free and adaptable resource describes the state of the field as of mid-2024 and surveys the four clades of eukaryotic "supergroups." It particularly emphasizes the diversity of major animal phyla and causes of infectious disease in humans and domestic animals. The text features up-to-date, streamlined, and intuitive cladograms constructed using evidence-based best practice methods, which help students avoid common pitfalls in interpreting trees. It includes detailed, accessible dissection figures and guides, with a wealth of original, Creative Commons-licensed, and public domain images facilitating functional anatomy interpretation. The laboratory components feature guided inquiry and active learning exercises, challenging students to integrate concepts as they examine specimens. The text is now in a second edition and has improved student access to high-quality academic materials at several universities and high schools.

## Position of negative feedback loops within signaling pathways affect fitness

*Danial Asgari, Ann Tate*

Signaling pathways are often regulated by negative feedback loops (NFL), which are activated upon stimulation and dampen the response to stimuli. These NFLs generally fall into two categories: those that decrease input into the pathway by acting upstream (e.g., by removing receptors) and those that function downstream to reduce the output (e.g., by reducing transcription of target genes) while maintaining the signaling process. Although multiple-level regulation of signaling by NFLs is ubiquitous, it is yet unclear how the position of NFLs affects host response and fitness upon stimulation. To address this knowledge gap, I have devised mechanistic models that are inspired by the insect immune response and studied the effect of the position of NFLs on host fitness in different environmental contexts. My work suggests that the benefits of NFLs are partly dependent on the stimulant. For example, I have shown that against bacteria that rapidly proliferate, downstream NFLs are more beneficial, whereas, against slow-dividing bacteria, upstream NFLs are favored. On the other hand, my work suggests that the position of NFLs is crucial in modulating noise in the output of the signaling pathway which ultimately affects host fitness. Finally, I complement results from mechanistic models with evolutionary models that measure selective pressure on components of signaling pathways and identify factors favoring the evolution of downstream and upstream NFLs.

## Scaling of Puncture Forces for Needles with Simple Geometry

*Haaris Asghar, Mattia Bacca, David Labonte*

Many plants and animals have independently evolved needle-like structures for a diverse array of functions. The morphological "design" of each needle is a reflection of its specific functional requirements, but it is also subject to hard constraints – the physical laws involved in puncture. Ideal needles puncture a target material with minimal force, but are also be robust to failure from fracture or buckling. In combination, these opposing demands impose constraints on the geometrical and mechanical "design" of needles as they change in size. In order to test how the force required to initiate puncture scales with the tip radius of the needle, we here conduct model experiments with 3D printed needles of well-controlled geometry, puncturing target materials made from silicone rubber. Our results suggest that the tip radius of the needle, its characteristic length scale, competes with a characteristic length scale of the target material such that puncture forces scale either with tip radius or tip radius squared, depending on which length scale is largest. These results have implications for the ideal needle geometry across needle sizes, and seemingly demand a systematic change in needle geometry beyond the transition length to maintain equal relative resistance to needle buckling.

## Exploring ncRNA-mediated gene regulation during key developmental stages in *Montipora capitata*

*Jill Ashey, Ariana Huffmyer, Crawford Drury, Hollie Putnam*

Coral development is governed by complex molecular mechanisms that facilitate critical transitions, such as the maternal to zygotic transition (MZT) and the zygotic genome activation (ZGA). While gene expression during these stages have been characterized, the regulatory mechanisms, particularly the role of non-coding RNAs (ncRNAs), remain unexplored in corals, despite their importance in developmental stages in other taxa. This study aimed to identify the repertoire of ncRNAs that regulate gene expression during MZT and ZGA in Montipora capitata, a reef-building coral in Hawaiʻi. Egg-sperm bundles were collected from Kāneʻohe Bay, Oʻahu, and embryos were sampled at key developmental stages: 1 hour post fertilization (hpf; egg), 4 hpf (cleavage), 9 hpf (blastula), 14 hpf (early gastrula), 22 hpf (mid gastrula), 28 hpf (late gastrula), planula (48 hpf), and swimming larvae (72 hpf). mRNA and small RNA sequencing was conducted to capture RNA expression profiles across these stages. Preliminary data suggest distinct RNA (ncRNAs and mRNA) expression profiles at each life stage, highlighting potential dynamic regulatory roles. We anticipate microRNAs, a type of ncRNA, will be key in degrading maternal transcripts, facilitating ZGA. This represents the first comprehensive study of the roles of ncRNAs in coral MZT and ZGA, providing insights into developmental gene regulation.

## Consequences of sharing pollinators in the Anthropocene

*Tia-Lynn Ashman*

Native flowering plants most often exist in multispecies communities where they share pollinators. Anthropogenic activities are increasingly being recognized as forces altering the structure of plant-pollinator communities via both species gains and losses, potentially changing the functional aspects of the of these communities. The quantity and quality of pollen transferred within and between plant species is well recognized to determine reproduction, population abundances, and mediate selection on floral traits and mating systems, but also may also be critical to pathogen transmission. I will draw from a diversity of studies in my lab to illustrate how community-level patterns in pollinator sharing result in variation in pollen transfer among plants. I further will discuss how plant traits, pollinator traits, changes in plant and pollinator communities, and surrounding landscapes can affect pollen transfer. Finally, I explore the ways these features cascade to impact plant reproduction via the quantity and quality of pollen transferred, fitness lost through improper (heterospecific) pollen transfer and potentially via pollen-associated viruses transferred among plants. Appreciating this panoramic view of pollinator-mediated interactions in plant communities will help efforts to conserve natural biodiversity as well as promotes sustainable agricultural practices.

## Snakes on the Plain: Effects of Biogeographic Barriers in the Southeastern Coastal Plain

*Ali Ashraf, John Phillips*

Historic barriers to dispersal can be studied through detection and delineation of phylogeographic breaks resulting from divergence. In eastern North America, these patterns often arose during periods when glaciation-associated phenomena caused major shifts in geography such as the swelling of major river systems and the reduction of Florida to an island archipelago. However, there is complexity in how organisms respond to these barriers. Not all taxa, even those with similar ecologies, exhibit phylogeographic breaks at the same hypothesized barriers. This study seeks to detect phylogeographic structure associated with hypothesized biogeographic barriers in the banded water snake, Nerodia fasciata, across its range. While previous systematic work on this species has been limited to Florida, in this study we sampled its range throughout the southeastern coastal plain. We sequenced both mitochondrial (cytochrome b) and nuclear (prolactin receptor) genes to evaluate biogeography in this complex, consisting of three putative subspecies. We found three distinct mitochondrial lineages occurring in the western, eastern, and peninsular Florida portions of its range. The distributions of these lineages do not correspond to noted biogeographic boundaries such as the Mississippi and Apalachicola Rivers, but more closely match the three morphologically described subspecies of N. fasciata. Further exploration of this system will contribute to our understanding of how organisms respond to long term changes in geography across continental land masses.

## Evaluating the Effectiveness of DNA metabarcoding in Assessing macroinvertebrate communities

*Maame Asiamah, Segun Oladipo, Iysa Olorunshina Muhibbu-Din, Lotanna Nneji*

African freshwater ecosystems are facing increasing pressures from pollution, sedimentation, and other anthropogenic pressures. Recent studies have emphasized the importance of robust biomonitoring protocols to detect trends in the decline of aquatic resources. Aquatic macroinvertebrates are indicators of ecological conditions in freshwater biomonitoring programs; however, these diverse groups can present challenges to morphological identification, and coarse-level taxonomic resolution can mask patterns in community composition. Here, we evaluated the usefulness of environmental DNA (eDNA) metabarcoding to explore the diversity and variability of aquatic macroinvertebrate communities from an African freshwater ecosystem at small spatial scales. Using standard protocols, we collected water samples for aquatic macroinvertebrate surveys from three locations (Afon, Laduba and reservoir) across the Asa River in Nigeria. Through eDNA metabarcoding, we discovered that aquatic macroinvertebrate communities exhibit significant diversity even at small spatial scales, with a remarkable level of local taxonomic turnover. Our species pool estimates also revealed many rare taxa and suggested that a significant proportion of species went unidentified by our sampling efforts. The result shows the spatial patterns of macroinvertebrate diversity in relation to habitat characteristics. The result of our study enhanced our understanding of the macroinvertebrates as well as demonstrated the utility of eDNA metabarcoding as a tool for biomonitoring in African tropical freshwater ecosystems.

## Elevated FKBP5 expression in *Peromyscus* leucopus across urbanized landscapes

*Vania R Assis, Gabriella Cifarelli, Bethany Beekly, Cédric Zimmer, Ben Dantzer, Natalie Tronson, John Orrock, Marty Martin*

Urbanization imposes significant challenges on wildlife, affecting behavioral and physiological traits. This study examines the relationship between FKBP5 and urbanization across NEON (National Ecological Observatory Network) sites, focusing on Peromyscus leucopus (the white-footed mouse), an important reservoir host of zoonoses. FKBP5 encodes a co-chaperone protein that binds to the glucocorticoid receptor, modulating its sensitivity and impacting the hypothalamus-pituitary-adrenal (HPA) axis. Elevated FKBP5 levels reduce receptor sensitivity, leading to prolonged HPA activation and lower HPA flexibility, defined here as the ability of an individual to regulate its hormones. Our findings revealed a strong, positive correlation between FKBP5 expression in the blood and urbanization. This result was unexpected, as we initially predicted that individuals better adapted to urban environments would exhibit lower FKBP5 expression, reflecting high HPA flexibility since stressor novelty (in an evolutionary sense) should be higher in cities relative to surrounding natural areas. However, P. leucopus may not cope as effectively with urbanization as anticipated, and the increased FKBP5 expression could reflect a physiological rather than an evolutionary response to rapid environmental changes. As urbanization has intensified only recently, these patterns likely indicate acute stress responses rather than long-term adaptations. These results highlight the complexity of urban stressors and their impact on wildlife, underscoring the need for further research into how species manage urban environments and the potential implications for host competence and disease transmission.

## From pond to Lab: the Impact of stressors on Amphibian immune response

*Vania R Assis, Stefanny C Titon*

Amphibians, like other vertebrates, respond to stressors through the activation of the hypothalamus-pituitary-interrenal (HPI) axis, leading to elevated levels of glucocorticoids in the bloodstream, with corticosterone (CORT) being the primary hormone involved. As seen in many other vertebrates, physiologically increased CORT levels are commonly associated with immune modulation, which might enhance or suppress the immune response. This outcome is influenced by several factors, including the duration and intensity of the stressors, the body condition of individuals, life-history and species-specific traits. To elucidate the role of stressors and CORT in amphibian immunity, we have conducted a series of studies both in natural environments (“Pond”) and controlled settings (“Lab”). These studies involve the application of various stressors, including restraint, captivity, and exogenous hormone treatments, alongside “in vivo” and “in vitro” immune assays. Our findings reveal that CORT levels and their effects on immunity are highly variable, yet they do not act in isolation. There is a significant interaction between CORT and other hormones, such as testosterone and melatonin, which further influence the immune response in amphibians. This interplay underscores the complexity of the stress-immune relationship and suggests that a holistic approach is essential to fully understand the impact of stressors on amphibian health and conservation.

## Only skin deep: a novel biomimetic control strategy for rectilinear locomotion in snake robots

*Henry Astley*

Snakes are masters of movement through cluttered, confined, and complex habitats, and snake robots seek to replicate these capabilities to improve our access to these challenging environments. Snakes use a variety of locomotor modes to traverse different habitats, but rectilinear allows snakes to move through even the narrowest of spaces which preclude other modes. However, this mode relies on motion of the muscular skin rather than axial bending, making it challenging to replicate in robots. Prior methods used dedicated secondary actuator systems (e.g. motorized treads or prismatic joints), anteriorly propagating waves, and/or "inchworm" kinematics, which require additional mechanical complexity, high vertical clearance, or symmetry-breaking via anisotropic friction or grippers, respectively. Here, I present an alternative method, based on matching the robot to the motion of the ventral skin. Particular segments are assigned roles of either rigid ventral scutes or flexible intrascutal skin. As in biological snakes, "scute segments" are lifted clear of the substrate and moved forward via contraction and expansion of the "intrascutal motors" anterior and posterior to the scute, respectively. By regulating the motor motions, slip in the non-lifted segments is minimal. This control algorithm allows rectilinear locomotion in any snake robot with more than nine vertical motors, without the need for additional specialized actuators or frictional surfaces, with similar performance to other strategies.

## The gut microbiome of the African Forktail Catfish (Chrysichthys nigrodigitatus) revealed by 16S rRN

*Olabisi Atofarati, Segun Oladipo, Ifeanyi Nneji, Kehinde Adelakun, Lotanna Nneji*

The gut microbiota has become a topic of increasing importance in various fields, including ichthyology. Several fish species have been the subject of investigations concerning the intestinal microbiota, but not the most economically important fishes from the African aquatic ecosystems. In this study, we analyzed the gut microbiomes of an economically important fish - the African Forktail Catfish (Chrysichthys nigrodigitatus) - collected from different Nigerian aquatic ecosystems to understand its microbiota compositions and spatial variations in the gut microbiomes. Microbiota data were obtained using a 16S metabarcoding approach by analyzing the V3–V4 hypervariable regions of the corresponding 16S rRNA. Our metabarcode data showed that the core microbiota of the African Forktail Catfish. Indeed, alpha and beta diversity analysis revealed differences between the gut microbiota composition of fishes collected from different sampling locations. Our work represents the first study on the intestinal microbiota of African Forktail Catfish. Our study further highlights the usefulness of metabarcoding tools in unveiling gut microbiomes of the diverse African fish species.

## Role of hoxa13 and hoxa11 on cartilage development in the zebrafish pectoral fin.

*Augustin Au, Anindita Basu, Neil Shubin, Katelyn Mika*

Cartilage development is less understood in fins than their homologous tetrapod counterparts, limbs. I am investigating how hoxa13 and hoxa11 drive zebrafish cartilage development. Hoxa13 and hoxa11 were chosen as they are key to cartilage differentiation in the tetrapod autopod and zeugopod. Without them, there is insufficient levels of bone morphogenetic protein 7 and 2 (bmp7 and bmp2), leading to defective cartilage formation. Zebrafish are the ideal model for this study as they have a known genome, are relatively inexpensive, and express lubricin, a protein signifying that fish joints experience pressure and degenerative diseases like those of humans. To investigate this question, we collected single cell sequencing data (DROPseq) on wildtype, hoxa13a knockout, and hoxa13b knockout zebrafish pectoral fins. I am isolating articular cartilage cells by identifying the region of co-expression of hoxa13 and hoxa11, as well as regions of mutually exclusive expression of hoxa13 and hoxa11. Next, I will identify differences in gene expression between these regions, paying particular attention to known cartilage markers such as bmp7 and bmp2, to reveal the role hoxa13 and hoxa11 play in zebrafish cartilage development and maintenance. To confirm expression patterns of genes of interest, I am performing fluorescent in-situ hybridization. Future findings may contribute to a better understanding of cartilage maintenance in fish and tetrapods, ultimately providing some insight into osteoarthritis prevention.

## Tempo and mode of trait evolution in the adaptive radiation of Malagasy vangas

*Anya Auerbach, Euan Lim, Sushma Reddy*

Adaptive radiations are emblematic examples of evolution and offer powerful opportunities to help understand the processes which generate ecological and phenotypic diversity. We examined the tempo and mode of diversification in a spectacular yet understudied radiation of birds, the Malagasy vangas and their relatives (Aves: Vangidae), focusing on two areas of ongoing debate in the adaptive radiation literature. First, how important are early bursts versus other temporal dynamics of diversification, and what factors influence rates of trait evolution? Second, what is the role of integration versus modularity in facilitating evolvability? Using 3D geometric morphometrics of multiple anatomical regions and phylogenetic comparative methods, we assessed patterns of morphological diversity, examined the relationship between integration and diversification, and evaluated rates of trait evolution through time. Rather than the classical pattern of an early burst, we found that accelerated rates of trait diversification in Malagasy vangas are best associated with the origin of novel foraging strategies in one subclade, which may have served as a key innovation facilitating subsequent ecomorphological diversification and specialization. The presence of extreme, unique morphologies among vangas is an iconic component of their radiation but challenges straightforward interpretation; these idiosyncratic patterns of trait covariation complicate our conclusions regarding the role of integration and modularity in diversification. Our study highlights the importance of examining multiple traits and considering more complex models of trait evolution.

## Males of a fighting insect differ in whether their sexually selected hind leg spines bend or break

*Giovanna Avellar Figueredo, Elizabeth Greenway, Christina Salerno, Walter Federle, Christine Miller*

Many species have evolved sexually selected weapons in male-male competition. Much remains unknown about how nutrition impacts weapon construction and structural integrity. In the insect Narnia femorata (Hemiptera: Coreidae), males use their spiny hindlegs as weapons to grab and squeeze male opponents in competition over mating opportunities. Previous studies have established in this species that high-quality juvenile nutrition improves injury resistance of the hind leg weapons. Yet, the effects of adult nutrition on injury resistance are largely unknown. Further, we do not know the effects of nutrition on an essential offensive component of the insect's weapon: its spines. For this purpose, adult N. femorata were reared on natural diets varying in quality. Hind legs were removed 28 days post-eclosion. We tested the structural integrity of the terminal femur spine by pressing a force transducer against the spine tip with increasing normal force. A spectrum of responses was observed: some fractured, while others bent strongly without breaking. Strong bending of the spines was also dependent on the flexible cuticle supporting the spine. Insects reared on low-quality diets showed a trend of lower bending and breaking forces. These differences suggest that despite their similar size, shape, and appearance, spines can differ strikingly in their mechanical response. Future studies in this area will examine the degree to which spine bending or breaking affects performance in male-male competition.

## Intramandibular joint disrupts morphological integration of guppy oral jaws

*Tess Avery, David Matthews, Terry Dial*

The highly evolvable craniofacial apparatus in fishes provides a powerful model for examining morphological integration. Here, we use Trinidadian guppies (Poecilia reticulata), a poeciliid fish exhibiting population-level differences in diet type, to examine the degree of morphological integration among jaw elements in a derived system with mobility between the two elements of the mandible. We use μ-CT scans and geometric morphometrics to analyze the three-dimensional shape of jaw bones from replicated generalist and benthic populations. We quantify the relative importance of plasticity and genetics in determining morphology by comparing patterns of integration between wild-caught ($n = 51$) and lab-raised ($n = 32$) fish. We find, with the exception of the posterior portion of the mandible (anguloarticular) ($p = 0.62$), there are significant shape differences between generalist and benthic-feeding populations of wild-caught guppies ($p < 0.05$). This points to a decoupling of morphological evolution in the lower jaw, suggesting morphological integration of jaw elements may be driven by shared mechanical demands. We find that the shape of oral jaw bones in lab raised guppies (5/6 pairs) are integrated, while the same bones show little integration in wild populations (1/6 pairs). This suggests that while genetic integration maintains morphological covariance in the lab-reared populations, environmentally driven plasticity is not constrained in this way and allows each element to independently respond to the local environment.

## Effects of bidirectional deformation on colony-scale flow around a sea fan

*Adetokunbo Awonusi, Arvind Santhanakrishnan*

Sea fans such as Gorgonia ventalina exhibit whole colony flexibility in habitats experiencing moderate to high flow currents. The entire colony can undergo unidirectional and bidirectional deformation depending on the environmental flow conditions. While unidirectional deformation benefits attachment by reducing drag and feeding by influencing local flow, the impact of bidirectional deformation on filtration and drag force production remains unclear. To investigate this, particle image velocimetry (PIV) measurements and numerical simulations were conducted on simplified models of G. ventalina under varying oscillation parameters (angular amplitude, frequency) under continuous background flows. Findings suggest that bidirectional deformation induces flow recirculation and fluid displacement across the downstream and upstream sides of the colony. Increased angular amplitude results in generating more vorticity, retaining particles within the vicinity for further encounters. Vorticity production is enhanced at lower frequencies.

## The effects of flow on prey capture in largemouth bass (Micropterus salmoides)

*Erik Axlid, Tim Higham*

Most vertebrates must capture prey or evade predation while dealing with complex environmental conditions. In aquatic habitats, this complexity is caused in part by spatial and temporal variations in flow. Fluid velocity plays an important role in determining flow patterns and varies widely within both freshwater and marine environments. Although the effects of flow characteristics on the speed, kinematics, and efficiency of swimming have been studied in several fish species, few studies have measured the effects of flow on prey capture kinematics and success. Examining these relationships will aid in understanding how hydrodynamically variable conditions influence prey capture ability. Largemouth bass (Micropterus salmoides) can inhabit a wide variety of habitats and flow regimes, and their prey capture kinematics have been described extensively under a variety of conditions. These include a range of light levels, prey types, levels of satiation, and acute temperature changes. However, nothing is known about how ambient flow conditions impact the approach and capture of prey. We investigated the prey capture dynamics of largemouth bass feeding on suspended mealworms in flow velocities from 0-75cm/s by using 3D high-speed video. We then extracted kinematic variables related to both the approach and strike. Our data shed light on the importance of incorporating ecologically relevant conditions into studies of predator-prey interactions in fishes.

## The influence of pathogen diversity and temperature on eelgrass wasting disease outcomes

*Angela Ayala, Rebecca Maher*

Eelgrass meadows are highly biodiverse marine ecosystems found worldwide; however, warming temperatures threaten their vital roles in carbon storage, coastal protection, and as fish nurseries. Eelgrass hosts a complex microbial community on its surface that reacts jointly to environmental changes; therefore changes in microbial life caused by abnormal heat waves serve as an indicator of meadow health. Eelgrass is vulnerable to invasion by Labryinthula zosterae, a pathogenic protist that is the causative agent of eelgrass wasting disease (EWD). Deeper understanding of opportunistic conditions for L. zosterae to cause EWD is becoming increasingly important as eelgrass meadows rapidly decline. At Friday Harbor Labs, WA, we tracked the eelgrass (Zostera marina) microbiome and disease severity to evaluate how differing pathogen strains and elevated temperatures influence disease outcomes. Eelgrass leaf segments were placed into 11°C or 19°C aquarium tanks and inoculated with two L. zosterae strains: a historic lab strain, MVA V1 and a newly isolated strain. Microbiome sampling occurred before, during, and after inoculation to assess 16S rRNA sequencing. After measuring final percent lesion severity, we observed that MVA V1 is more pathogenic than the new strain at 11°C and led to complete tissue death at 19°C. Additionally, warmer temperatures significantly exacerbated lesion severity for both strains. These findings provide insight into eelgrass meadow disappearance by demonstrating how warmer temperatures exacerbate disease severity and tissue wilting.

## Plants and their microbiomes: from integrative organismal biology to student engagement and training

*Mentewab Ayalew*

Plants are intimately connected to soil, a complex environment that is a source of essential nutrients. It is also inhabited by a diverse set of organisms, especially bacteria, some of which are found in or on plant organs, especially roots. The discovery that plants have antibiotic resistance genes underscores this notion. The characterization of the Arabidopsis antibiotic resistance gene suggests a role in maintaining metal uptake while limiting entry of antibiotic in the plant vasculature. This discovery also prompts questions on the prevalence and significance of antibiotics in the vicinity of plant roots. We analyzed high quality shotgun metagenomic datasets to identify bacterial species enriched in roots as well as biosynthetic gene clusters involved in the production of known antibiotics. Assembling reads matching antibiotic BGCs further allowed us to identify species harboring antibiotic BGCs. This analysis revealed that several streptomyces species were consistently enriched in roots and provided a first insight on potential antibiotics. The analysis further establishes Arabidopsis as a model for investigating plant-microbe-microbe interactions mediated by antibiotics. This line of research also served as a vehicle for supporting genomic data science through the development of a new course on Microbiomes and student driven research projects.

## Investigating eye-facing photophores in context of counterillumination among mesopelagic shrimps

*Umut Ayoglu, Heather Bracken-Grissom, Laura Bagge, Lorian Schweikert*

Many animals that live in the deep sea are vulnerable to predation as dim downwelling sunlight creates silhouettes of the body that are visible from below. Counterillumination is a form of camouflage that obscures these silhouettes using emissions from bioluminescent light organs, known as photophores. For camouflage to be effective, the brightness of emitted light must be matched to changes in the downwelling light field, but how animals might assess the degree of match remains unknown. Diverse animals are thought to monitor their own glow via eye-facing photophores, but this has yet to be shown in mesopelagic crustaceans, a group heavily dependent on counterillumination. Here, we set out to determine whether eye-facing photophores exist among 14 species of mesopelagic shrimps represented by the families Sergestidae, Oplophoridae, and Acanthephyridae. Using light microscopy and micro-computed tomography (micro-CT), we then further characterized the morphology of apparent eye-facing photophores in Challengerosergia talismani and Systellaspis debilis, finding differences in the positioning of their photophores (on either the eye or eyestalk) and in their direction of light emission (to either the proximal or distal eye). These findings provide new evidence for the presence of eye-facing photophores in deep-sea crustaceans, further suggesting the importance of self-monitoring bioluminescence among animals capable of counterillumination.

## That stinging sensation: the cnidocyte as a model for sensory cell evolution

*Leslie Babonis*

The evolutionary diversification of sensory systems has enabled animals to translate similar environmental cues into unique behavioral, physiological, and developmental outputs, promoting biodiversity. While these outputs are realized largely at the whole-animal level, integration of sensory information is mediated by individual cells. Found only in cnidarians, cnidocytes (stinging cells) are sensory-effector cells that translate physical and chemical cues from their environment into the explosive release of a projectile stinging apparatus. Diversification of the projectile throughout cnidarians has resulted in the emergence of a wide variety of cnidocytes with distinct functions. More than just a peculiar fascination, the past 100 years of study into the form and function of cnidocytes has established this cell type as an important model for understanding the integration of sensory information at the level of the individual cell and for investigating the evolution of sensory cell diversification. Here, I summarize historical and recent contributions to our current understanding of cnidocytes as specialized sensory cells and outline an exciting path forward for future studies into cnidocyte specialization.

## Shifts in *Pisaster ochraceus* larval growth and development during and after marine heat waves

*Kiani Baetsle, Sophie George*

In the Northeast Pacific, marine heatwaves (MHWs) are increasing in frequency, intensity, and duration. MHWs have resulted in significant ecological impacts to marine life with up to a 90% reduction in the keystone predator Pisaster ochraceus at several sites. This study is focused on the effect of MHWs on the larval stage of this sea star. Larvae were maintained at ambient temperatures of 12°C or subjected to a 7- or 14-day MHW at temperatures of 20°C. PCA analysis was used to quantify the trait space occupied by larvae from the three treatments. The results from PERMANOVA and PERMDISP indicate that, for every age group, the trait space occupied by larvae in the controls differed significantly from those exposed to a 7- and 14-day MHW. The controls formed a cluster that was characterized by smaller larvae with larger and rounder stomachs while the 7- and 14-day MHW cluster overlapped and larvae were larger with narrower stomachs. Over time, the control larval cluster partially eclipsed the 7- and 14-day MHW larval clusters. The PERMDISP indicated that the within-cluster variation increased significantly at the end of a MHW for the 7- and 14-day MHW larvae. This study shows that larval morphological shifts can occur during and after MHWs and may have a negative effect on progress to metamorphosis and larval settlement.

## Parasites, Fungi, and the Skin Microbiome: Disease Dynamics of Urban Gray Tree Frogs.

*Rafael Baez-Segui, Valentina Alaasam, Anthony Snead, Kristin Winchell*

Once widespread across the New York City metropolitan region, Gray Tree Frogs (Dryophytes versicolor) have largely disappeared within the city limits. As urbanization increased and freshwater green spaces disappeared, this wetland-dependent amphibian has become confined to an increasingly shrinking number of ponds and wetlands that are surrounded by high-intensity developed land. These isolated urban populations are forced to use the same ponds every year, breeding in densities that potentially exceed that observed in non-urban sites where there is greater habitat connectivity. Combined with the novel stressors of urban environments, this forced breeding site fidelity may result in chronic stress in the form of elevated leukocyte counts, and higher incidences of infection from highly transmissible diseases like chytridiomycosis or blood-borne trypanosomal infections. To evaluate the impacts of urbanization on amphibian health, I examined disease prevalence, population size, and compared skin microbiome assemblages of 80 D.versicolor individuals from 12 wetlands throughout their breeding season and we see evidence of variation in pathogen prevalence and immunity markers.

Our findings provide insight into how breeding site characteristics influence the skin microbiome and health of these understudied tree frogs, informing on potential routes for conservation in a rapidly urbanizing world.

## Emergence and organization of trophoblast giant cells across placentation in deer mice

*Natalie Báez-Torres, Kathryn Wilsterman*

Peromyscus maniculatus, a North American rodent renowned for its local adaptation, has emerged as a valuable model system in biological research. However, the reproductive biology of P. maniculatus, especially early developmental processes and placental progression, remains poorly defined. This study addresses the gap in knowledge surrounding the abundance and organization of trophoblast giant cells (TGCs), a critical placental cell type, across placental development in P. maniculatus. Implantation site tissues collected at different gestational time points were evaluated by means of immunohistochemistry, and TGCs were characterized through an immunofluorescence image analysis. Our findings demonstrate the presence of TGCs within distinct placental regions throughout gestation. As expected, TGCs were found throughout the trophectoderm in early gestation. Subsequently, TGC accumulations were observed towards the edge of the placental disk during mid-gestation. Finally, until late gestation, TGCs were widely distributed in the junctional zone adjacent to maternal blood channels and appear to play a role in controlling the entry of maternal blood to the labyrinth zone, where nutrient and gas exchange occurs. Collectively, these findings enhance our knowledge of placentation and gestational physiology in P. maniculatus, offering a comparative framework with other rodent species, such as murids and cricetids.

## Fire ant water launching via meniscal manipulation

*Hosain Bagheri, Haolin Zeng, Surya Narasimhan, Aaliyah James, Michael Goodisman, Takao Sasaki, Daniel Goldman*

Semiaquatic arthropods use diverse gaits and locomotion to navigate water surfaces, leveraging form drag, capillary forces, and curvature forces. Previous studies have examined how insects such as water striders and water lily beetle larvae ascend menisci to transition from aquatic to terrestrial surfaces by manipulating local surface curvature through postural changes [Hu & Bush 2005, 2006]. Here, we study how red imported fire ants (Solenopsis invicta), known for rafting during floods, transition from land to water. We discovered that ants (N=68, 4.9±1.1mm) use diverse body-posture adjustments to overcome the meniscal pull and thus “launch” into the water. These mechanisms including dorsal flexion, ventral flexion, lateral flexion, and lateral rotation. Analysis of peak speed (normalized by body length, BL) during launches from the meniscus revealed that vertical flexion postures (head elevated: 5.9±2.4BL/s, n=28; gaster elevated: 6.8±1.8BL/s, n=5; gaster lowered: 5.4±2.4BL/s, n=6) resulted in higher speeds compared to lateral postures. Smaller ants (4.3±0.9mm) primarily used vertical flexion, achieving higher velocities, while larger ants (5.7±1.0mm) exhibited slower velocities with lateral flexion (3.6±0.9BL/s, n=7), lateral rotation (3.6±3.0BL/s, n=18), or by swimming/walking away (3.7±0.4BL/s, n=4). These findings show how ants leverage meniscus manipulation via body posture changes to achieve tasks such as pontoon bridge construction [Zeng et al., SICB 2023]. Overall, our results reveal new mechanisms by which terrestrial animals effectively move on fluids.

## Assessing black-spot disease in benthic stream fishes over 50 years in north-east Arkansas

*Austin Bailey, Thomas Naylor, Brook Fluker*

Freshwater fishes often exhibit black-spot disease, caused by the encystment of digenetic trematodes which burrow into fish skin and scales during their life cycle. The fish's immune response forms melanin deposits to infection sites resulting in distinctive black spots on the body. Little is understood of the prevalence and consequences of black-spot disease on small stream fishes. This study focused on evaluating the prevalence of this disease and its relationship to body condition for two benthic fishes, Rainbow darters (Etheostoma caeruleum) and Stonerollers (Campostoma spp.) over a 50-year period in Myatt creek, a tributary of the Spring river in north-east Arkansas. Historical specimens of both species from the 1970s were obtained from the Arkansas State University Museum of Zoology (ASUMZ), while contemporary specimens were sampled from the wild in May 2024. Specimens were measured for standard length (SL), weighed, and analyzed for the number of black-spot encystments relative to body condition. Preliminary results from the historical samples suggest that infection rate differs between the two species, with both species also showing different relationships of infection rate and body condition. Contemporary samples of these species will be similarly analyzed and then compared to the 1970s collections. This comparison will provide a better understanding of black-spot disease for benthic stream fishes, as well as a unique look at potential differences in black-spot infections over a 50-year period.

## Effects of red tide on sea turtle nest success in Sarasota County, FL

*Drew Bailey, Jake Lasala*

Exposure to red tide (Karenia brevis) in varying quantities has been known to affect the wellbeing of numerous species in a variety of ways. In sea turtles, prolonged exposure can lead to extreme detrimental impacts on muscular, neurological, and immune function, resulting in potential sublethal and lethal conditions. While these direct effects are well studied, less is known about how K. brevis uptake by nesting females can affect real time behavior or hatchling survival. One study showed that brevetoxin can remain in sea turtles for up to a year after a bloom, potentially impacting reproductive success long after a bloom has dissipated. It is unknown if red tide blooms impact nesting success (the number of nests over the total number of crawls), nor the hatch/emergence success of nests laid during or after a bloom. Historical K. brevis data were collected from 2007-2024 within Sarasota County, Florida - a rapidly growing sea turtle rookery in the Gulf of Mexico - and compared to loggerhead (Caretta caretta) & green (Chelonia mydas) sea turtle nesting, hatch, and emergence success rates. Satellite tag data of nesting females were assessed as a case study to identify if turtles could be confirmed to pass through areas of K. brevis and possibly pass the toxin to their offspring.

## Triploids or diploids? An online decision support tool for oyster aquaculture

*Kiran Bajaj, Paul McElhany, Shallin Busch, Craig Norrie*

Oyster aquaculture in Puget Sound is a highly valued industry of both economic and cultural importance. To increase yields, some oyster farmers choose to plant triploid oysters (individuals with three sets of chromosomes), for their faster growth rate, sterility, and marketability during the summer months when diploids are reproductive. However, farmers must balance these advantages with observed mortality in triploids that is likely to be influenced by one or more stressors including high temperature, hypoxia, desiccation, and food availability. We conducted a meta-analysis of diploid-triploid experiments to evaluate the risk of triploid mortality as reported in the literature so far under various stressors. We compared environmental data from long-term monitoring buoys and cruises around Puget Sound to loggers placed directly on farms to estimate an offset in conditions. This analysis is an important step towards mapping risk of triploid mortality. To synthesize the best available data into a user-friendly format and decision support tool, we developed an interactive R Shiny app. The app helps farmers understand existing triploid mortality data and receive information relevant to their farm given its environmental conditions. Because the direct link between triploid mortality and the environment is currently not well parameterized, the tool will be improved to provide increasingly confident recommendations as more experimental data is reported.

## Ontogenetic Shifts in Brain Size of the Sockeye Salmon, Oncorhynchus nerka

*Abigail Baker, Sarah Gardiner-Rheinsmith, Thomas Quinn, Andrew Dittman, Kara Yopak*

Sockeye salmon (Oncorhynchus nerka) live an anadromous lifestyle, where they hatch in freshwater, mature at sea, and return to their natal stream to spawn. In addition, the nervous system of fishes grows continuously throughout their life cycles, with a high capacity for neural plasticity as they encounter changes in habitat and behavior. However, few studies have investigated how sensory structures and brain size varies throughout ontogeny in O. nerka. This study assessed changes in eye size, brain size, and brain organization in sockeye salmon ($n = 61$) across all major life stages (fry, parr, smolt, at-sea juveniles, migrating adult, maturing adult, and spawning adult). The relative size of six major brain regions (olfactory bulbs, telencephalon, diencephalon, optic tectum, cerebellum, and medulla) was assessed using the ellipsoid method. Using Ordinary Least Squares regression, both eye and brain size increase significantly with body size throughout ontogeny in O. nerka, with a steeper period of allometric growth in early life stages, tapering off in adulthood. Rate of growth of major brain regions also varies throughout life, which may reflect the shifts in sensory specialization. Ontogenetic changes in nervous system structures across life stages may reflect shifts in sensory specialization and/or varying metabolic constraints at key stages, which may have implications for understanding the sensory cues guiding these commercially important species.

## $\mu$CT of hawkmoths and silkmoths reveals distinct muscle morphologies for hovering vs. bobbing flight

*Joanna Baker, Ethan Wold, Leo Wood, Brett Aiello, Simon Sponberg*

Hawkmoths (Sphingidae) and wild silkmoths (Saturniidae) are sister families in the superfamily Bombycoidea which have evolved two distinct strategies for agile flight. Most hawkmoths feed from flowers using high-frequency hovering flight, while most wild silkmoths do not feed as adults, instead using erratic bobbing flight to evade predators. These differences are evident in their wing morphology and kinematics, but we lack an understanding of how thoracic flight muscle morphology reflects this divergence. Silkmoths' low-frequency, high-amplitude wingstrokes and large maneuverable wings may increase demands on steering muscles. Conversely, hawkmoths' higher flight frequencies may place greater demand on power muscles and necessitate frequency modulation for stability and maneuverability. To test these hypotheses, we segmented mesothorax muscles from microCT scans of twenty bombycoid species. Ratios of steering to total flight muscle volumes are higher in silkmoths and inversely correlate with wingbeat frequency. The subalar, a steering muscle involved in wing rotation and depression, is enlarged among silkmoths. Hawkmoths universally have large, straight dorsal oblique muscles, possible frequency modulators present in nearly all hovering insects; in silkmoths these are diminished or absent, and always bent when present. Phylogenetic analyses using a composite tree verify that hawkmoths and silkmoths exhibit distinct muscular phenotypes. These findings, consistent with our hypotheses about power versus steering demands, also illuminate specific muscles which may exhibit divergent functional adaptations for producing hovering versus bobbing flight.

## Ancient DNA from tar pit fossils? Planting ideas for reconstructing late Pleistocene paleoflora

*Kimberly Baker, Robert McAfee, Lindsey Emily*

Woody plant fragments, hypothesized to be associated with Eremotherium dung, were collected from a late Pleistocene asphalt locality in coastal Ecuador but are largely morphologically unidentifiable. While DNA extraction has not been previously successful from organics within asphalt deposits (e.g. bone), the hearty nature of plant tissues and their rather pristine appearance made them a suitable candidate to attempt extraction on samples having undergone various treatments. To best access any extant genetic material for potential sequencing, DNA extraction methods developed for plants were used as a foundation, with slight modifications due to the nature of the samples. As little is known regarding DNA preservation through various deasphalting treatments, DNA extraction and analysis was performed on four samples, treated with differing deasphalting reagents, and one untreated sample. All processed samples yielded DNA. Purified samples were submitted for shotgun metagenomics, and bioinformatics analysis was performed to identify potential species. Alignments of samples ranging from 700 bp to 1000 bp and containing identities of 88% or higher were further explored via comparison with known native species to the area. Resulting matches of both Family Ulmaceae (elm) and Dioscorea (yam) were identified. While preliminary, this suggests a potential method for future research into reconstructing the paleofloral communities from asphalt sites around the world.

## Course-based Undergraduate Research Courses Involving Solitary Bees Can Be Used in Integrative Studies Involving Ecology and Metabarcoding

*Stokes Baker*

The Vision and Change policy statement recommends that undergraduate biology education be modernized by engaging students through research experiences while emphasizing concepts like form and function, information flow, and evolution. One approach is to use course-based undergraduate research experience (CURE) courses that incorporate the core concepts. As part of the University of Detroit Mercy's Building Infrastructure Leading to Diversity (BUILD) program, a

CURE entitled Applied Metagenomics was established in 2019. Over the years, the course has evolved to focus on bee behavior using nanopore sequencing technology to assess honey pollen profiles. In 2024, a study was initiated to assess the habitat of an urban park prairie established by the US Fish and Wildlife Service (USFWS). Nesting boxes for alfalfa leafcutter bees (Megachile rotundata) were placed in the USFWS prairie plot and a naturally regenerated prairie in the park. Solitary bees are an ideal experimental system for CUREs because they are inexpensive, easy to establish, and do not need the protective gear used in honeybee husbandry. Students in the Ecology Laboratory have conducted a community survey to compare the two habitats and will use DNA barcoding to determine the cocoon material preferences. During the winter of 2024, students in Applied Metagenomics will use the previously established protocols to evaluate the pollen profile found in the leafcutter bee cocoons.

## Nano-mechanical properties and application of intertidal and subtidal sea urchin glue

*Zachary Baker, Scott Dietrich, Keegan Lutek, Carla Narvaez Diaz, Austin Garner, Alyssa Stark*

Sea urchins often adhere in high wave intensity environments using a physically and chemically complex glue-like secretion. Although the basic components of the glue are known, how the glue is applied, how it performs at the nanoscale, and if the composition or properties vary with habitat is less studied. Here we used behavioral observations and nanoscale adhesive force measurements to assess differences in the adhesive system of purple sea urchins (Strongylocentrotus purpuratus) from two habitats that differ in wave intensity. Glue samples were collected from sea urchins native to two regions in the Strait of Juan de Fuca near Clallam Bay, Washington: the intertidal zone (high wave forces) and the subtidal zone (low wave forces). To explore glue application behavior, we collected videos of attachment process of tube feet discs, the terminal structures of tube feet responsible for adhesion. We performed force-distance spectroscopy with an atomic force microscope to characterize the topography of the sea urchin glue (in the form of footprints) as well as measure the nanomechanical properties, including the stiffness and adhesive force of each footprint. We also used these samples to begin to explore differences in chemical composition among habitats. Our work will improve our understanding of sea urchin adhesion at the small-scale, which may be used in the future for development of bioinspired water-resistant glues.

## Parasite removal alters heat tolerance in a tropical lizard

*Leah Bakewell, Carrie Alfonso, Karla Alujevic, Samantha Fontaine, Jaden Keller, Yanileth Lopez, Nathaly Ponce, Alejandro Vivas, Claire Williams, Kelly Wuthrich, W. Owen McMillan, Michael Logan, Christian Cox*

Climate change can influence host-parasite dynamics by altering the abundance and distribution of hosts and their parasites. Additionally, as temperatures become more variable, organisms are at greater risk of infection due to the temperature dependence of immune function. While the physiological effects of hosting parasites have been studied in aquatic systems, tradeoffs associated with parasitic infection in vulnerable terrestrial vertebrates, such as tropical thermoconforming ectotherms, require further study. These organisms are increasingly vulnerable as climate change continues because they have a limited scope for using behavior to alter their body temperature while already experiencing temperatures close to their critical thermal maxima. We treated a tropical thermoconforming lizard (Anolis apletophallus) with antiparasitic drugs and measured their heat tolerance and immune function after treatment. We found that treated lizards had decreased nematode and cestode infection intensities compared to control lizards. Immune function was not altered by treatment; however, heat tolerance increased in treated lizards. This indicates that increasing environmental temperatures from climate change may have especially severe effects on host survival when parasites are present.

## A Slow Burn Romance: The Phenology of Pheromone Attraction in Winter Fireflies

*Cleo Baldoumas, Hannah Holmes, Charlotte Herbert, Aidan Burns, Greg Fahrner, Tipton Gentry, Xander Ritsch, Lulu Wright, Jocelyn Millar, Douglas Collins, Sarah Lower, Gregory Pask*

The winter firefly, Photinus corruscus, is a diurnal firefly that has lost the ability to flash as an adult. Long believed to find mates via pheromones, our group recently identified hydroxycamphor as a female-produced sex pheromone. With an extended adult lifespan of approximately 10 months, significantly longer than the typical 2-4 weeks observed in other unlit firefly species, P. corruscus and the identified pheromone presents a unique opportunity to explore the onset of reproductive activity after a prolonged overwintering period. We conducted a five-month field study in Ripton, VT, focused on understanding the phenology of male fireflies' attraction to the female-produced pheromone. Each week we monitored winter firefly presence in the environment and in pheromone-baited traps and reported the peak window of winter firefly mate-seeking. A long-term goal is to identify pheromone receptor genes using individuals collected before and during peak attraction to the pheromone. Our findings aim to advance our understanding of unlighted firefly natural history and provide insights into the evolution of chemical communication following the loss of bioluminescence in firefly lineages.

## Behavioral effects of thermal stress in mantis shrimp (Stomatopoda)

*Miya Ball, Olivia Turner, Patrick Green*

As ocean temperatures rise and marine heatwaves become more frequent, studying marine animals' responses to warming is critical for predicting changes in behavior, ecosystem impacts, and survival. Mantis shrimp, or stomatopod crustaceans, reside in burrows in dead coral and rock in tropical coastal waters, and use spring-powered, fast-moving raptorial appendages for prey capture and intraspecies fighting. Current research on thermal stress in stomatopods has focused mainly on genetic and physiological responses, overlooking behavioral changes essential for survival and ecosystem function. We studied behavioral responses to thermal stress in two species of mantis shrimp, Gonodactylus childi from Mo'orea and Neogonodactylus oerstedii from Florida. We set the testing tank to 28°C and raised the temperature by 0.5°C every ten minutes to a maximum of 39°C or until the animal showed signs of distress. We observed each animal's pleopod beat rate (similar to respiratory rate) and their likelihood to strike with their raptorial claw We found that pleopod beat rate initially decreased as temperatures warmed, then increased towards the end of trials. The likelihood of striking decreased as temperature increased. Overall, the Mo'orea species withstood higher temperatures than the Florida species, a result that may be driven by body size differences. Our results elucidate acute stress signs across two species of mantis shrimp from disparate parts of the globe, showing how ecologically-relevant behaviors change with warming temperatures.

## Hydrodynamic consequences of horns and spines on the nauplius of the barnacle *Lepas anserifera*

*Will Ballentine, Mimi Koehl, Kit Yu Karen Chan*

Many planktonic animals have spines. but their effects on the hydrodynamics of ecologically important functions remains unresolved. We are using nauplius larvae of crustaceans to study the hydrodynamic consequences of spines because nauplii provide broad morphological variability in the number, position, size, and shape of spine-like extensions. The planktotrophic nauplius of the barnacle Lepas anserifera, a common flotsam- dwelling pelagic barnacle, has a long tail spine and horns. To investigate the hydrodynamic consequences of individual horns and tail spines, we 3D-printed a dynamically-scaled model of L. anserifera with removable spine and horns. Model configurations were towed through a viscous medium at speeds which matched the Reynolds number achieved by L. anserifera during locomotion and the hydrodynamic forces and moments were recorded. We visualized the effect of body extensions on the surrounding fluid environment using Particle Image Velocimetry. We found that body extensions significantly affected both the drag and lift of the nauplius, but that magnitude and direction of the forces depended on the phase of locomotion (power vs. recovery stroke). Additionally, we found that body extensions significantly increased the flux of fluid into the feeding zone of the nauplius during the recovery stroke, potentially increasing the efficacy of feeding. These results suggest that biomechanical constraints imposed by body extensions influence the evolution of larval form.

## How does the shape of sexually selected weapons vary with body size in the insect, Narnia femorata?

*Elizabeth Bane, Elizabeth Greenway, Christina Salerno, Walter Federle, Christine Miller, Noraly van Meer*

Sexually selected weapons, such as deer antlers and crab claws, can vary dramatically within a species. Studies have demonstrated that weapon size increases with body size, however it is not well established how the shapes of weapons change with body size. In the insect Narnia femorata (Hemiptera: Coreidae), males use their enlarged, spiny hind legs to squeeze their competitors, with their spines often digging into and trapping the opposing male. Here we use N. femorata as a model to understand how weapon shape, specifically the area, angle of the spine axis to the femur, and curvature of the terminal femur spine, varies naturally among individuals. We photographed a lateral view of this spine on adult N. femorata and extracted its area, angle, and curvature using ImageJ. We found that the morphology of the spine varied dramatically among individuals, and we found intricate changes in shape that occur as insects get larger. Our results highlight the natural variation of sexually selected weapons which may have consequences for fighting behavior and ultimately their mating success.

## Comparison of hydrodynamic characteristics of salt marsh harvest mice and co-occurring rodents

*Julian Banuelos Torres, Arianna Ramirez, Diego Sustaita*

The salt marsh harvest mouse (SMHM; Reithrodontomys raviventris) is an endangered rodent species endemic to the San Francisco Estuary. Natural tidal fluctuations and resource management practices throughout the estuary often flood salt marsh harvest mouse habitats. However, previous studies have shown that these mice do not leave the area to escape flooding events. Therefore, the aim of this study was to compare the morphological characteristics of salt marsh harvest mice to co-occurring species to determine their implications for hydrodynamic efficiency. We hypothesized that salt marsh harvest mice would be better adapted to maximize buoyancy and minimize drag than co-occurring western harvest mice and house mice. Hair density estimates were determined by taking skin samples from several mouse carcasses. Fineness ratios were determined by taking measurements from the snout tip to the tail base and dividing by the widest part of the animal. Drag forces were obtained by tethering mouse specimens to a force transducer in a recirculating water tank. We found that salt marsh harvest mice have a higher dorsal hair density than do co-occurring species, and that there was an optimal range of fineness ratios that seemed to minimize drag forces. Our data suggests that the selective pressures on the salt marsh harvest mouse may favor increasing buoyancy over streamlining of the body to reduce drag forces.

## Sifting through a haystack - efficiently finding rare behaviors in big datasets

*Shir Bar, Or Hirschorn, Shai Avidan, Roi Holzman*

Rare events play an important role in animal ecology. Behaviors such as evading predators or reproduction can occur rarely but are critical for the animal's fitness. The difficulty in collecting sufficient observations of these rare behaviors hinders their investigation, often hampering our ability to test hypotheses regarding their ecology. Attempts to automate the detection of rare behaviors using Machine Learning (ML) methods face difficulties because it is difficult to generate the large, labeled datasets required to train these models.

We present a method that first uses a no-label ML model to search the data for anomalous behaviors. Based on this search, labeled datasets can be built with high efficiency to train the main ML model used to detect rare behaviors. We adapt graph-based convolutional neural networks used for human behavior and show that they are well-suited for analyzing the kinematics of animal behavior. We tested our approach on 3 datasets, two featuring larval fish behavior in the laboratory, and an additional dataset of accelerometry acquired from meerkats in the wild. Our results show that, for behaviors that account for $< 1$ .5% of the observations, our method is twice more accurate than that trained using a traditional approach. Importantly, we find that the graph-based networks produce good results using much smaller datasets, by allowing the model to focus on animal kinematics rather than the filming environment.

## The Munidopsis serricronis (squat lobster) species complex in the North Atlantic Ocean

*Mina Barajas*

Individuals within the family Munidopsidae, specifically, the species Munidopsis serricornis, present morphological complexity; they are often found on scleractinian coral colonies (Desmophyllum pertusum) showing a potential symbiotic relationship. The species has a wide geographic distribution with multiple localities across the Atlantic Ocean, suggesting the existence of a species complex. Molecular phylogenetic analyses were used to discover species diversity and intraspecific variation across the species geographic range (n=99). To further differentiate this species complex, ROV video analyses were used to observe in situ colorations and assess the relationship between M. serricornis and deep-sea corals. The diversity of Munidopsis serricornis species complex is represented by 6 lineages with each lineage representing a specific geographic range. M. serricornis sensu stricto is restricted to the Northeast Atlantic including populations near the type locality (Weather Islands, Sweden) where the species was originally described. Preliminary identification suggests taxonomic confusion among the four species described within the complex. The remaining lineages may represent different species but further ecological, morphological, and genomic nuclear data will help in deliminating these species. All of these factors will help us increase our knowledge of the diversity, ecology, and habitat use of squat lobsters, as well as coral symbioses in the deep sea.

## PAX6 Gene Variation Across Gnathostomes

*Sofia Barajas, Rafael Rios, Matthew Gross, John Phillips, Christopher Heesy, Leigha Lynch*

The regulation of brain and eye development has been of interest in model systems due to phenotypic diversity that arises from modifications to these genes.

Yet we lack an understanding of the base-line natural variation within these genes across animalia. We sought to fill this gap by quantifying interspecific gene variation in brain regulatory genes, with a focus on paired box gene 6 (PAX6) among gnathostomes. 270 gnathostome sequences of the PAX6 gene were acquired from Genbank and aligned using Geneious. All species were assigned to one of 9 clades; birds, placental mammals, turtles, amphibians, alligators and crocodiles, squamates, marsupial mammals, lungfish, or monotremes with Amblyraja radiata (skate) as the outgroup. To quantify genetic variation, we evaluated SNPs across the entire gene and within ORFs using Geneious. We also calculated genetic distances and performed a Z-test for selection within and between clades using MEGA. Monotremes and amphibians had the highest within clade genetic distances (p-distance=0.19) while alligators and crocodiles had the smallest (p-distance=0.01). Results showed significant purifying selection among gnathostomes as a whole (p=0.00) and individual clades. The results of this study suggest that certain clades have more genetic variation within PAX6, which may be related to greater flexibility in phenotypic traits. Further, PAX6 could be under negative selective pressures across multiple clades due to the high regulation of brain and eye development.

## Differences in social phenotype between and within a wildtype and a domesticated songbird species

*Nicole Baran*

Domestication—the adaptation of wild animals to mutualistic relationships with humans—has been associated with widespread changes to physiology, brain, and behavior. Here we investigate two species of Estrildid finches: the wildtype zebra finch (Taeniopygia guttata, ZF) and a domesticated strain of the white-backed munia, the Bengalese finch (Lonchura striata domestica, BF). Previous work suggests that BF differ from both ZF and from their wild counterparts in several social behaviors. BFs differ in their parental care, are more affiliative, are less responsive to stressors, and sing more syntactically complex song. However, the two species have not been directly compared and BF social behavior remains poorly characterized. Through focal observations, automated nestbox monitoring, and an experimental examination of corticosterone responses to social isolation, we uncover substantial differences between the two species in the degree of sexual heteromorphism. We find that ZF males are more aggressive than females, but BFs of both sexes show similarly low levels of aggression. Furthermore, SFs of both sexes spend significantly more time perching in contact than ZFs. SFs are more likely to spend time together inside the nestbox, whereas ZFs are more likely to tradeoff incubation responsibilities. ZFs also show a larger corticosterone response to social isolation compared to ZFs, suggesting altered stress physiology. This work lays the foundation for future investigations into the neural and genetic basis for these differences.

## Effects of behavioral syndromes on interaction outcome in cleaner shrimp-client fish mutualisms

*Bryce Barbee, Eleanor Caves*

Animals have individually-specific ways in which they act and this behavioral variation can affect important ecological relationships, such as mutualistic interactions. Marine cleaning mutualisms are interactions in which shrimp remove parasites from larger ‘client’ fish species. In the cleaner shrimp, Ancylomenes pedersoni, small groups live together at cleaning stations and interact with a large variety of client reef fish species. Previously, we have shown that cleaner individuals vary in certain aspects of their behavior, such as activity level and response to risk. This behavioral variation can potentially lead to some individuals being more or less willing to interact with clients, or variation in service quality, but to date, behavioral variation in cleaner shrimp has only been demonstrated in the lab. Here, we explore if certain individuals are more willing to interact with a larger diversity of clients that approach a station and if some are more likely to initiate cleaning services. We will also explore correlations between various cleaning-related behaviors to see if behavioral syndromes influence cleaning interaction outcome. Understanding variation in these interactions will give important insight into how these relationships have formed and are maintained, with implications for reef community health.

## Increased thermal variation and increased mean temperature affects development of Eastern bluebirds

*Salvador Barraza-Del Barco, William Kirkpatrick, Sarah Heissenberger, Sarah DuRant*

Avian development is directly affected by environmental temperature. Understanding how natural temperature impacts avian physiological development is crucial for understanding how climate change will impact birds. Under expected climate change, nesting environments will become warmer on average and more variable. To estimate the impact of shifting thermal conditions, we examined offspring growth and metabolic rate in nestling Eastern Bluebirds that were exposed to either an increased mean temperature nest box or an increased temperature fluctuation nest box relative to unmanipulated boxes. We collected growth measurements from nestlings on days 1, 5, 10, and 12, and resting metabolic rates on days 5 and 10. Preliminary analysis revealed that nestlings exhibited increased mass and skeletal growth in response to higher temperature fluctuations than those in increased mean temperature boxes. Metabolic data is still being analyzed, though initial anecdotal data suggests a positive relationship between metabolic rate and body size. The larger body size of the increased temperature fluctuation nestlings could suggest a higher metabolic rate. While a larger body size for a nestling might provide benefits for overwinter survival, increased temperature fluctuation nests also saw smaller clutch sizes than other treatments, suggesting an overall reduction in nest productivity.

## Forktail damselfly navigation strategies

*Elina Barredo, Veronica Muzio Crego, Jamie Theobald*

Damselflies (Zygoptera), like their sister group the dragonflies, are globally distributed aerial predators, with the ability to hover, dart, and glide -behaviors that rely on sophisticated visual processing. But notable differences exist between the groups. Dragonflies, with larger, fused eyes, usually hunt by prey interception in clear areas. In contrast damselflies, with smaller, rounder, separated eyes, often glean prey from cluttered vegetation, and frequently perform sliding flight, in which they translate in directions other than their heading. This unusual maneuver may allow them to move without losing sight of a target, but its visual consequences and control are largely unexplored. To understand this flight style, we recorded high speed videos of Rambur's forktail damselflies (Ischnura ramburii) flying in the field, then reconstructed 3D trajectories, and orientation of specific body parts (eyes, head, and tail). We found head movement coordination consistent with certain gaze-stabilization strategies, which may help optimize information intake in a crowded environment.

## Expanding the knowledge of non-native annelid worms in the Florida panhandle.

*E Hope Barrett, Viktoria Bogantes*

Non-native species play a part in the loss of native ecology in ecosystems, and they are one of the biggest causes of biological homogenization. When a non-native species is introduced to an environment, they face no natural predators and can usually outcompete native species resulting in the loss of native biodiversity. Florida has the highest record of introduced species in the United States, however, there are many areas which lack recent data. The goal of this study is to survey marinas and ports in the Florida Panhandle to create an inventory of marine invertebrates and identify if non-native species are present in this area. Sediment samples and sessile marine invertebrates associated with pylons were collected and preserved in different solutions (formalin and ethanol) for morphological and molecular studies. Additionally, samples from autonomous reefs artificial structures (ARMS) associated with artificial reefs were collected. Once the organisms have been identified, the abundance of non-native species in each locale will be determined. This information will help assess the scale of the non-native species invasion issue in the Florida Panhandle. Given that marinas are considered hot spots for introduction of species, it is expected that marinas will contain a larger abundance of non-native marine species than reef environments.

## Beware of water bears: Morphological and molecular identification of tardigrades

*Kayla Barrett, Logan Kesner, Elizabeth Struble, Courtney Clark-Hachtel*

Tardigrade tolerance to ionizing radiation (IR) is nearly 1,000 times higher than human tolerance. Previous research has suggested that this is due to the robust upregulation of DNA repair genes, which enables tardigrade recovery from DNA damage. However, our understanding of tardigrade IR tolerance is limited to a handful of lab-reared species, and researching other species would enhance our understanding of biological responses to radiation. We aimed to cultivate wild tardigrade populations from western North Carolina (WNC) with the goal of increasing the diversity of lab-reared species for IR tolerance studies. To do this, we extracted tardigrades from moss and lichen samples collected from the mountains of WNC. We characterized the diversity of local populations with both molecular identification and morphological identification, and we have also established culturing methods for these wild-caught species that are effective for some of the local species. This work improved our understanding of the make-up of local tardigrade populations, revealed a seasonality to tardigrade abundance at our collection sites that may be related to soil moisture conditions, and has paved the way for increasing the diversity of lab-reared tardigrade species. Cultivated local species will be used for future IR tolerance assays in the lab. This research will expand the currently limited database of biological responses to radiation in tardigrades and improve our understanding of mechanisms of IR tolerance.

## Effects of freshwater salinization on productivity of green tree frog tadpoles and their predators

*Alex Barron, Cole Miller, Maya Mylott, Allison Welch*

Coastal freshwater habitats face the threat of increased salinity due to sea level rise and storm surges. Many freshwater organisms are sensitive to elevated salinity concentrations, and amphibians specifically face a threat due to their permeable skin. Amphibians are important members of freshwater communities, facilitating the transfer of biomass from ephemeral freshwater habitats to terrestrial ecosystems as they metamorphose. Thus, we predict that negative impacts of salinity on amphibians will disrupt the food web within their aquatic environment and reduce the export of biomass to terrestrial systems. Using experimental mesocosms, we investigated interactions between green tree frog tadpoles (primary consumers), algae (primary producers), and dragonfly nymphs (secondary consumers) at control and elevated levels of salinity. We predict that elevated salinity will reduce tadpole survival and biomass and, in turn, dragonfly nymph survival and biomass will be decreased due to reductions in their food supply. Ultimately, we predict that less consumer biomass, in the form of metamorphosing frogs and dragonflies, will be exported under elevated salinity conditions. The results of our experiment will allow us to better understand the effects of freshwater salinization on trophic interactions and ecosystem function.

## Genetic adaptation to climate change among nursery habitats of the bull shark (Carcharhinus leucas)

*Shannon Barry, Mathew Ajemian, Charles Bangley, Marcus Drymon, Bryan Frazier, Laura Garcia Barcia, Jayne Gardiner, James Gelsleichter, Dean Grubbs, Neil Hammerschlag, Mike Heithus, Bradley Strickland, Tonya Wiley, Toby Daly-Engel*

The distribution of marine species is likely to be heavily altered by climate change, with some marine species observed migrating poleward to novel habitats that were previously outside of their geographic range. In 2018, bull sharks (Carcharhinus leucas) were found to have expanded their critical reproductive habitat in the northwestern Atlantic Ocean, with recent genetic data supporting a poleward expansion of habitat >900 km of their previously described northernmost nursery, an expansion that was correlated with rising sea surface temperature (SST) over the past 30 years. This raises the question: If shark populations are undergoing poleward expansion in response to climate change, then what will be the resulting impact to the genetic diversity and viability of these species? This research seeks to investigate this question by identifying signatures of local adaptation of bull sharks within nursery habitats using Single Nucleotide Polymorphisms (SNPs) to identify genetic structure and diversity metrics. These results, plus telemetry data (acoustic tag detections, provided by collaborators in the Florida Atlantic Coastal Telemetry (FACT) network) will be mapped to a seascape of oceanographic factors such as salinity, depth, and SST to identify gene-environment correlations. These data will provide insight into how bull sharks are currently adapting to habitat changes, with future directions incorporating these data into species distribution models to accurately predict climate impacts on the future distribution of bull shark populations.

## Geometric morphometric analysis of softshell turtle (*Apalone sp.*) head shape in context

*Jacob Barthelemy, Christopher Murray, Allison DeLoache*

In this study, we use geometric-morphometric analysis of museum specimens to explore variation in cranial morphology of all three extant species of North American softshell turtles, Apalone spinifera, A. mutica, and A. ferox, across several major river basins and compare historical lineage phenotypes among species and basin specific phenotypes within and among species. In particular, we search for instances of potential character displacement morphologically by looking for basin-specific instances in which species cranial shape divergence occurs among taxa in functional opposition to other sympatric Apalone. We found species specific cranial phenotypic differences, largely in orbital morphology, maxilla, and jugal length; structures thought to correspond to dietary niche, corroborating and expanding prior morphometric analyses. We found infrequent species-specific divergences in morphospace among basins, and in cases such as Apalone mutica from the Pearl River, where divergence was observed, the cranial phenotype converged with Apalone spinifera in that drainage. We found no evidence of potential character displacement and suggest that competition has no contemporary influence on Apalone cranial morphology.

## Antagonist muscle force generation in guinea fowl during decelerations from treadmill locomotion

*Dan Bartlett, Brandon Reder, Andrew Biewener, Nicolai Konow*

Decelerations are challenging locomotor tasks requiring precise coordination of muscle function to control and stabilize movement. Antagonist coordination is considered critical for joint stabilization and frequently inferred from muscle activation. However, antagonist contraction and force dynamics, including the interplay between limb antagonists during rapid decelerations, remain underexplored. We investigated lateral gastrocnemius (LG) and tibialis anterior (TA) function in guinea fowl (Numida meleagris) using tendon buckles, sonomicrometry, and EMG during rapid treadmill-induced decelerations. We hypothesized that during decelerations, both duration and impulse of antagonistic force overlap between the LG and TA would increase. Our findings supported this hypothesis, showing a significant increase in the duration and impulse of antagonistic force overlap between the LG and TA throughout decelerations. While LG impulse steadily increased during decelerations, TA impulse unexpectedly decreased in the second-to-last stride before peaking in the final stride. Our results suggest that as deceleration progresses, LG transitions from propulsion to absorption, whereas TA maintains a stabilizing role with the increasing force overlap likely smoothing LG's functional transition. However, the consistent drop in TA impulse hints at more complex dynamics, possibly involving changes in muscle activation, mechanical advantage, or center-of-mass dynamics as the bird stops. By studying the antagonist-specific roles during decelerations, we can gain a deeper understanding, with potential implications for musculoskeletal function and its evolution, designing clinical interventions and bioinspired design.

## Squid paralarvae turn with high agility using a range of jet flows

*Ian Bartol*

Turning is critical for survival in the ocean, as marine animals need to maneuver to capture prey, elude predators, and navigate complex environments. Recent studies indicate that some juvenile and adult neritic squids can turn tightly at moderate angular velocities, but much less is known about early ontogenetic stages (paralarvae) that locomote within lower Reynolds number regimes. To evaluate turning proficiency and the role of the pulsed jet in maneuvers, longfin squid Doryteuthis pealeii paralarvae swimming in a viewing chamber were studied using particle image velocimetry and kinematic motion analyses. Paralarvae exhibited a wide repertoire of turning behaviors, including those performed arms-first and tail-first. Relative to juvenile and adult squids, paralarval turns were broader (higher length-specific turning radii) and faster (higher angular velocity), with some turns (~8%) involving peak angular velocities >2,000 deg s-1. Paralarval jets ranged from isolated vortex rings (short pulses) to elongated vorticity structures with and without leading edge vortex ring formation (long pulses). While strong relationships between L/D (jet length to diameter ratio based on the vorticity extent) and performance properties were not observed, short and long jets with higher angular impulse produced turns of greater angular velocity and total angular displacement. The ability of squid paralarvae to produce a diversity of directed jets is integral to their turning versatility and ultimately survival.

## Habitat complexity influences anti-predatory behavior of *Ancanthurus nigrofiscus*

*Dkaria Bascom, Kai Davis, Adrianna Johnson, Anthony Philbois, Paul Barber, Alex Davis, Caitlin Fong, Peggy Fong*

Intense fish herbivory is critical to maintaining healthy coral reefs by limiting algal proliferation. Healthy herbivore populations are maintained partly by the high structural complexity of coral reefs by providing refuge from predators. However, coral reef ecosystems are increasingly losing structural complexity due to anthropogenic stressors, potentially disrupting the behavior of herbivorous fishes. We examined the relationship between the structural complexity of a fringing reef of Mo'orea, French Polynesia, and the anti-predator behavior of a common herbivorous fish, Ancanthurus nigrofuscus. We compared anti-predator behavior in 3 paired plots that differed significantly in rugosity (LME, $p=0.0068$). Across 181 replicate behavioral trials, individual fish hid from an approaching snorkeler more frequently in high rugosity plots but fled more often in low rugosity plots (chi-squared, $p<0.0001$). However, counter to predictions, fish size or plot rugosity had no impact on flight initiation distance (LME, $p=0.539$). This change in fish behavior could have far-reaching implications, as declines in structure that result in fish fleeing more could reduce total herbivory, potentially triggering cascading effects that accelerate the global decline in coral reef ecosystems. Thus, understanding these dynamics is essential for mitigating the ongoing deterioration of reef ecosystems.

## How easy is it to shoot fish in a barrel?: Puncture mechanics of unrestrained, multi-layered targets

*Bishal Baskota, Bingyang Zhang, Philip Anderson*

The vast majority of studies on biological puncture, whether at quasi-static or dynamic speeds, utilize targets comprised of homogenous materials that are held in place. While such experimental design is key to being able to control specific variables during testing, they it is a far cry from actual biological systems. As an example, certain cone snails utilize a ballistic radular tooth to stab passing fish, delivering a powerful toxin. These animals must shoot their ballistic tool at an object suspended in water made of multi-layered heterogenous materials. Previous work done by the Anderson lab has suggested that both the existence of an outer layer and a lack of constraint on target movement will reduce puncture performance. Here, we utilize a ballistic testing system based on known cone snail kinematics to test how both a protective outer layer and an unrestrained target alter puncture performance. We performed a series of variable-speed puncture tests on fish tissue samples both with and without intact skin layers. Results from these show that even a thin layer of fish skin can greatly reduce penetration at lower speeds. We also tested puncture performance with a suspended (unrestrained) fish carcass and found that at lower speeds, very little puncture was achieved. Overall, it appears a key strategy to overcoming both multi-layered and unrestrained targets is greater energy/velocity.

## Maternal investment and reproductive natural history of the American grass mantis

*Bridget Battaglia, Charles Watson*

Within many biological communities, mantids are important predators of small insects. The American grass mantis, Thesprotia graminis, is an understudied mantis native to the Coastal Southern United States. We measured the mass of multiple instar mantids of both sexes and the masses of oothecas (egg cases) pre- and post-hatch to document elements of their reproductive natural history. Using the masses of the mothers, oothecas, and offspring, we were able to estimate variation in reproductive investment among females and the average number of offspring produced. Most notably, we found that this species lays multiple, progressively smaller, oothecas throughout the reproductive season from which similarly sized offspring emerge. In many cases, the total mass of oothecas across time cumulatively exceed the mass of the female. This reproductive strategy may allow a single female to maximize reproductive output by continuing to allocate accumulated resources to reproduction across multiple oviposition events.

## Wiggling, bending, and paddling: how modulating tomopterid traits affects their swimming performance

*Nick Battista*

The soft-bodied, midwater polychaete Tomopteris is an interesting swimmer. They are fast, agile, voracious predators. Tomopterids propel themselves forward by simutaneously performing two locomotive modes: metachronal paddling and bodily undulation. They have two rows of flexible parapodia positioned on opposite sides of its body, which beat out of phase to one another but occur in concert with a lateral bodily undulation. For forward swimming, they use a forward-directed body wave, which is opposite to smooth-bodied polychaetes, who exhibit rearward-directed waves. In this work we disentangled how modulating tomopterid traits affected their swimming performance. In particular, we uncovered trade-offs between speed, energy expenditure, and cost of transport for different morphologies and swimming kinematics using a blend of computational fluid dynamics, machine learning, and uncertainty quantification.ppt

## Comparing stress physiology in brood parasitic and non-parasitic blackbirds

*Alexandria Baum, Kathleen Lynch, Kathleen Lynch*

Brood parasitic blackbirds do not build nests, incubate eggs or feed their own young. Instead, they leave their eggs in nests of a host which allows them to continue laying eggs throughout the breeding season. Consequently, brood parasitic species, such as the brown-headed cowbird (Molothrus ater), have a 10-fold increase in annual fecundity compared to other songbird species. Here, we use the comparative approach to understand whether stress physiology maps onto the different life history strategy of closely related blackbird species. We examine natural seasonal fluctuations in corticosteroid in these two species as well as species differences in response to captivity stress, adrenocorticotropin hormone (ACTH) administration and dexamethasone (DEX) treatment. Seasonal profile of corticosterone in cowbirds and non-parasitic red-winged blackbird (Agelaius phoeniceus) reveal that cowbirds have significantly lower concentration of corticosterone. However, preliminary results from DEX-treated birds indicate cowbirds have less resiliency of the hypothalamic-pituitary-adrenal axis compared to red-winged blackbirds. We are currently using RT-qPCR to examine whether this difference is mediated by species differences in corticosterone receptor abundance in the hippocampus, and periventricular nucleus / ventral medial hypothalamus. These results will identify if species differences in stress physiology map onto differences in either parental care or annual fecundity in parasitic and non-parasitic blackbirds.

## Are pterosaurs special? Comparing bone distribution in pterosaur humeri to birds

*Stephanie Baumgart, Michael Habib, Matthew Brown, Andrew Moore, Emma Schachner*

Powered flight evolved in archosaurs multiple times, first in pterosaurs and then at least once in birds, each with a unique wing structure. Using microCT data, we examine bird humeri across four orders of magnitude in body size (8g-11,300g) to map out how phylogeny and ecology relate to bone distribution and biomechanical properties. We evaluated humeri from 84 species covering 27 orders and a range of ecologies. We found that birds have a loosely correlated negative relationship between body mass and bone compactness (Cg). Relative shaft length and degree of bone curvature were also key variables to separate different ecologies.

The pterosaur species included here overlap with birds in body mass, but also include one of the largest known pterosaurs, Quetzalcoatlus northropi, with estimated mass between 200-300kg. The medium-sized pterosaur Tupandactylus is comparable in humeral bone distribution to birds of similar body mass (∼10-12kg). However, overall pterosaur Cg plummets after body masses reaches 10kg and continues to have a negative relationship with body mass. Pterosaur Cg is as low as 0.12 in Q. northropi compared to the lowest bird value in the Shoebill (Balaeniceps rex, 0.26), or the heaviest bird, the Andean condor (Vultur gryphus, 0.42). This indicates that pterosaurs had an internal humeral structure divergent from birds, likely accommodating increased stresses of quadrupedal stance and powered flight experienced by their much larger body sizes.

## Navigating the costs of movement: characterizing the energy expenditure of large Neotropical bats

*Travis Bayer, María Camila Calderón-Capote, Margaret Crofoot, Dina Dechmann, Teague O'Mara*

To be successful, animals must manage their energy expenditure and intake. This balance can be quantified using GPS to track locations and tri-axial accelerometers to measure movement, which correlates with energy expenditure in many birds and terrestrial mammals. However, the complex kinematics of bat flight may make these proxies less accurate in chiropterans. Because bats live at their energetic ceiling, understanding their energy expenditure is key to testing fundamental hypotheses of ecology. We tested if accelerometer-based movement predicts energy expenditure in bats by deploying heart rate loggers, GPS, and accelerometers on 11 free-roaming Phyllostomus hastatus on Isla Colón, Panamá. Heart rate-based estimates helped develop relationships between vectorial dynamic body acceleration (VeDBA) and energy expenditure, incorporating airspeed as an additional metric. These relationships calibrated movement-based energy landscapes, showing energy expenditure distribution over space and time. We hypothesized that heart rate would correlate positively with VeDBA, and behavioral information would enhance this relationship. Because airspeed can predict metabolic flight requirements, we also hypothesized bats would primarily fly within energetically optimal flight speeds. Through modeling (GAMMs) we found a strong positive relationship between VeDBA and heart rate, with improved models when behavior states were included, providing support for VeDBA as a reliable predictor of energy expenditure in bats. Our models reflected previous power curve estimates for this species and showed most flights were flown within energetically optimal airspeeds.

## Seasonal variation in immune proteins of a widespread migratory bat species

*Daniel Becker, Amanda Vicente Santos, Kristin Dyer, Lauren Lock, Michael Smotherman, Ariadna Morales, Michael Hiller, Benjamin Neely*

Bats harbor a diverse assemblage of pathogens, some of which can infect humans. Although bats often host such pathogens without showing disease, this tolerance of infection is hypothesized to be disrupted by intrinsic and extrinsic stressors. However, most work has ignored the immune mechanisms linking these stressors to pathogen infection in bats. Here, we assess whether long-distance migration may function as an immunological stressor in bats, analyzing plasma proteomes from a population of Mexican free-tailed bats sampled monthly over a year in western Oklahoma. Each year, these bats migrate north from their wintering grounds in Mexico during spring to form large maternity colonies in the southwestern United States, birth and raise their pups, and then migrate back south to Mexico. We leverage the recent genome assembly and annotation for this bat species developed by Bat1K to identify over 200 proteins, for which abundances spanned seven orders of magnitude, in 100 seasonally collected plasma samples. We use generalized additive models and multivariate methods to test if and how the abundance and composition of the plasma proteome vary between spring migratory arrival, summer birth and pup-rearing, the non-reproductive period in late summer, and the pre-migratory period in autumn. Our work emphasizes migration as an immunologically and epidemiologically relevant period for bats and highlights the need for genomic resources in immunological studies of bats.

## Nutritional stress disrupts symbiosis between an anemone and its symbiotic algae during development

*Samuel Bedgood, Virginia Weis, Keyla Plichon*

A stable symbiosis between corals and symbiotic dinoflagellate algae is essential for coral health, and it is driven by nutrient exchange between partners. The stability of this symbiosis during the adult stage is well-studied, but less is known about the dynamics between the host and algal symbiont during host development and regeneration. Our research addresses this gap by examining the impact of symbiotic algae and heterotrophic feeding on the development of asexually-produced offspring (G1) in the model organism Exaiptasia diaphana (Aiptasia). We investigated how autotrophic and heterotrophic nutrition influences developmental rates, focusing on the metabolic costs and benefits of symbiosis under varying nutritional conditions. We hypothesized that the presence of symbionts would increase the development rate and growth of G1 offspring, and that food would also improve development and growth as an additive effect. Surprisingly, our results refute some of our hypotheses and bring up interesting new questions about the interacting effects of immunity, host age, and nutrition on symbiosis health and regulation. We found that the presence of symbionts enhances growth in fed conditions but has a detrimental effect on development and survival under starvation. Notably, the impact of symbiont presence on starved offspring is dose-dependent. We suggest that these patterns may be driven by the suppression of immunity during development, leading to an increased vulnerability in symbiont-laden individuals under nutrient-limited conditions.

## Defining the relationship between early-life stress and telomere erosion in an arboreal squirrel

*Bethany Beekly, Sarah Westrick, Britt Heidinger, Andrew McAdam, Stan Boutin, Jeffrey Lane, Ben Dantzer*

The relationship between early life stress, health, and lifespan is complex, with early life stress seemingly capable of contributing to either improved or reduced resilience to subsequent stressful experiences. Maternal stress constitutes an important physiological and behavioral cue to offspring about the future environment that can have a lifelong impact, but in some circumstances, it may also have deleterious effects. One mechanism thought to link early-life stress to higher disease morbidity and mortality is telomere erosion. Previous work in North American red squirrels (Tamiasciurus hudsonicus) has shown that exogenous glucocorticoid administration to reproductively active dams differentially affects growth rate, gene expression, and behavior of offspring in a sex- and timing-dependent manner. However, experimentally elevated glucocorticoids were not found to affect offspring telomere length. We sought to determine whether (a) higher glucocorticoid doses and/or (b) variables likely to co-vary with maternal glucocorticoids would correlate with altered average offspring telomere length. We also compared two methods for the measurement of telomere length: a Southern blot quantification method and a qPCR-based technique. Validation of the qPCR assay offers a non-lethal alternative to traditional methods of quantifying telomere length, enabling future longitudinal monitoring to understand the lifetime correlation between short telomere length at birth and mortality. This will ultimately enable more holistic predictions of the potential impact of anthropogenic and other environmental stressors on wildlife populations.

## Investigating the impacts of micro- and nanoplastics exposure on olfactory-mediated behaviors of fat

*Rachelle Belanger, Levi Storks*

The amount of micro- and nanoplastics found in the Great Lakes and freshwater ecosystems is rapidly increasing due to inadequate management of plastic waste. Plastics enter freshwater environments from wastewater treatment plants, litter, agricultural and stormwater runoff, landfill leakage, and industrial effluents or spills. Microplastics in the environment are fragmented plastic waste pieces with diameters $< 5$ mm. Nanoplastics are synthetic polymers with dimensions ranging from 1 nm to 1 $\mu$m. Micro- and nanoplastic exposure can negatively impact organisms with several negative toxicological endpoints observed. Current evidence suggests that microplastic exposure alters behavior, including olfactory-driven behavior, and exerts neurotoxic effects on the nervous system. Given that fish rely heavily on olfaction for several key behaviors (e.g., feeding, reproduction, migration, predator avoidance), microplastic exposure could severely impact fish ecology in natural systems. This could be particularly important in the context of predator avoidance, which is mediated in part by olfaction in fish. In this study, we measured avoidance of fathead minnows (Pimephales promelas) to a conspecific alarm cue after exposure to environmentally relevant concentrations of polystyrene micro- and nanoplastics. Data from this study will demonstrate how microplastic exposure might alter responses to important environmental cues and underscore the ecological consequences of plastic pollution in freshwater environments.

## Playing nano-soccer: understanding the mechanics of leafhopper brochosomes

*Elizabeth Bello, Marianne Alleyne*

Many insect surfaces have nano- and microscale cuticular features that enable multi-functional properties such as water repellency, antimicrobial behavior, and anti-reflectivity. Leafhoppers (Hemiptera: Cicadellidae) produce and coat themselves with unique, extracuticular particles called brochosomes. These hollow nanoparticles, composed of proteins and lipids, have complex (soccer-ball-like) geometries that vary between species and make the cuticle both highly water-repellant and anti-reflective. Inspired by this distinctive system, we've taken brochosomes from nature to the lab to explore their morphological variability, material and structural characteristics, and investigate the mechanics that influence their function. We will show that their unique size, shape, and material properties influence a brochosome's compressive resistance, which is important for their multi-functionality under different conditions. In addition, we determined that these characteristics determine how well brochosomes adhere to a surface through adhesive and frictional forces. Our work provides valuable insights into the guided design of novel removable multi-functional materials inspired by nano-sized brochosomes.

## Size selectivity in aquatic carnivorous plants: expanding predator-prey models to plant predation

*Danica Belman, Ulrike Muller, Otto Berg*

Many species of bladderwort (genus Utricularia) use hundreds of tiny underwater suction traps to capture zooplankton as ambush predators. Their capture characteristics make bladderworts an interesting test case for predator-prey interaction models: a large number of predators attack a large number of prey, and capture probability is strongly affected by predator size, prey size, and prey behavior. This project aims to expand existing predator-prey interaction models so they can be applied to carnivorous plants to test hypotheses about the traps' size selectivity. To do so, we conducted in vitro batch-mode trials between bladderwort (U. australis) and free-swimming ostracods (Cypridopsis spp.). We recorded approximately one thousand capture events and measured capture success as a function of prey and trap size. These differential predation rates include size and speed of both predator and prey, and a time budget adjusted for the peculiarities of the bladderwort traps' capture mechanics. The theoretical model correctly predicts the upper size limit, but not lower size limit of capture success as a function of predator size. Our study highlights differences between animal and plant predation that affect key model parameters, such as search time. In this way, suitably detailed rate laws, when applied to a predator-prey microcosm, can be used to test and quantify the elementary steps of a prey capture mechanism.

## These strain transients were made for walking: analyzing dynamic locomotion work modulation

*Caitlin Bemis, Monica Daley, Kiisa Nishikawa*

To better understand how muscles modulate work during different phases of the cycle, such as passive, loading, and unloading phase, we need to be able to replicate in vivo force in controlled experiments. By doing so, we can manipulate strain and activation systematically to measure their effects on work modulation and predict based on in vivo conditions. Muscle force is difficult to predict, a refined methodology is required to bridge in vivo and ex vivo approaches and examine specific phases of movement. In our study, we used scaled in vivo muscle fascicle strains recorded via sonomicrometry and electromyographic activation of the lateral gastrocnemius (LG) and digital flexor-IV (DF) in guinea fowl as inputs for work loop experiments. We used these in ex vivo work loops on the mouse extensor digitorum longus (EDL). EDL work loops closely mirrored those observed in guinea fowl LG and DF during treadmill locomotion at varying speeds. The best replication of force occurred for the DF at the fastest speeds, where greater strain and velocity transients were evident. By refining ex vivo methodologies to replicate in vivo muscle function, we can enhance understanding of muscle properties and function during dynamic locomotion. Replicating in vivo during ex vivo controlled experiments, allowed us to further dissect the interactions between different phases of gait to understand how muscles modulate work output. NSF DBI-2319710

## Characterizing root system diversity in Australian bush tomatoes

*Rebecca Beneroff, Chris Martine*

The Australian "Solanum dioicum + S. echinatum Group" is a clade of ∼45 bush tomato species within the "spiny solanum" group (Solanum subgenus Leptostemonum) found throughout the Australian Monsoon Tropics (AMT) subject to a narrow environmental niche characterized by periods of extreme rainfall, severe drought, and semi-frequent fire. Previous literature has shown that this clade is disturbance-adapted and prone to clonality, indicating that their root systems are likely important to their survival. Although Solanum is famous, in part, due to the enlarged below-ground storage organs (modified stems) found in potatoes (Solanum tuberosum) and their relatives, few other clades within the genus have been observed to have them. Much more prevalent are rhizomes (also modified stems), observed in 11 clades including the Eastern Hemisphere Spiny clade (EHS). While rhizomes generally store small amounts of water and starch, their primary purpose is to enable lateral spread by sprouting clones. Many species within the EHS clade have evolved rhizomes, but none have been found to have storage roots. At present, no true underground storage organs have been reported in any Solanum taxa of the EHS clade (including Australian taxa). An ex-situ survey of underground organs of representative taxa from the "S. dioicum complex" resulted in the discovery of what we believe to be the first record of true underground storage organs in both Australian Solanum and the EHS.

## Octopus arm flexibility facilitates complex behaviors in diverse natural environments

*Chelsea Bennice, Kendra Buresch, Jennifer Grossman, Tylar Morano, Roger Hanlon*

The octopus arm is one of the most flexible biological structures in nature; however, arm flexibility has yet to be studied comprehensively in wild octopuses. This study quantified arm flexibility using a novel hierarchical approach by observing naturally behaving octopuses across diverse habitats. To capture the extensive repertoire of octopus arm flexibility, 25 field videos of Octopus vulgaris were analyzed from 6 sites in the western Atlantic and Caribbean that varied in habitat structure. From each video octopus behaviors were delineated into 12 arm behaviors consisting of 4 arm deformations (shorten, elongate, torsion, bend). Overall, 3,907 incidences of arm behaviors and 6,781 incidences of arm deformations demonstrated all arms were capable of executing each arm behavior. Anterior arms performed more arm behaviors than posterior arms while there were no differences between left and right arm pairs. Similarly, deformations were used across all arm behaviors; however, bend accounted for the majority of deformations observed with the frequencies of the other deformations differing across specific arm behaviors. Deformations also varied by arm regions (proximal, medial, distal). The combination of deformations and arm behaviors implemented to achieve complex behaviors illustrates the extreme flexibility and coordination of these appendages and their wide range of functions. Characterizing the form and function of arm flexibility in octopus is of keen interest to researchers in biomechanics, neuroscience, and soft robotics.

## SEA Scholars: diving into science through education and the arts

*Chelsea Bennice, Jeanette Wyneken*

The mission of the Florida Atlantic University Marine Science Laboratory (FAU Marine Lab) is to conduct novel and necessary research on marine life, train the next generation of scientists, and share discoveries with the public to increase conservation awareness and ocean stewardship. This commitment to bridging scientific discovery and community outreach sparked formation of the lab's first cross-disciplinary program, The Glenn W. and Cornelia T. Bailey Marine SEA (Science, Education, and Arts) Scholars program was created. SEA Scholars "dive in" by participating in research, engaging in public education and outreach activities, and becoming effective science communicators to broad audiences. This program capitalizes on the students' diverse backgrounds from the fields of science, education, and the liberal arts and encourages students to engage their skills and interests to develop content that conveys research in fun fascinating, and understandable. To share a day-in-the-life of a scientist, a sea of resources for "marine explorers" of all ages has been created. Marine animal coloring fact sheets, 3D animal models, and interactive research lessons featuring "meet the scientist" are available. The interactive lessons have added value in providing pre- and post-assessments to identify if SEA Scholars are clearly communicating FAU Marine Lab research. Those SEA Scholars who completed their time in the program highly ranked this program as progressing their science communication skills and preparation for a STEM-related career.

## A generative model of the hinge muscle in Aplysia californica using Approximate Bayesian Computation

*Michael Bennington, Victoria Webster-Wood*

Traditional rigid-body biomechanical models cannot always capture the mechanical behavior of soft-bodied organisms due to the continuous nature of their musculostructural deformations. Being able to model soft-bodied biomechanics is critical to understanding how adaptive behaviors arise in these species. One tractable model system for investigating soft-body mechanics is the feeding structure of the mollusk Aplysia californica. Previous Aplysia feeding models utilized rigid body assumptions, and while they could capture many system characteristics, mismatches still exist in the predicted neuromechanics. One structure shown to be particularly mis-modeled using line element muscles is the "hinge" muscle. This muscle structure contracts and bends as the grasping structure of the mouthparts protracts and retracts. To better model the bending/stretching mechanics of the hinge, we developed a model utilizing nonlinear beam mechanics. We validated this model using animal data from the literature and showed that the model captures the hinge's force response well. We then utilized Approximate Bayesian Computation techniques to investigate the model parameter distributions that reproduce the variability seen across specimens. This technique successfully produced a distribution of parameters that can be used to simulate a population of realistic hinge muscles. Future work will incorporate anatomical variability into the sampling process to correlate possible mechanical parameters to different anatomies seen in the animals and to extend this approach to other subsystems of the overall feeding structure.

## Muscle structure does not change in house sparrows acclimated to different thermal treatments

*Jack Bennink, Chelsi Marolf, Sampath Anandan, David Swanson, Ana Jimenez, Leyli Mammedowa*

Increasing thermal variability is one of the predicted effects of global climate change, including sudden cold snaps, which will require rapid and flexible physiological adjustments to match environmental conditions. Such requirements for rapid physiological adjustment could lead to physiology-environment mismatches. Organismal-level phenotypic differences commonly occur in birds across seasons but the cell-level changes linked to these seasonal phenotypes are less well understood. At the ultrastructural level, trade-offs may manifest in the morphology of functional tissues like the pectoralis muscle, such that muscle fiber diameter changes may be closely tied to other ultrastructural changes in muscle tissue itself, such as myonuclear domain (MND), which is important during muscle remodelling. Here, we acclimated summer-phenotype house sparrows (Passer domesticus) to three different six-week acclimation treatments: stable warm, stable cold and fluctuating cold. Following acclimation, we measured fiber diameter, number of nuclei per mm of fiber and MND from pectoralis muscle of birds from each treatment. We found no differences in pectoralis muscle ultrastructure for any variable across thermal acclimation treatments, suggesting that summer phenotype house sparrows may be physiologically equipped to withstand variable thermal conditions. However, we did find ultrastructural differences between winter-phenotype (previous study) and summer phenotype muscle ultrastructural changes. These data suggest potential tradeoffs among thermogenic capacity, muscle mass, and muscle ultrastructure with seasonal phenotypes in house sparrows.

## Corticosterone rapidly alters ketone dynamics in young seabird chicks

*Morgan Benowitz-Fredericks, Sierra Pete, Maria Pisciotta, Eadaoin Kelly, Shannon Whelan, Alexander Kitaysky*

Rapid glucocorticoid elevation during a stress response is presumed to alter energy allocation, adjusting the dynamics of circulating energy metabolites. Ketones are lipid metabolites – products of fatty acid oxidation. In birds, circulating ketones increase with lower food availability on the scale of days to months; however, the sensitivity of ketones to rapid changes in corticosterone are not well-studied. We tested the hypothesis that elevated corticosterone rapidly alters ketone dynamics in plasma of 5 day old, free-living black-legged kittiwake chicks from food-supplemented and unsupplemented nests. Ketones were higher in unsupplemented chicks when their corticosterone levels were also higher. Fifteen minutes after either endogenous or exogenous corticosterone elevation, ketone levels dropped. Sixty minutes after exogenous treatment, corticosterone remained elevated but ketones no longer differed from control. Despite the transient decrease in ketones following corticosterone elevation, ketones and corticosterone levels remained positively correlated. The exogenous corticosterone treatment separates a role of corticosterone from other components of the stress response like catecholamines (which increase ketogenesis in mammals) and indicates that corticosterone is independently involved in rapid changes in the synthesis, mobilization and/or uptake of lipids. We conclude that in young kittiwake chicks ketone levels not only reflect long term nutritional status, but can fluctuate on very short time scales in response to elevated corticosterone. Mechanisms of corticosterone involvement in rapid lipid dynamics in birds warrant further attention.

## Rattlesnake thermo-hydroregulation as a model for understanding responses to climate change

*Derek Benson, Dale DeNardo*

Of utmost importance to an organism is the ability to maintain homeostasis in response to a variety of environmental conditions. Though climate change is predicted to increase maximum and minimum temperatures 2-3°C while also decreasing rainfall for many xeric environments, the impact that this will have on wildlife remains unclear. Most physiological processes are highly sensitive to temperature and water balance, and small deviations in either can significantly affect performance. Thus, whether organisms can mitigate the effects of increased temperature and reduced rainfall may in part determine the effects of climate change on organisms. Accordingly, we utilized a natural precipitation and temperature gradient relevant to climate change to investigated whether individuals in a population of western diamond-backed rattlesnakes (Crotalus atrox) in a more arid location maintain similar body temperatures and water loss rates to conspecifics in a cooler, less arid area. Additionally, using the warmest and driest portion of the aridity gradient, we investigated whether C. pyrrhus, a species predominantly found in arid areas, maintains body temperatures and lower water loss rates than a sympatric population of C. atrox, a species that is widespread across the southwest.

## Improving Population Counts Using Neural Networks

*Ian Bentley, Marwan Gebran*

Neural networks can greatly improve population counts in software used to track animals. The need for this improvement is particularly critical in the video analysis of high-density events where it is a challenge to resolve moving individuals. Two critical ingredients needed to successfully train a neural network for this purpose are the architecture of the network and the curation of training data. The refinement of both aspects will be discussed in a general manner so that it can potentially be beneficial to other related studies. Moreover, algorithms used to create a robust set of images for training from a smaller subset of images will be discussed in detail. Results in the context of a trained network applied to videos of bats and a few avian species will be discussed.

## Methyl farnesoate, MEKRE93, and molting: a crustacean transcriptional network

*Vanessa Bentley, Jorge Perez-Moreno, David Durica, Donald Mykles*

Methyl farnesoate (MF), the precursor to insect juvenile hormone III (JH-III), is produced by the crustacean mandibular organ (MO) and is implicated in several physiological processes including protein metabolism, reproduction (vitellogenesis), metamorphosis, and molting. Previous studies demonstrated that MF stimulates or inhibits the synthesis of 20-hydroxyecdysone (20-E) produced the Y-organ (YO). These data indicate that MF action facilitates the YO through the transcriptional cascade of Methoprene tolerant (Met), Krüppel homolog 1 (Kr-h1), and E93 (MEKRE93). It is hypothesized that MEKRE93 signaling, in conjunction with 20-E responsive genes and co-transcriptional mediators, determine Halloween gene expression. Bioinformatic analysis of the blackback land crab (Gecarcinus lateralis) YO transcriptome identified and characterized the MEKRE93 and Steroid receptor coactivator (Src) transcription factors along with the regulators C-terminal-binding protein (CtBP) and CREB-binding protein (CBP). Differential expression of these genes in YOs from adults induced to molt by multiple leg autotomy (MLA) or eyestalk ablation (ESA) indicate that this network may influence the YO phenotype throughout the molt cycle. Specifically, interactions between MF and 20-E signaling may contribute to the transcriptional repression of the YO during postmolt. These findings constitute an entirely novel function of MF in the regulation of molting and growth, which has substantial implications for fisheries, aquaculture, and ecological disciplines. Supported by NSF (IOS-1922701 and IOS-1922755).

## Bio-inspired sensing for disturbance detection on unmanned aerial vehicles

*Sarah Bergbreiter, Regan Kubicek, Bram Miller*

Neural mechanosensing strategies used in insects achieve hyper-efficient information processing for agile and robust flight. In this work, we explore two types of mechanosensors for disturbance detection in flight: strain and flow. Prior work has shown that complex strain patterns on insect wings can be efficiently encoded by strain-sensitive neurons. We have designed and fabricated strain sensitive ‘switches’ that can be fabricated directly onto flexible wings. These switches open and close at a designated strain threshold inspired by the nonlinear filtering of neurons embedded in the insect wing. We show that the timing of these switch closures allows us to detect and classify disturbances as well as body rotations (sinusoidal yaw rotation with 4 rad/s amplitude). We also explore placement of these sensors on the wing using a combination of computational and experimental approaches. We have also extended this paradigm to flow sensing inspired by the many hairs found on insect wings and bodies. Using the same switch-based approach, sub-millimeter scale flow sensors have been shown to the reversal of airflow direction (useful for stall detection) as well as airflow velocities as low as 0.5 m/s.

## Visualizing shell thickness variation in bird eggs with ImageJ

*Avi Berger*

Despite extensive research effort into other aspects of bird evolution, the diversification of avian eggs is a recently growing field of study. While all bird eggs serve the same functions, they are highly morphologically diverse, including interspecific variations in shell thickness. Shell thickness is often used as a proxy for resistance to breakage of the eggshell overall, with thicker shells offering greater protection from impact and predation attempts. This attribute is under great selective pressure to protect the embryo within until hatching, balancing impermeability, effective gas exchange, and hatchability. Majority studies involving shell thickness measures empty shells at three points or less, losing thickness variation nuance across the whole shell. To evaluate the accuracy of this method, I apply CT scanning and imaging technology to developing eggs from a diversity of avian taxa to measure thickness variation, natural shell thinning during incubation, and embryo mortality across embryonic developmental stages. Non-destructively characterizing shell morphology and creating effective scanning methodology that can be ethically applied to a diversity of live eggs could improve conservation efforts and contribute unique resources to 3D image repositories. This poster overviews the process of extracting shell thickness data from live eggs and compares the results and methodology to the 3-point shell measurements typically used in ornithology.

## Phylogenomics provides insights into the repeated evolution of medusozoan eyes

*Cory Berger, Paulyn Cartwright, Marina Stoilova, Maria Pia Miglietta, Rebecca Varney, Todd Oakley*

Eyes have evolved at least nine times within jellyfish (Medusozoa), ranging from simple eyespots to complex lensed eyes, providing a powerful system to study the repeated convergent evolution of a complex trait. Additional eye origins are possible, but uncertain due to insufficient taxon sampling and unresolved phylogenetic placements. The major clade Hydrozoa—which contains most eye origins and species diversity within Medusozoa—remains an extremely challenging phylogenetic problem due its ancient radiation and short internal branches. Such conditions lead to high levels of incomplete lineage sorting and gene tree discordance, potentially misleading conventional concatenation-based species tree methods. To address this problem and more fully resolve eye evolution in jellyfish, we assembled a large dataset of genomes and transcriptomes, including representatives of lineages under-represented in previous phylogenomic studies. We used coalescent species tree methods to infer a phylogeny of Medusozoa with a fully-resolved hydrozoan backbone, produced a time tree using comprehensive fossil calibrations, and reconstructed eye evolution. We find strong support for at least two additional eye origins, including multiple origins within Scyphozoa (true jellyfish), bringing the minimum number of eye origins within jellyfish to 11. Eyes have also been lost several times, but less often than they have been gained. This work pinpoints numerous convergent gains and losses of sensory structures throughout the history of an ancient and diverse clade of animals.

## Kinematic diversity and determinants of swimming performance in lizards

*Philip Bergmann, Emma McLellan*

Lizards, like most tetrapods, retained the ability to swim. Indeed, the vast majority of lizards can swim, despite little research on the diversity of how they do it. We studied swimming in 28 species from 12 major clades using high-speed video. We performance as Froude number and thrust efficiency, and kinematics as the amplitude, wavelength, and frequency of waves along the body, and whether they used their limbs. We considered the diversity of swimming kinematics, and tested (1) what aspects of kinematics most modulated performance, and (2) how performance and axial kinematics change with the use of limbs. We found that there was little diversity in axial kinematics, with the greatest variation in limb use. Similar to fishes, wave amplitude decreased from the head to the pectoral girdle and then increased further posteriorly. Performance was modulated most by wavelength, less by frequency, and not by wave amplitude. Most in non-aquatic species used their limbs, with some clade differences. Use of limbs increased wave amplitude and decreased wave frequency, resulting in decreased Froude number. Lizard swimming kinematics appear highly conserved and may be shaped by the same physical constraints as fishes, which are ancestrally and obligately aquatic.

## Impact of ambient light levels on silver and bighead carp schooling behavior

*Amelia Berry, Michael Frett, Brooke Vetter, Allen Mensinger*

Silver (Hypophthalmichthys molitrix) and bighead carp (H. noblis; collectively bigheaded carp) are invasive fish species that have spread along the Mississippi river and now threaten to establish populations in the Great Lakes. There are currently many efforts to control bigheaded carp populations involving research on non-physical deterrents to prevent them from swimming upstream and mass collection efforts. Understanding the schooling behaviors of bigheaded carp can aid in these deterrent or removal strategies, as researchers can target schools of fish rather than individuals. In addition to the lateral line, vision likely plays a key role in bigheaded carp school formation, so it is important to determine how light availability impacts schooling behavior. The differences in schooling behaviors of bigheaded carp were examined between different light conditions and times of day. Overhead lights were programmed to a 24-hour cycle to simulate 6 natural light conditions in a 10,000 L model lock and dam tank. Schools (N=6) of silver or bighead carp (N=10 individuals) were placed in the tank to acclimate for 12 hours overnight and then observed the following day during the sunrise, daylight, and sunset programmed times the following day. Results suggest that both schooling and swimming behavior in bigheaded carp are impacted by different light levels. The findings from this study could potentially aid in the effectiveness of invasive carp deterrent research and capture strategies.

## Center of mass manipulation and its effect on walking control

*John Bertram, Ryan Schroeder, James Croft*

Legged locomotion is often considered in terms of the kinematics and forces associated with individual joints, tendons, muscles, etc. However, the greater purpose of these components is to facilitate energetically effective transportation of the animal's whole body, represented by its centre of mass (CoM). Here we consider human walking as a model of cyclic locomotion, where the CoM oscillates vertically with each step. We applied vertical force oscillations to the body as a direct manipulation of the CoM and observed human gait synchronization (or frequency matching) with the external oscillation. Sensitivity was tested by gradually increasing oscillation amplitude until the individual adjusted their gait to match the oscillation frequency. Synchronization range was also tested, by matching the oscillation frequency to the individual and then drifting it either higher or lower, gradually in time. On average, subjects synchronized with external oscillations under most conditions but were more sensitive to frequencies near and below their baseline step frequency (measured while walking with no oscillations). Individuals also synchronized over a broader range of frequencies below versus above baseline. Our findings suggest that gait frequency is not fixed for a given speed, but rather, emerges as a dynamic response to interactions between the CoM and the external environment, whether due to the entrainment of nonlinear oscillators in the central nervous system or other control mechanisms (e.g., energy optimization).

## Is feather microstructure changing in response to rising temperatures in a widespread songbird?

*Bethany Bespoyasny, Samuel Lane, Isaac Rush, Britt Heidinger*

In many organisms, both the timing and expression of traits involved in temperature regulation are shifting in response to climate change with important effects on fitness. In birds, one aspect of the phenotype that may be important is feather microstructure. While there is evidence that environmental temperature can impact feather microstructures, the factors that drive these changes and the timescales over which they occur are not well understood. Yet, this information will be essential for predicting how birds will respond to rapidly changing environmental conditions. To address these questions, we sampled feathers from House Sparrow (Passer domesticus) specimens within populations along a latitudinal gradient and supplemented with historical counterparts from the 1960s. The House Sparrow is an ideal species for this study due to its extensive range over North America, its relatively recent introduction, and high variability in body size and color. We measured several aspects of feather microstructure (barb and barbule density and the plumulaceous to pennaceous ratio) on samples taken from the belly, vent, and mantle regions. We predicted that barb and barbule density and the plumulaceous to pennaceous ratio would increase with latitude and decrease in response to rising temperatures. This study will enhance our understanding of how aspects of feather morphology, which are expected to be important for thermoregulation are responding to climate change.

## Mitochondrial Genome Phylogeny of Alvinellidae (Annelida: Terebelliformia)

*Dakota Betz, Greg Rouse*

Alvinellidae are endemic to hydrothermal vents in the Pacific and Indian Oceans. These extremophiles live in tubes and are found from 1500-3500m depth, often near vent chimneys. Currently, there are 13 species described, and they are placed in three genera: Alvinella, Nautalvinella and Paralvinella. Samples collected over 20 years from hydrothermal vents have given access to all known Pacific species plus a series of new taxa. Whole mitochondrial genomes and nuclear 18s rDNA sequences were mined from genome skimming data to provide the first comprehensive phylogeny of the group. This allows for a reassessment of the current taxonomy of the group, its biogeography and provides evidence of several new species.

## Pathogen specialization among competing hosts drives coexistence and pathogen dilution

*James Bever, James Adelman, Maarten Eppinga, Elizabeth Archie, Vanessa Ezenwa*

Pathogens can have large impacts on their host populations, but the extent to which host community diversity is governed by pathogens and, in turn, the extent to which pathogen dynamics are governed by host community diversity, remains to be understood.

In plant communities, accumulating evidence identifies host-specific pathogens as important drivers of negative microbiome feedbacks that contribute to the maintenance of plant community diversity. Recent empirical work used the microbiome feedback framework to demonstrate that the impact of host-specific pathogens is diluted by host community diversity. We use host-microbiome feedback theory to identify the conditions under which pathogen specialization will contribute to both the maintenance of host community diversity and the dilution of pathogen impacts with host community diversity and productivity. We then illustrate the causal connections between pathogen specialization, coexistence of competing hosts, and pathogen dilution using data on plant-pathogen interactions from North American grasslands. Finally, we test the conditions for pathogen-specialization to mediate coexistence and pathogen dilution in an ungulate community in the western US. Together, these projects outline an approach to examining host-pathogen dynamics that can inform the generality of pathogen-mediation of host community diversity and pathogen dilution across systems.

## Hydrothermal physiology limits distribution of the Mink Frog, *Rana septentrionalis*, in North America

*Catherine Bevier*

The cold-adapted Mink Frog, Rana septentrionalis, is the most aquatic species of the Aquarana clade. Its distribution is restricted to southeastern Canada and the northeastern United States, with a southern distributional limit north of the 43rd parallel. Several inherent factors influence this boreal frog's distribution, including low tolerance to desiccation and egg development that requires cold, well-oxygenated water. In a lab-based controlled desiccation experiment, adult Mink Frogs lost a higher percentage of body mass than Green Frogs (R. clamitans), which corroborates results of previous studies and explains the species' confinement to aquatic habitats. During the reproductive season, globular egg masses swell quickly and sink to the bottom of water bodies. Successful larval development requires cold, well-oxygenated water, as ascertained in captive breeding conditions where only eggs in well-aerated tanks developed and hatched. Mink Frogs in Maine are at the southern limit of their distribution, and their dependence on cold water habitats in the humid cold climatic region make them vulnerable to climate change. They will likely experience a shift in distribution or reduction in suitable habitat given current projections of warming temperatures from climate change models.

## Heat shock factor binding site variation across cnidarian genomes: patterns and potential function

*Janki Bhalodi, Adam Reitzel*

Heat shock factors (HSFs) are highly conserved transcription factors that govern diverse processes including stress response and development. HSFs bind to heat shock element (HSE) motifs in gene promoters, triggering the expression of target genes. The diverse developmental strategies and variable environments inhabited by cnidarians make it an excellent group to explore variation in the HSF regulatory system. Here, we used comparative genomics to identify the genome-wide distribution patterns of HSF binding sites in various cnidarians across the phylum. Our results suggest that HSEs are widely distributed throughout these genomes with most motifs being present within the exons and introns of gene bodies. We also found that genes with a high number of HSEs in the likely promoter regions were associated with stress response gene ontology terms and correlate with the extent of transcriptional activity. Additionally, we discovered that HSE numbers were not conserved between orthologous promoters of single-copy genes among cnidarians. Together, these findings suggest the genes regulated by HSF are liable over evolutionary time with extensive lineage-specificity. Future work will investigate the functional relevance of HSE diversity and distribution in cnidarians via reporter assays, transcriptomics, and identification of HSF genome occupancy.

## Mechanisms of turning in *Drosophila*

*Vikas Bhandawat, Marcello Codianni*

Because of the many degrees of freedom, legged locomotion is a complex problem. How animals coordinate their limb movements to efficiently traverse their environment is still being understood? In recent years, Drosophila has become an important model for the study of legged locomotion and much progress has been made in the neural control of walking in Drosophila. In this study, we describe turning in Drosophila. We created a novel arena in which we could measure the movement of the fly with high spatial and temporal resolution. We also track the tips of each of its limb. Using this dataset we describe greater than ten thousand sharp turns in Drosophila. We find that based on kinematics of turn, the turns can be divided into three types. Each turn-type is associated with characteristic change in gait and kinematics. We also analyze turns that are induced optogenetically by a recently discovered set of descending neurons. We find that the optogenetically-induced turns have kinematics that are completely distinct from those of naturally occurring sharp turns implying that the associated circuits do not reflect the full mechanism underlying turning. Finally, we build a biomechanical model that can produce each turn type. Overall, this study leverages an important genetic model organism to provide insights into turning during legged locomotion.

## Computational Design and Additive Manufacturing of Bioinspired Architected Materials

*Dhruv Bhate*

Despite the enormous potential of leveraging the rich information embedded in biological form, and the rising interest in bioinspired design, there is no generalized, accessible computational design tool that enables it. In this presentation we will identify what I believe are the reasons for this gap and propose a framework to address it in the context of nine distinct types of architected materials, introduced here as "Bio-Motifs". This framework consists of three pillars: (i) knowledge graphs, (ii) mathematical models, and (iii) data and information. I will elucidate aspects of this framework with examples from prior and ongoing work in our group over the past 5 years, spanning diverse organisms and structures such as sea sponge networks, honeybee hair, honeycomb, scales and branches. I will demonstrate how we use computational design, simulation and additive manufacturing to both understand the functional basis for biological form, and leverage that understanding to engineer novel application solutions.

## Genetic variation causes structural variation in the IGF1 protein among Anolis lizards

*Sagar Bhowmik, Blake Lee, Morgan Muell, Megan Benedict, Shawn Yates, Abby Beatty, Tonia Schwartz*

Anolis lizards have diversified in morphology including body size, limb lengths, and coloration. The insulin and insulin-like signaling pathway plays crucial roles in determining many aspects of body size and shape. This study investigates the genetic variation and protein structural variation in the insulin-like growth factor 1 (IGF1), a key hormone in this pathway, across nine Anolis species. IGF1 sequences were obtained from public databases or newly generated for a subset of species. Every species had a unique IGF1 amino acid sequence, with substantial amino acid variation (42.7% identity) concentrated in the functionally important C-domain of the IGF1 protein that regulates binding affinity between the IGF1 and its receptors. To test if the sequence variation affects protein structure, we used Swiss-Model to predict high-quality structures. Using the green anole, A. carolinensis, as a reference, we conducted structural comparisons using PyMOL that revealed varying levels of conservation levels across the species. Further analyses are being conducted contrasting each species' structure to predict whether the changes are likely to alter the hormone-receptor binding affinity, providing broader insights into the evolutionary mechanisms driving the remarkable morphological diversity within this genus.

## Winds of Change: Chicago's Urban Impact on Mammalian Evolution

*Luna Bian, Alyssa Stringer, Stephanie Smith, Anderson Feijo*

Due to human-induced environmental changes, microevolutionary adaptive responses are occurring rapidly in urban mammals. Studying these responses may allow us to better understand human impacts on the evolutionary process. Despite this, past studies have been limited by a shorter timescale or focused primarily on overall animal size changes. To understand how mammalian skull morphology has changed due to urbanization over the past century, we examined two common urban species from the greater Chicago area: the eastern meadow vole (Microtus pennsylvanicus) and the eastern chipmunk (Tamias striatus). For each species, we surface-scanned cranial specimens from the Field Museum covering the last 120 years, including up to 25 specimens from each decade where possible. We analyzed skull shape with a combination of linear measurements and 3D geometric morphometrics. The toothrow length of Tamias became shorter in more recent years, however, this did not occur in Microtus. In Microtus, the auditory bulla and braincase width increased in size; in addition, we observed an increase in the degree of cranial asymmetry. Due to their different lifestyles, varying degrees of human interaction, and diets, these two species are responding to urbanization in different ways. Our findings suggest that morphological changes in response to urbanization may be more variable than previously thought. Future studies may benefit from the use of diet or degree of urbanization data in conjunction with morphology.

## Does epigenetic aging underlie trade-offs between development and aging?

*Abby Bickle McKittrick, Ethan Shealy, Marilyn Mason, Benjamin Parrott*

Across vertebrate taxa, the rate of development is linked to longevity, with faster development associated with reduced lifespan. This trend is observed across ecological and evolutionary scales including at the species, population, and individual levels. Despite the apparent universality of this relationship, the mechanistic basis underlying the connections between development and aging are unresolved. Recent work has demonstrated that embryos undergo an 'epigenetic rejuvenation' process, and we hypothesize that faster development compromises epigenetic patterning at loci that later acquire age related DNA methylation patterns. Using newly developed epigenetic aging resources for medaka fish, we aim to investigate the effect of individual developmental rates on epigenetic age and age-related life-history traits. We induced disparate developmental rates in medaka (Oryzias latipes) embryos using three temperature treatments: 31.0°C, 25.0°C, and 18.5°C. Developmental rate was tracked for individuals and hatched fry were kept individually housed at room temperature, measured monthly, and checked weekly for sexual maturity until sacrifice at ∼5 months after hatching. Whole hepatic DNA methylomes were sequenced and investigated for altered aging patterns. We find that incubation temperature results in stark differences in developmental timing and identify significant relationships between days-to-hatch and growth rate in both sexes as well as age at maturity in females. We also report preliminary analysis of how development rate and life-history traits relate to methylation patterns and estimated epigenetic-age in individuals.

## Differential gene expression is constrained by clade and ecological divergence in a Baja California endemic lizard (Urosaurus nigricaudus)

*Austin Biddy, Greer Dolby, Kenro Kusumi, Raul Araya-Donoso, Liz Davalos-Dehullu, Adrian Munguia-Vega, Andres Lira-Noriega*

Urosaurus nigricaudus is a lizard endemic to the Baja California peninsula BCP that comprises northern and southern clades that may have diverged in part due to ecological divergence based on niche analysis. Therefore, we hypothesized that these wild populations would exhibit gene expression differences due to core organismal processes (due to lineage divergence), reproductive processes (suggesting early reproductive isolation), or ecological/microclimate disparities (e.g., related to metabolism, osmoregulation/temperature, diet). Based on climate analysis and RNA-seq of 31 wild-caught lizards, we found the populations occupy separate microclimates, distinguished mainly by temperature (south), precipitation (north), and monthly solar radiation. After controlling for sex, we found 671 genes were significantly differentially expressed between northern and southern populations and 363 GO terms that were statistically enriched. These terms include Lipid Metabolic Process (e.g., Cyp2j6, Dgka, Gpat4), Mitochondrion (e.g., Mt-atp6, Cox6b1, Fmc1), and Response to Abiotic Stimulus (e.g., Angpt4, Vegfc, Hspb1, Dnaja4), supporting the hypotheses regarding transcriptional differences in metabolism and ecological demands. Populations in the southern BCP had more upregulated genes associated with cellular respiration and lipid biosynthesis, suggesting differential allocation of energy for life history traits (e.g., reproduction, growth). Northern populations had more upregulated genes associated with angiogenesis and vasodilation, which is associated with oxidative stress. We posit gene expression differences are either a response to different local climates or due to genetic divergence and adaptation of these populations.

## Impact of life cycle variation on the expression of crystallin genes in *Eurycea*

*Emily Bierbaum, Ronald Bonett*

A commonly observed pattern in visual ecology is the tuning of the sensory system to available light in the environment. This is accomplished by the duplication, diversification, and differential expression of visual system genes. Proteins involved in the visual system can reside in the lens, which is composed of crystallins. In the lens of the eye, crystallin genes have undergone extensive duplications and deletions, but it remains unknown how they have diversified with respect to changes in lens morphology and function across diverse environments. Within amphibians, salamanders are an excellent model to study visual systems because of their diverse life cycle modes and extreme transitions in habitat across ontogeny. The life cycles of salamanders not only include the typical metamorphic life cycle of a frog (aquatic juvenile, terrestrial adult), but also permanently aquatic and terrestrial lineages. Representatives occupy a plethora of habitats ranging from ponds, streams, lakes, swamps, and caves that vary in light environment and media type. As a consequence, their visual systems have undergone repeated transitions in visual media, often across development. Amphibian lenses also appear to change shape from round as larvae to flattened as adults, which allows them to accommodate differently between water to land. To understand the diversity of crystallin genes I deep transcriptome sequenced whole eyes.

## Exploring vibration attraction behavior in North American cavefishes (Amblyopsidae: Percopsiformes)

*Orran Bierstein, Pamela Hart*

Caves represent an extreme habitat for aquatic organisms to colonize; these subterranean habitats are characterized by a total absence of light and low nutrient availability. Such conditions produce a need to find food efficiently while being unable to locate food sources visually. The impact of mechanosensory (i.e., tactile) systems on cave-obligate organism survival and evolution remains largely understudied. Vibration attraction behavior (VAB) is a phenomenon in which fishes detect and move towards select mechanical stimuli produced by external sources. Fishes can detect these vibrations via the mechanosensory lateral line located along the head and body. Previous work on the model fish Astyanax mexicanus, a single species containing both sighted and blind phenotypes, has shown that blind cavefishes tend to move towards water vibrations in contrast with surface phenotypes; this indicates that a lack of vision may play a significant role in the evolution of VAB. Amblyopsidae is the largest group of cavefishes in North America and has undergone multiple independent colonizations of subterranean habitats, resulting in non-sister obligate cavefishes, facultative cave-dwellers, and obligate surface fishes. These factors make this family an ideal group with which to explore the importance of the mechanosensory system and potential presence of VAB in other cavefish species. I examined the degree and variability of VAB in fishes within Amblyopsidae with comparison between one cavefish species and two facultative cave-dwelling species.

## Insights into the respiratory and musculoskeletal adaptations of Hydrolagus colliei across ontogeny

*Meghana Binraj, Cassandra Donatelli, Karly Cohen, Olivia Hawkins, Sarah Arnette, Adam Summers*

Functional integration- the covariance of multiple morphological traits- is one mechanism of optimizing organismal performance and can provide insight to the natural history of organisms. One example of such integration is between respiratory and musculoskeletal anatomy in swimming vertebrates. Previous research in chondrichthyans has established a relationship between gill anatomy and swimming performance; here, we consider how key respiratory structures (filament length and lamellar density) and locomotor structures (pectoral fin muscles), vary across ontogeny in Hydrolagus colliei. We dissected multiple individuals across a range of sizes, including fixed and frozen specimens. Our objectives were to describe gill and pectoral fin morphology and quantify the changes in linear morphometrics of each with increasing body length. Understanding the scaling relationship between these structures over ontogeny can provide information about the changing energetic demands of these fish, and may reveal trade-offs that balance locomotor performance with metabolic efficiency. By investigating these relationships, this study will deepen our understanding of how H. colliei might optimize its physiological structures to thrive in varying environments.

## Is the hydrozoan actinula larva locally tuned to chemical cues from microbial biofilm?

*Sydney Birch, Adam Reitzel*

Microbial communities in marine biofilm produce diverse chemical cues that invertebrate larvae may detect with their sensory systems, influencing settlement behavior. Significant differences in how larvae from distinct populations respond to microbial biofilms can impact local population dynamics, influence gene flow, and can result in local adaptation over evolutionary time. However, it is currently unknown how changes in microbial communities influence larval settlement decisions that ultimately determine population structure and impact community dynamics in benthic marine communities. Here, we use the biofouling marine cnidarian Ectopleura crocea and its actinula larva to assess if the larval settlement decision is consistent with local adaptation. We hypothesize that distinct populations of E. crocea are locally adapted to specific biofilms, where larvae are cueing in on adult-associated microbes. To investigate this hypothesis, we performed a reciprocal transplant larval settlement experiment across a panel of localities and found that larvae show a preference for biofilms from their home locations. We are currently working on metagenomic analyses to identify how the microbial community varies for biofilms from each location. Additionally, we will perform metagenomic analyses on microbes collected from the surface of adults from each location, along with a population genetics study assessing the genetic structure of E. crocea populations. This work will provide insights into the conditions that lead to local adaptation and how larval sensory systems may be involved.

## Comparative Biomechanics of Insect Antennae

*Megan Bishoff, Kostya Kornev, Adam Puchalski*

Insect antennae are multifunctional hemolymph-filled fibers where a external cuticular wall provides rigidity and protection. This study undertakes a comparative analysis of the tensile properties of insect species encompassing aerial Lepidoptera, Manduca Sexta (Carolina hawkmoth) and Vanessa cardui (painted lady butterfly), and extends to previously untested terrestrial organisms, Aedes Domesticus (house cricket), Peruphasma Schultei (stick insect) and Periplaneta Americana (American cockroach).

We showed that all tested antennae except of cockroaches exhibit characteristics akin to brittle fibers. Cockroaches showed a J-type stress-strain characteristics demonstrating stiffening behavior when subjected to stretching. At the connecting membranes, the features of breakup are distinguishable between species: Lepidopteran and cricket antennae break forming a clean crack perpendicularly to the antenna axis. While, stick insects break forming a rough crack with delamination of interlayers. In these insects, the stresses are concentrated at the connecting membranes and flagellomeres remain almost undeformed. Morphologically, the antennae of cockroaches and crickets are similar, yet breakup of antennae of cockroaches is unique as it deforms uniformly along the flagellum as evidenced by the movement of sensilla. We hypothesize mobility of cockroach antennae significantly depends on hemolymph flow.

To test this, we conducted loop tests on active and sedated cockroaches showing the active insects vigorously bend antennae even with the fixed scape-pedicel pair. The results suggest new coupling of hemolymph flow and mechanical response and point to the need for reevaluation of mechanisms of mechanosensing in insects.

## Role of indirect wing steering muscles during free flight in *Drosophila*

*Debojyoti Biswas, Han Kheng Teoh, Abby Leung, Kemper Ludlow, Samuel Whitehead, Erica Ehrhardt, Michael Dickinson, Itai Cohen, Noah Cowan*

Flapping flight is an inherently unstable form of locomotion that requires insects such as Drosophila to constantly fine-tune their wing motion within milliseconds by coordinating a dozen pairs of wing-steering muscles. While past research has focused mainly on the direct wing steering muscles, little attention has been given to the role of indirect wing steering muscles during flight. We investigated the role of the dorsal tergopleural (tp) muscle, an indirect wing steering muscle, for pitch stabilization in a free-flight behavioral assay. Our findings reveal that flies compensate for minor disturbances in angular velocities ($< 1000$ deg/s) along the body pitch axis by modulating the wing stroke forward sweep angle, with little change to wing pitch. However, for larger disturbances, flies utilize both lift and drag forces to produce higher corrective torques by also considerably changing the wing pitch angle. Through optogenetic experiments targeting the tp muscle, we identify its crucial role in modulating the wing pitch angle during corrections to larger disturbances. A control-theoretic model of parallel proportional-integral controllers for both wing stroke and pitch angle modulation elucidates further the complex role of tp muscle during flight. Our findings expand our understanding of body pitch control by accounting for the hierarchical interaction of multiple wing degrees of freedom as well as shed light on the functional importance of the tp muscle in flight.

## Extended phenotype affects somatic phenotype in spiders

*Corinthia Black, Jeffrey Shultz, Hannah Wood*

Reciprocal selection between extended and somatic phenotypes is an active area of investigation. Recent research on the influence of web building on somatic evolution in spiders has produced conflicting results, with some finding no effect of web use on somatic evolution and others showing significant effects. However, the studies yielding these results differed in focus, with the former surveying general anatomical traits and the latter concentrating on somatic systems with significant functional roles in prey capture. Here, we propose and test the hypothesis that prey immobilization by webs is broadly synergistic with cheliceral biting force and that web builders have lower cheliceral forces than free hunters. Our analysis focused on the intercheliceral (IC) sclerite and muscles, a newly characterized synapomorphic system ubiquitously distributed in spiders. Using $\mu$CT scans, we quantified IC sclerite shape and modeled IC muscle function. Statistical analyses using phylogenetic comparative methods showed that inferred size-corrected isometric muscle force is lower in web-builders than free-hunters. No such association was found for IC sclerite shape. These results highlight the importance of relevant functional parameters when investigating reciprocal selective effects of extended and somatic phenotypes.

## The spectral sensitivity of mosquito photoreceptors can explain preferences for colored stimuli

*Adam Blake, Jeff Riffell, Gregor Belušič*

Vision underlies many important mosquito behaviors such as floral foraging, seeking out vertebrate hosts, and the location of oviposition sites. Despite the medical importance of mosquito born illness and the prominent role of vision in their behavior, the spectral sensitivities of their photoreceptors have until now remained uncharacterized. Using intracellular recording methods in Aedes aegypti, we report the spectral sensitivity of mosquito photoreceptors present in the ventral compound eye of females. These recordings demonstrate conclusively that the majority of mosquito photoreceptors (R1-6) are green sensitive and gain UV sensitivity through a sensitising pigment. The central photoreceptors, which are thought to play a role in color vision, show peak sensitivities in the UV, green, or show a dual peak in the blue and green. Complementing the electrophysiological data, we also investigated mosquito responses to visual stimuli through wind tunnel bioassays using visual stimuli created with a pair of novel LED spectral arrays capable of generating stimuli in the range of 390-740 nm. These visual stimuli were also paired with different odors allowing us to investigate the effect of odor on visual responses. In the presence of CO2 only, the observed spectral preferences can be largely explained through an achromatic intensity response from the outer photoreceptors. However, in the presence of other odors, these preferences are influenced by input from the central photoreceptors.

## The effect of thermotolerance on honeybee foraging time

*Brendon Blake, Kiara Lopez, John Barthell, Victor Gonzalez*

Apis mellifera are one of the most economically important insects throughout the world. While they can be found foraging all throughout the day, previous research suggests some individuals forage in shifts, with some of them foraging only during the morning while others only during the afternoon. Because daily temperatures change dramatically throughout the day, we predicted that this division in labor is correlated with a difference in their thermotolerance. We hypothesized that individuals that foraged during times with relatively cool ambient temperatures (about 20°C) would have lower thermotolerance than individuals that forage during periods when the ambient temperature reaches its peak (about 40°C). To test this, we conducted an experiment on the Greek island of Lesvos, in which we determined three periods to serve as our "shifts": a morning shift (6:00 – 8:00), afternoon shift (12:00 – 14:00), and evening shift (18:00 – 20:00). Honeybees were marked on a feeder throughout these shifts to determine when each individual foraged. Then, individuals exclusive to each group were collected, in addition to individuals that foraged during all three shifts. We assessed bees' heat tolerance as the maximum temperature that each individual could endure (CTmax). We found no significant differences in CTmax among honeybees that forage during different periods of the day. This suggests that differences in foraging time between honeybees is not associated with individual thermotolerance.

## A look at presence and preference of cirri appendages in wild-caught dwarf seahorses

*Paige Bland, Megan Sims, Emily Rose*

Seahorses are cryptic fishes found in coastal marine environments that grow skin filaments, also known as cirri or fronds. Cirri presence has been reported to vary across seahorse species and tend to disappear in captive individuals. Dwarf seahorses (Hippocampus zosterae) were collected and photographed monthly during a year-long study in Tampa Bay to determine what factors influence the presence of cirri across the sexes and age distributions in the wild. Cirri were measured at four locations on the fish, including eyes, head, crown, and body segments, and found to be more abundant during the wet season, which coincides with the peak breeding season for dwarf seahorses. Females displayed more cirri than males or juveniles, leading to a hypothesis that cirri could be a sexually selected trait. Mating trials were conducted in the laboratory consisting of three size-matched seahorses to determine male preference between highly and non-ornamented females. Males mated with the highly ornamented female in 17 of the 19 trials, supporting our hypothesis that cirri could be under sexual selection pressures. Additionally, wild-caught females were maintained in the laboratory and photographed at six consecutive time points over 21 days, allowing for on-going measurements and analysis of cirri changes in captive individuals. Future studies will investigate if cirri are a condition-dependent trait to disentangle the potential causes and mechanisms leading to cirri reduction.

## Using two chemotypes of invasive Melaleuca to compare herbivory on opposite coasts of South Florida

*Blake Blaskowski, Peter Stiling, Melissa Smith, Andrea Carmona-Cortes, Anthony Garcia*

Melaleuca quinquenervia is an invasive plant native to Australia that impacts south Florida, especially in the Florida Everglades. Three main biological control agents have been released against it: a leaf-feeding beetle, Oxyops vitiosa, a sap-feeding psyllid, Boreioglycaspis melaleucae, and a stem gall fly, Lophodiplosis trifida, each of which target different niches within Melaleuca, and subsequently reduce its biomass, growth rate and reproductive rate. Two main chemotypes of M. quinquenervia are present in Florida, one known as E-Nerolidol, which grows mostly on Florida's east coast, and the other, E-Viridiflorol, on the west coast. These biocontrol agents have differing preferences for chemotypes of Melaleuca, but may also have local adaptation to host plants (adaptive deme formation).We used reciprocal common gardens of each chemotype on both the east and west coasts to further investigate the relationship between chemotype, geographic locations and herbivory. Trees were surveyed monthly over a year for the presence of herbivores. Results found that there was a significant difference in preference of psyllids between sites, but in the opposite direction of deme formation. There was also interaction between chemotype and location for both psyllids and gall midges, but not beetles. Chemotype and environmental differences in herbivory may help explain the presence of recalcitrant Melaleuca populations in Florida and such phenomena could also occur in other populations of invasive plants which have differing plant chemistry.

## Genome Sequencing and Annotation in an Antarctic Copepod to Study Early Visual Development

*Auden Block, Joseph Covi*

The zooplankton visual system is necessary for hatching and subsequent larval movement in response to light cues (phototaxis). However, the impacts of thermal and chemical stress on visual development and behavior prior to the formation of bilateral eyes remain unexplored. To effectively use transcriptomics as a tool to examine the role of light receptive systems in the breakage of the diapause state, a genome is needed to scaffold the transcriptome. The goal of the present study is to sequence the genome of the Antarctic freshwater copepod, Boeckella poppei, as a first step toward understanding vulnerabilities in early visual development. Oxford Nanopore Technologies sequencing and the newest basecaller, Dorado, were used in combination with Pacific Biosciences High-Fidelity (HiFi) sequencing to obtain genetic sequences for genomic assembly. Quality control was conducted using BUSCO, QUAST, and k-mer analysis. Opsin, central nervous system, and heat-shock genes were searched for via BLAST using reference sequences from Daphnia magna and Artemia franciscana. Gene prediction tools were further used to develop an annotated genome of Boeckella poppei.

## Identifying stress biomarkers in cetacean blubber using transcriptomics

*Kelvin Boateng, Jane Khudyakov, Nick Kellar*

Many marine mammal species are in decline and are threatened by anthropogenic disturbance, so there's pressing need to understand the impacts of physiological stress on health. Stress alters production of hormones (i.e. cortisol, thyroid hormones) that regulate expression of genes involved in the response to stress, including those that impact lipid homeostasis, immunity, and other functions. Repeated or chronic stress may adversely impact energy stores, immune function, and reproduction via such genes. We are using transcriptomics to identify gene markers of stress in blubber collected from bottlenose dolphins (Tursiops truncatus) with varying levels of baseline and capture-induced stress. However, isolation of sequencing quality RNA from cetacean blubber has proven challenging due its high fiber and fat content. We first compared the effects of tissue preservation and homogenization methods and RNA isolation kits on the quality of RNA extracted from cetacean blubber. We found that blubber preservation in RNAlater reagent, cryogenic milling followed by bead beating, and two phase extractions using a kit developed for fatty and fibrous tissue RNA extraction produced sequencing-quality RNA. We are currently analyzing the T. truncatus blubber transcriptome to identify gene expression differences between blubber layers and individuals responding to capture and handling stress to identify molecular markers of stress that can be measured in blubber obtained by removing biopsy from wild cetaceans.

## Tentacles as a model for understanding the ctenophore sensory-motor transformation

*Yuriy Bobkov, Urvashi Goswami, Natalia Padillo-Anthemides, Leslie Babonis, Joseph Ryan*

Ctenophores, as the sister group to other animals, represent a crucial lineage for investigating the origin and early evolution of neurons. The focus of this project is to describe the primary sensory and motor system associated with elementary sensory-motor transformation of ctenophore tentacles. Sensory-motor transformation is the fundamental principle by which animals detect, interpret, and react to environmental signals. This transformation relies on sensory cells, and neuro-muscular cell infrastructure. Using single cell transcriptomic analysis, imaging, physiological, and behavioral techniques, we identify and characterize in detail the various tentacle cell types (including ciliated sensory cells, colloblasts, muscle cells, and neurons) and their mechanisms of sensory transduction, intercellular communication and effector functions. Our data suggest that ctenophores, like their bilaterian and cnidarian counterparts, utilize a similar molecular repertoire involved in the detection and transduction of mechanosensory and chemosensory signals, as well as in signal transmission and muscle fiber excitation/contraction. This molecular and functional similarity can also be extended to an interesting feature of the tentacular neuronal architecture, where the afferent and efferent signaling pathways innervating the tentacles appear to be structurally indistinct, possibly sharing the same bidirectional neuronal tract. In addition to improving our understanding of the neural mechanisms of modern-day ctenophores, our integrative approach provides important insights into the sensory, motor, and other capabilities of the last common ancestor of animals.

## Chemically mediated behavioral responses of early benthic juvenile Caribbean spiny lobsters

*Yuriy Bobkov, J. Strickler, Charles Derby*

Spiny lobsters use their chemical senses throughout their lives to acquire resources such as shelter and food, avoid predators, and interact with conspecifics. However, if and how these responses change over developmental stages is unknown. Here, we used early benthic juvenile Caribbean spiny lobsters (Panulirus argus) with calcium imaging to investigate the structural arrangement and physiological properties of olfactory sensory neurons (OSNs) and in behavioral analysis to characterize chemically triggered responses. We found that the basic structural design of chemosensory organs and chemosensory neuronal pathways is similar in juvenile and adult lobsters. OSNs of both life stages have similar patterns of spontaneous activity, tuning characteristics, sensitivity, and kinetic parameters of responses to chemicals. Regarding behavior, both life stages produce currents following chemical stimulation, navigate through the chemical plumes to locate a food source, respond to alarm cues (conspecific hemolymph), and show antennular grooming behavior to chemical stimulation. Our findings suggest that the chemosensory systems and behavior patterns are similar across developmental stages, making juvenile lobsters an adequate model for studying chemosensory transduction, coding mechanisms, and chemical-driven behaviors. The smaller scale of juvenile lobsters allows the use of compact, miniature benchtop laboratory setups, offering significant flexibility for medium-throughput pharmacological analysis and studies of courtship-related pheromones, visual stimuli, hydrodynamic landscape conditions, temperature, pH, toxic plankton metabolites, and other favorable and stress factors.

## Sex- and age-associated transcriptional patterns in a turtle with TSD and female-biased longevity

*Samantha Bock, Luke Hoekstra, Fredric Janzen, Anne Bronikowski*

Sexes frequently differ in key life history traits including body size, lifespan, and age at sexual maturity. Aging, the progressive decline in physiological function over time, is a particularly central process contributing to sex-specific life histories, yet the mechanisms driving sex differences in aging trajectories remain largely unresolved. Long-term mark-recapture efforts have demonstrated a striking pattern of female-biased longevity in the painted turtle (Chrysemys picta), a species with temperature-dependent sex determination (TSD). As a result, this species provides a compelling system to examine the mechanisms of sex-specific aging in the absence of sex chromosomes. Here, we characterize sex- and age-associated patterns in the blood transcriptomes of wild painted turtles ($n = 93$) whose capture histories allow for precise age estimates. We identify widespread gene expression differences between females and males, while age-associated expression patterns are more limited. Ongoing work aims to functionally characterize differential gene expression patterns and identify molecular pathways contributing to sex-specific aging in this system.

## Shrinking sparrows: How climate change impacts avian morphology and fitness

*Rachel Bockrath, Britt Heidinger, David Westneat*

Changes in climate are expected to alter selective forces on species across life stages. Bergmann's rule describes the commonly observed pattern of body size being smaller at lower latitudes owing to the heat dispersion benefits of smaller bodies. This connection has been invoked to explain the worldwide trend of shrinking avian body sizes since the 1960s. Although shrinking is often assumed to be adaptive, such conclusions are often drawn from adult populations. It is unclear if shrinking is driven by weather conditions experienced during the developmental phase, selection as adults, or across life stages. We used 30 years of banding records of over 10,000 house sparrows (Passer domesticus) and concurrent local weather data to investigate the link between climate change and body size over different timescales. Avian studies generally find positive relationships between body size and fitness. However, Bergmann's rule would predict the development of smaller nestlings during high temperatures. Nestlings may be particularly affected due to their rapid growth and confinement to the nest. Using linear mixed models, we found that house sparrow nestlings have gotten significantly lighter since 1993 ($p < 0\ .01$), though tarsus length has not changed significantly. We also investigated the influence of temperature and precipitation as they are commonly seen to affect growth. Identifying adaptive and non-adaptive changes in body size is critical to understanding the long-term fitness impacts of global warming.

## Tentacle remodeling as a source for a novel adult structure in a stalked jellyfish

*Kennedy Bolstad, Leslie Babonis*

Tissue remodeling is an important mechanism for generating distinct adult structures from juvenile precursors. For example, many medusozoan cnidarians (i.e., jellyfish and hydroids) remodel their tissues as they transition from a benthic polyp to a pelagic medusa. Staurozoans (stalked jellyfish) are atypical medusozoans- they remain as benthic polyps throughout their lives and only remodel a subset of their juvenile tissues as they transition into adults. Haliclystus sanjuanensis has specialized adhesive organs (anchors) that facilitate attachment to intertidal substrates. These anchors, found only in some adult staurozoan clades, are remodeled from a subset of juvenile tentacles (ubiquitous across staurozoans). This remodeling is accompanied by a cell-type transition from cnidocytes (i.e., stinging cells in the juvenile tentacles) to gland cells (anchor specific). Using light microscopy, we quantified changes in cnidocyte abundance and type during the transition from juvenile tentacle to anchor. Further, we labelled proliferating cells and observed a shift in their localization, consistent with a shift from investment in the juvenile tissue to investment in the adult tissue. This poses an important question: Can a tissue reverse this investment, or is it hardwired to continue developing the adult structure? To test this, we examined whether cnidocytes fired from the juvenile tentacle can be replaced at different stages during this tissue transition. Together, these experiments seek to understand the role of tissue remodeling in generating novel structures.

## The role of skeletal morphology on thrust dynamics in batoids

*Bart Boom, John Michael Racy, Spencer Truman, Charbel El Khoury, Tadd Truscott, Adam Summers, Ed Habtour*

Inspired by batoid musculoskeletal systems, we develop novel “propulsive skeletons” to explore the nonlinear dynamics underlying the relationships between the specialized morphology of batoids’ unique skeletal morphology and swimming kinematics. Prior research attempts to emulate the propulsive hydrodynamics of batoids used complex actuation or control to force the undulatory kinematics. Our synthetic skeletal analogues allow for experimental investigation into the ability of batoid pectoral fins to generate thrust from simple, vertical excitation. Comparing input force, amplitude and frequency to thrust, and output amplitude we reveal the nonlinear responses involved in structurally induced undulatory propulsion. Changing the skeletal architecture we map the effect of stiffness on performance (output amplitude and thrust). Using PIV, we analyze the structure-fluid interactions and demonstrate how Strouhal number affects vortex shedding. The results suggest that oscillating batoids generate more thrust at higher stiffnesses, however undulating batoids create more thrust at lower stiffnesses. The insights into pectoral fin shape and stiffness provide insight into the functional morphology of batoid locomotion, and will inform the design of more efficient engineered propulsive systems.

## The outcome of total sexual selection in the leaf footed cactus bug

*James Boothroyd, Michael Forthman, Christine Miller*

The capacity for sexual selection to produce astonishingly varied phenotypes has long captured the attention of biologists. Darwin was first to conceive of its two primary components: male-male competition and female choice. These forces are typically examined independently, despite acting together in nature. While these two components often favor similar traits in males, female preferences do not always align with competitive male traits, potentially leading to stabilizing, disruptive, or negligible net selection. Thus, explicit measures of total sexual selection are crucial to fully understand how sexual selection shapes phenotypes. Narnia femorata (Hemiptera: Coreidae), the leaf-footed cactus bug, is an excellent tool with which to measure total sexual selection. Male N. femorata compete using weaponized hind legs. Males with larger weapons have an advantage at excluding rivals from their cactus territories and mating opportunities, yet males with smaller weapons may bias paternity in their favor through sperm competition. Females often mate multiply and select territories to mate, feed, and lay eggs. Here, we estimated selection gradients for male-male competition and female mate choice, and we determined which best predicted paternity. Such explicit measures of sexual selection deepen our insights into the evolutionary dynamics of sexual selection to make more accurate predictions about the emergence of successful mating strategies.

## Investigating sensory system evolution through functional and anatomical studies in ctenophores

*Cezar Borba, Fredrik Hugosson, Natalia Padillo-Anthemides, Joseph Ryan, Mark Q. Martindale, James Strother*

Ctenophores are one of the earliest branching lineages, with recent studies suggesting them as the likely sister group to all other animals. Consequently, neurons have been independently evolving in ctenophores longer than in any other animal phylum, making them a powerful model for understanding the evolution of nervous systems. However, little is known about the anatomy, functional architecture, and molecular biology of the ctenophore nervous system. Most ctenophores have a structure known as the apical organ which contains sensory cells that project to the comb rows, a structure of linked cilia used for locomotion. Past studies have found ciliated sensory cells within the apical organ that are opsin-positive, and therefore believed to be photosensitive. In this study, we examined the mechanism of the visual response in the cydippid ctenophore Mnemiopsis leidyi. First, a list of likely gene candidates involved in the visual sensing pathway was determined through pfam domain analysis and relative expression comparison from 10x single cell RNA sequencing. Next, we used fluorescent in situ hybridization to label relevant gene markers alongside opsin to determine a likely phototransduction pathway. Then, ctenophore apical organs were labeled with calcium indicators and responses to visual stimuli were captured using two-photon microscopy. The results of these experiments shed light on the mechanisms of sensory processing and provide new insights into the evolution of nervous systems in animals.

## Investigation of immune, energetic tradeoffs associated with the coral-algal symbiosis

*Erin Borbee, Lauren Fuess, Roh-Allah Jalil*

The coral-algal symbiosis has long been characterized as a mutualism. The coral host receives organic nutrients from the algal symbiont to produce energy and the algal symbiont receives inorganic nutrients essential for photosynthesis. However, transcriptomic data from tropical corals suggest that to maintain this symbiosis, the coral immune system is suppressed, potentially making corals more susceptible to disease and challenging the characterization of this relationship as a mutualism. Additionally, the obligate nature of this relationship in tropical corals makes it difficult to distinguish whether the responses to changes in symbiont density are caused by the symbionts or by external stressors. Here, we use a facultatively symbiotic coral Astrangia poculata to characterize both constitutive and induced immunity and energetic reserves using biochemical assays, transcriptomics, and metabolomics. Astrangia poculata exists naturally in both symbiotic and aposymbiotic forms, allowing us to understand how symbiont density affects immune response and energetic reserves independent of environmental stressors. Preliminary data suggest that symbionts may provide extra energy to the host to allow for stronger constitutive immunity in symbiotic corals, which is in direct contrast with what we see in tropical corals. The data from this project will provide insights applicable for understanding symbiosis in context of coral conservation and restoration efforts, but can also help us more broadly understand the energetic and immune tradeoffs associated with endosymbiosis across many study systems.

## Insights from genome skimming of Remipedia (Xibalbanus spp.)

*Elizabeth Borda, Max Sahi, Fernando Calderon Gutierrez*

Remipedia is a class of elusive insect-like blind crustaceans, adapted to the marine water layers of anchialine caves around the world. Together, the Yucatan Peninsula and Cozumel Island host four species including Xibalbanus tulumensis and Xibalbanus fuchschockburni from coastal caves of Quintana Roo, Xibalbanus cozumelensis of Cozumel and Xibalbanus cokei from marine caves in Belize. Species delimitation based on morphology and molecular data has supported three distinct species in Mexico. However, DNA sequence data from specimens collected from type localities have only been available for X. fuchscockburni and X. cozumelensis, respectively, and X. cokei has been evaluated based on morphology alone. The goal of this study was to expand the molecular data available for all Xibalbanus species and from their respective type localities to serve as species references. Initial screening via DNA Barcoding (i.e., COX1) supported that X. cozumelensis is distributed across multiple caves on Cozumel Island, previously thought to be endemic to a single cave, but highlighted the need to further evaluate the other three Yucatan Peninsula species using genomic approaches. Data generated and evaluated from low pass whole genome sequencing (i.e., genome skimming) confirms that the Yucatan Peninsula hosts a single broadly distributed Xibalbanus species and implies that single gene analyses may have led to incorrect species designations due to PCR biases caused by the presence of competing pseudogenes.

## Pore Unfortunate Souls: a comparative look at elasmobranch sensory pore morphometrics

*Stephanie Borden, Breana Ramirez, Omolara Fola-Matthews, Michelle Huang, Ingrid Hyrycena, Buddhi*

*Maheshika Pathirana, Jasmin Graham, Lauren Simonitis*

Elasmobranchs (sharks, skates, and rays) have an electrosensory system known as the Ampullae of Lorenzini (AoL) that allows them to detect changes in the electrical field given off by all living organisms to track and hunt their prey, as well as navigation. The pores of the AoL on the surface of the skin lead to jelly filled canals which terminate in an ampullary organ. While they are found along the length of elasmobranchs, AoL are primarily clustered in the head of sharks. This project aims to analyze the AoL patterning across multiple elasmobranch species, many of which come from data deficient fisheries in the Global South. Using Image J, photos of the ventral surface of elasmobranch heads were used to gather morphometric data such as head dimensions, nasal morphology, as well as pore field density and distribution. These data will be used to look for interspecific differences as well as ecological and phylogenetic relationships. Because our methods involve photography and ImageJ, a free to use software, our workflow is accessible to scientists in regions of the world that lack access to expensive equipment and proprietary software as well as the ability to extensively process samples locally or ship samples internationally to collaborators.

## Effects of wing-tail interaction on bird-inspired morphing tail control authority during perching

*Kaleb Bordner, Cooper Cook, Todd Henry, John Hrynuk, Christina Harvey, Kevin Haughn*

Birds can transition from steady flight to a precision landing with apparent ease. This perching maneuver requires adequate pitch control to navigate high angle of attack aerodynamics, which proves challenging for engineered aircraft. Conventional fixed-wing aircraft rely on an elevator far behind the wing for pitch control. By contrast, birds use a morphing tail located a short distance behind the wing. In this configuration, downwash from the wings may complicate the local aerodynamics of the tail, particularly in the high angle of attack regime characteristic of perching. The impact of this unique wing tail interaction effect on bird maneuverability at low speeds is not well understood. In this work, we investigated the wing-tail interactions of a bird-inspired morphing tail to characterize the resulting pitch control authority across the range of angles of attack observed during perching. We isolated static wing-tail interaction effects by comparing force and moment data from a full aircraft against the superposition of wing and tail data collected individually. We found that the effects of wing-tail interaction during perching influence tail control authority and can be quantified as functions of configuration, such as the distance between the wing and tail. This fundamental understanding allows for the development of computational models to further investigate avian and bio-informed flight control and informs aircraft design practices.

## Scaling of head morphology and the four bar linkage in seahorses (Hippocampus)

*Samantha Borruso, Jonathan Huie, Meg Vandenberg, Olivia Hawkins, Cassandra Donatelli, Graham Short*

Seahorses (Hippocampus spp.) are suction feeders with a unique cranial anatomy that allows for rapid simultaneous head rotation and buccal expansion. This behavior, known as "pivot feeding," has been observed in larger seahorse species and is attributed to elastic energy storage in the four-bar linkage. The seahorse four-bar linkage is composed of bones and tendons that act as levers to facilitate mouth opening and closing as well as head elevation. Hippocampus is divided into: non-pygmies (max size=35cm), one dwarf (max size=2.5cm), and pygmies (max size=1.4cm). These fish exist in vastly different fluid regimes and must adapt anatomically or behaviorally to cope. Here we investigate the scaling of head morphology and joints in the four-bar linkage across Hippocampus. We collected micro-computed tomography scans of 14 non-pygmies, the 1 dwarf, and 3 pygmies, and used 3D geometric morphometrics to analyze shape variation. Most variation in seahorse head shape morphology is explained by differences in snout length and the distance between two joints in the four-bar linkage that contribute to lower jaw depression. A longer snout is thought to be more beneficial for prey capture, and a longer distance between the joints may allow for greater buccal depression, likely generating greater suction forces. These morphological differences may point to a difference in pygmy feeding mechanics, fluid dynamics, and elastic energy storage capabilities.

## What's in a 'Game'? A video game improves undergraduate learning outcomes in evolution education

*Jacob Botello, Matthew Wolak*

Evolution can be a difficult subject to learn and teach owing to its broad scope and widespread cultural misconceptions. One possible solution to this problem may involve gamification, an approach that has been shown to be especially effective when integrating video games into the classroom. We developed a browser-based, 2D platformer game that allows students to interact with the process of evolution by placing the player in control of an entire population of individuals subject to selection within each game level. Player-controlled individuals who survive a level (i.e. those selected for) are randomly paired for mating to produce offspring (playable in the next level) with phenotypes generated based on the genetic makeup of their parents. We manage generation-to-generation changes in phenotypes by tracking the alleles of all parents and offspring in a multi-locus model and generate environmental deviations based on player-selected heritability. To test the efficacy of the game as a teaching tool we recruited >900 students from classes in the biology department at Auburn University and surveyed their knowledge of and attitudes about evolution before and after 30 minutes of gameplay compared to an equal period of time in the control group who did not play for the duration. We present quantitative and qualitative analyses and strongly advocate for the development and adoption of games as a major resource in undergraduate evolution education.

## Machine vision for assessment of enrichment items in Lesser Egyptian Jerboa (*Jaculus jaculus*)

*Matthew Boulanger, Juri Miyamae, Gerry Hish, Talia Moore*

Jerboas (family Dipodidae) present a compelling model to study biomechanics, as they are bipedal hopping rodents whose ricochetal escape responses involve unpredictable three-dimensional trajectories. However, these rapid maneuvers may make it difficult for observers to score behavior, as small lapses in attention may miss multiple behaviors. We hypothesize that machine vision will reach human-grade observations, with resistance to observer fatigue and drift. After a standardized orientation, we asked 9 observers to score videos of captive jerboa- achieving a mean accuracy of 71% and precision of 90% (12 minutes, 9 behaviors). We then trained a machine vision classifier with approximately 8 hours of annotated data to achieve an overall accuracy of 78% and precision of 92%, meeting our benchmarks and allowing for assessment of a larger dataset. This included a cross-over study wherein jerboa (n=8) were offered enrichment items for 2 weeks at a time. With these ethograms, multiple factors were examined- and fur thinning was noted to correlate with the behavior of grooming. Furthermore, it then appeared that socially based enrichment items decreased the incidence of behavioral grooming, suggesting the potential predisposition of grooming for maladaptive behaviorism in captive jerboa. By enhancing the speed and accuracy of ethogram-based observations, this machine vision classifier has the potential to enhance our ability to study behavior, optimize husbandry, and establish standard animal care protocols for novel model systems.

## Jumping performance in tree shrews and dwarf lemurs: Implications for primate evolution

*Gregoire Boulinguez-Ambroise, Madison Bradley-Cronkwright, Noah Dunham, Gabriel Yapuncich, Daniel Schmitt, Angel Zeininger, Doug Boyer, Jesse Young*

Paleontological evidence suggests powerful jumping abilities are characteristic of early crown primates. Over the past decades, some researchers have suggested that tree shrews (Scandentia) may be an appropriate ecological model for understanding the origins of primate locomotion. Here, we used force platform analyses to explore biomechanical determinants of jumping performance in arboreal Northern tree shrews (Tupaia belangeri, n=3) and compared their performance with data collected in fat-tailed dwarf lemurs (Cheirogaleus medius, n=3), arboreal primates of similar body size and jumping propensity. Individuals performed vertical jumps from an instrumented pole to perches of increasing height within a custom-built tower.

We found that tree shrews and primates displayed divergent mechanical strategies for increasing the velocity of the center of mass (CoM) at take-off (the primary determinant of the vertical jump height). T. belangeri prioritized force production by pushing forcefully against launching substrates, whereas C. medius prioritized CoM displacement during push-off by fully extending hindlimb joints. Moreover, C. medius used a strategy of arm elevation before landing, allowing them to reach a same target without generating as much mechanical power as tree shrews – indicating a possible advantage of longer forelimbs for jumping in primates. Our results highlight the questions of when, how and why different solutions for similar jumping abilities arose between tree shrews and primates. Such investigation should further inform on the ecological context of primate origins.

## Does exogenous iodide ameliorate behavior after perchlorate exposure in zebrafish (*Danio rerio*)?

*Emma Bourgeois, Michael Minicozzi*

Perchlorate ($ClO_4^-$) is a ubiquitous endocrine disrupting compound that competitively inhibits iodide at the sodium-iodide symporter by blocking iodide uptake into the thyroid follicle. Limited thyroid hormone production early in development can result in altered morphologies and behavior. Two predominant models in perchlorate research have been in zebrafish (Danio rerio) and in threespine stickleback (Gasterosteus aculeatus). Previous perchlorate trials in zebrafish and stickleback showed decreased swimming performance and behavior at all life stages and specifically in stickleback, a decrease in breeding performance. We hypothesized that the addition of exogenous iodide could ameliorate symptoms associated with altered behavior due to perchlorate exposure. To test this hypothesis, we chronically exposed zebrafish from fertilization with perchlorate at environmentally relevant concentrations (10ppm, 100ppm) or control water, with or without sodium iodide (70ppb). Fish were filmed with the yolk sac present (5dpf) and with yolk sac absent and actively foraging (10dpf) for analysis with Noldus EthoVision to determine activity and behavior during early development. We expect to see a decrease in activity in perchlorate treated fish compared to the control. We also expect to see the perchlorate-iodide treated fish to behave similar to the controls. The data from this research will provide further understanding to the mechanism of action on behavior that perchlorate has on fishes and if these effects are thyroidally mediated.

## Transcriptomic resilience of a winter-acclimated marine gastropod under elevated temperature stress

*Colleen Bove, Jan Pechenik, Sarah Davies*

Intertidal organisms experience dramatic temperature fluctuations when exposed to air temperatures during low tides. While the responses of intertidal organisms under extreme heat exposure during low tides in summer months have been relatively well-studied, few studies have investigated how winter-acclimated intertidal organisms respond to warm weather extremes, which are becoming more frequent under climate change. The marine gastropod Crepidula fornicata is common intertidally in New England and has been shown to be highly resilient to a variety of summer stressors, including those associated with global change. In this study, we exposed winter-acclimated (6°C) adult C. fornicata to short-term elevated temperatures (32, 35, or 37°C), simulating a natural warm weather event, and monitored respiration, mortality, and genome-wide gene expression across multiple timepoints to investigate the mechanisms underlying their thermal resilience. Forty-eight hours after exposure to the 32°C heat-stress, no snails had died; however, substantial mortality was observed 48 hours after the 37°C heat-stress exposure, suggesting that 37°C is above their critical thermal limit. Preliminary analyses identified more extreme shifts in gene expression profiles as temperatures increased. Given that warm-winter extremes are likely to increase in frequency, these data will illuminate mechanisms underlying the resilience of these marine gastropods to winter thermal events.

## How do ants avoid traffic jams?

*Kimberly Bowal*

Avoiding traffic jams in crowded environments is a significant challenge for collective motion across scales, from migrating herds to cellular cargo transport. Experimental work has shown that Argentine ants have the ability to avoid typical traffic jamming patterns at high densities and instead maintain a constant bidirectional flow between their nest and a food source (Poissonnier et al, eLife 8:e48945, 2019). No large-scale spatiotemporal organisation such as lane formation or oscillatory flow is seen, suggesting that there is another dynamic mechanism allowing the ants to navigate in crowds without jamming.

We use detailed experimental analyses of extant data combined with agent based modelling to explore individual ant trajectories and properties that make up the collective colony movement. By quantifying spatiotemporal patterns of density, interaction rates and ant speeds, we probe the role of the type of interactions and their rates on the group as a whole as it engages in crowded traffic. This leads us to propose feedback models by which individual ants respond to their local environment over time that capture the observed efficient movement in bidirectional crowds.

## Influence of heterogeneous cell motility and adhesion in biofilm spatiotemporal patterning

*Kimberly Bowal*

Heterogeneous cell types within surface-attached bacterial colonies, known as biofilms, appear to dynamically self-organise to aid their collective function. Within Bacillus subtilis biofilms two distinct cell types arise: motile cells that swim using flagella and matrix-producing cells that do not swim but form chains that grow and bend. In this work, we describe and investigate the spatiotemporal patterning of these cell types during biofilm expansion, focusing on the roles of cellular self-propulsion (motile cells) and adhesion-mediated chaining growth (matrix-producing cells). The dynamics of both motile and matrix-producing cell types are explored using experimental (confocal fluorescence microscopy) and computational (finite element modelling) tools.

We find that matrix-producing cells make up the majority of the cellular area within the biofilm monolayer edge and a non-uniform spatial distribution of both cell types is maintained as the colony expands. Loops are a dominant motif of the matrix-producing cells and both cell types display key topological features of an active nematic system. Local order, curvature, and mixing analyses provide further insight into the population structure. Finally, key interaction parameters are probed, leading to the hypothesis that cell-cell adhesion plays a more significant role than cell self-propulsion in biofilm edge patterning. This work illustrates how collective dynamics and biofilm properties emerge from the interactions of distinct cell types.

## Is behavioral fever in *P. glutinosus* quantifiably affected by variable amounts a chemical pyrogen?

*Noah Bowen, Joe Bidwell, Trevor Chapman*

While various pressures threaten global amphibian populations, pathogens are among the worst. Unlike endotherms, ectotherms cannot metabolically induce fever and instead seek out warmer microclimates to raise their internal body temperature. This phenomenon, termed “behavioral fever”, has not been explored heavily in salamanders. The goal of this project is to explore behavioral fever and physiological stress in response to a pyrogen or a fever inducing chemical. Here the dsRNA poly(I:C) was used. Specifically, we focused on the Slimy salamander (Plethodon glutinosus). Salamanders were randomly assigned one of four treatments (varying levels of poly(I:C)): control, 7.5 µg/g, 15 µg/g, and 21.5 µg/g. After injection and acclimation, thermal preference was tested using a custom behavior arena. Dermal swabs were collected for corticosterone analysis at three different time points: once upon capture, once before being placed in the behavioral arena, and once after a 36-hour period had passed.

## Regrowing the growth zone: metamorphosis kickstarts regeneration in the annelid Capitella teleta

*Alicia Boyd, Elaine Seaver*

The ability to regenerate can vary across an animal’s life history. We have previously shown that Capitella teleta, an annelid worm, gradually gains regenerative ability with age. C. teleta larvae display limited features of regeneration but do not completely replace lost structures (e.g. posterior growth zone, or pgz) prior to metamorphosis, whereas juveniles and adults are capable of robust posterior regeneration. To determine whether metamorphosis enables juvenile worms to regrow structures that were lost during larval stages, C. teleta larvae were amputated, removing the hindgut, pgz, anus, and pygidium. These amputated larvae were then induced to undergo metamorphosis and reared as juveniles for 72 hours, 1 week or 2 weeks. New growth in juveniles was characterized by the presence of the pgz, a ciliated hindgut/anus, and addition of segments. We assessed these characters by confocal microscopy, EdU staining, immunohistochemistry, and nuclear staining. A new pgz was observed within 72 hours of metamorphosis and new segments by 1 week. The presence of fecal pellets provided evidence of a functional gut and anus. Also, the digestive track underwent morphallaxis in the tissue anterior to the amputation site. Our results demonstrate that amputated C. teleta larvae can metamorphose into juveniles that can feed and grow new segments, suggesting that metamorphosis acts as a switch to enable the animal to reliably replace missing structures essential for growth.

## Cyclical gene expression under different light conditions in the fiddler crab, Leptuca pugilator

*Caitlin BrabbleRose, Quinton Krueger, Adam Reitzel, Paola López-Duarte*

Larval behaviors of many estuarine species are timed with lunar, tidal, and solar cycles to achieve export out of and transport into estuaries. While the behavioral components of circadian and circatidal clocks have been extensively studied, little work has been done to understand the genetic mechanisms underlying these clocks in early life history stages. We have previously examined gene expression in Atlantic fiddler crab (Leptuca pugilator) larvae maintained under a 14L:10D cycle to identify genes being rhythmically expressed with a 24- or 12-hr cycle. Larval tissues were collected every 2-hr for 48-hr, and comparative transcriptomics (TagSeq) was used to identify changes in gene expression over time. Cyclically expressed gene data was identified using the program DiscoRhythm to determine rhythmicity of expression. More genes were identified as having a 24-hr cyclical pattern of expression than a 12-hr cycle. We repeated this sampling protocol in larvae maintained under D:D conditions and expect to find fewer genes expressing under these conditions due to the lack of exogenous cues (light) that triggers gene expression. Sequences that are expressed under both conditions are potential candidates for core genes that underlie the circadian and/or circatidal clocks in this species, and this work will be used to understand how these clocks are expressed and function during the crucial larval dispersal phase of intertidal crustaceans.

## The development of electrical organs and their discharges throughout ontogeny in *L. erinacea*

*Emily Brady, Sonke Johnsen*

Electrocommunication is the ability certain species have to signal to conspecifics with electrical discharges, and involves being able to both sense and produce electrical signals with an electric organ (EO). It has primarily been studied in two groups of freshwater fish, the Gymnotiformes and the Mormyridae. In contrast, there has been far less research on electrocommunication in marine environments. One family of marine animals theorized to use electrocommunication are the skates (Rajidae), but the evidence for this has been inconclusive. It has been shown that skates of different species, specifically Leucoraja erinacea, the little skate, and Leucoraja ocellata, the winter skate, generate electric organ discharges (EODs) of different durations and patterns, the EODs can be evoked by tactile or electrical stimulation, the skate's electroreceptors are tuned to detect electrical stimuli similar to their EODs, and the EOs are sexually dimorphic in L. erinacea. Prior to this study, an exploration of how EODs specifically develop throughout ontogeny has never been conducted. Using L. erinacea, this study looks at EODs from hatchling and/or juvenile skates (immature) and how they compare to already documented EODs of sexually mature individuals.

## Under (hydraulic) pressure: an integrative analysis of jumping in salticid spiders

*Erin Brandt, Jasmine Nirody*

Spiders are unusual animals. Instead of using opposing sets of muscles to flex and extend the legs, spiders use hydraulic pressure to extend legs while walking, jumping and performing sexual displays. Hydraulic locomotion is thought to be slow and inefficient, yet jumping spiders (family Salticidae) are known for powerful, accurate jumps. Little is known about how the locomotion system works in jumping spiders, particularly how the muscles and hydraulic compartments in the body work together to produce their jumps. Here we combine studies of (1) jumping kinematics, (2) ground reaction forces generated by the legs during jump takeoff, and (3) measurements of anatomical structures within spiders to shed light on how an unusual system of locomotion leads to dextrous motion in the jumping spider Phidippus audax.

## Coupling hemolymph flow with the flight muscle contraction in hawkmoths

*Artis Brasovs, Alexandre Palaoro, Kostya Kornev*

For flying insects, hemolymph viscosity is a major physiological parameter controlling the flow rate of fuel to the flight muscles; the thinner the hemolymph, the easier it is to pump it through the body and the faster the fuel supply. The more viscous the hemolymph, the greater the metabolic energy needed to pump it through confined spaces of the muscles in the thorax. As these muscles contract and relax, the hemolymph is pushed and pulled through the intermuscular pathways to replenish the concentration of nutrients. Flowing hemolymph dissipates the muscular energy and, in turn, deforms muscles. This nontrivial coupling of hemolymph flow and muscular contraction/relaxation leads to a viscoelastic reaction of the thorax. We model hemolymph flow through the thorax during muscle contraction/relaxation and, using the data on viscosity measured in Ref.[1], estimated the total force the muscle bundles would require to maintain contractions at the wing beat frequency. The developed model and physical estimates can be used to couple the neuromechanical models with the hemolymph circulation phenomena.

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[1] Brasovs A, Palaoro AV, Aprelev P, Beard CE, Adler PH, Kornev KG. 2023 Haemolymph viscosity in hawkmoths and its implications for hovering flight. Proc. R. Soc. B 290: 20222185

## Differences in diets between male and female *Syngnathus scovelli*

*Lily Braun, Samantha Levell*

Seagrass beds are critical habitats that support diverse marine life, and food availability within these ecosystems plays a crucial role in the survival and reproductive success of fish species. In Sarasota Bay, three species of pipefish and two species of seahorses primarily inhabit these seagrass beds. The gulf pipefish, Syngnathus scovelli, is one of the most common pipefish species. Syngnathus pipefish primarily feed on small crustaceans, including amphipods, copepods, and mysid shrimp. Our monthly census efforts have revealed a female-biased sex ratio in the natural population. This study investigates potential sex differences in feeding habits between male and female S. scovelli, motivated by observations of females consuming more food than males in captivity. We collected Syngnathus pipefish, along with zooplankton and abiotic data monthly to explore how seasonal variations and prey availability within seagrass beds influence their diet. Although data collection is ongoing, this study aims to determine if females consistently consume more, or different, prey than males and to understand the broader implications for food availability and seasonal dietary shifts in S. scovelli.

## The neuromuscular substrate of elephant grasping

*Michael Brecht, Lennart Eigen, Lena Kaufmann, Thomas Hildebrandt*

The elephant trunk is one of the most complex grasping organs on the planet. Devoid of bones and cartilage it operates as muscular hydrostat. The extraordinary muscular complexity of the elephant trunk has been apparent since the first anatomists studied the organ. To understand neuromuscular control of trunk movements applied a multifaceted approach including (i) microCT imaging of trunk musculature, (ii) machine vision and image segmentation to deduce muscle structure, (iii) neuroanatomical analysis of trunk motoneurons, (iv) behavioral analysis. We confirm the immense muscular complexity of the elephant trunk, which is driven by a very large number of radial muscle fascicles (presumably involved in trunk extension). In the primate hand, which is actuated by a small number ($< 30$) of large muscles, one observes a massive convergence of motoneurons on individual muscles. In elephants, however, $\sim$90,000 structurally independent muscles outnumber motoneurons indicating motoneuron divergence. Behavioral experiments indicate a very fast and cognitively sophisticated control of trunk movements. We conclude that both primates and elephants perform sophisticated grasping, but do so by vastly different neuromuscular substrates.

## Differential gonadal gene expressions associated with breeding states in zebra finch

*Olivia Breisacher, Jason Strickland, Jessica Moodie, Jonathan Perez*

Aseasonal or opportunistic breeders utilize short-term environmental cues to regulate and time reproductive efforts. Unlike seasonal breeding taxa the mechanisms used by opportunistic breeders, such as Zebra Finches (Taeniopygia guttata), to initiate or terminate reproduction are poorly understood. Regulation of reproductive function can occur at multiple levels including the brain, pituitary, and gonads. In this project, we utilized a water restriction paradigm to induce a non-breeding state in Zebra Finches, this induced partial gonadal regression in females, but not males. Thus we compared the gonadal transcriptomes of breeding and non-breeding males and females to identify changes associated with reproductive state. We identified significant changes in expression of 17 genes in females, but only one gene in males, Steroidogenic Acute Regulatory protein (StAR). StAR plays a crucial role in regulating gonadal sex hormone synthesis. Thus altering expression of androgens responsible for modulating reproductive behavior. The fewer differences observed in males compared to females possibly reflect an evolutionary adaptation to optimize reproductive success. While females must invest more to maintain a developed follicular hierarchy, maintenance of moderately sized gonads and sperm production may pose minimal cost to males. Maintaining functional gonads across breeding conditions, while modulating androgen production would help males maximize their chances of successful reproduction when conditions become favorable.

## Burial behavior and kinematics of the Little Skate (Leucoraja erinacea)

*Noah Bressman, Angela Cordoba-Flores*

Many benthic fishes bury in the sediment to avoid detection by predators and prey. While burial behaviors have been described in many fishes, the behaviors the different groups of fish use are distinct, ranging from sand-diving to excavation to fluidization. However, despite the array of available literature on bony fish burying behaviors and the common knowledge that many benthic batoids (rays and skates) bury in sediment, the kinematics of burial behaviors have yet to be described for any chondrichthyan (cartilaginous) fish. Therefore, the goals of our study were to describe the burial behaviors and kinematics of the Little Skate (Leucoraja erinacea) and compare them to the burial behaviors of bony fishes, such as flatfishes. We recorded lateral and near-lateral views of skates burying in sand in aquaria ($N = 18$) using an Edgertronic High-speed camera at 500 fps, along with dorsal views recorded using a GoPro Hero 10 Black camera at 240 fps. Kinematics were analyzed using the ImageJ software. Overall, skates bury using a combination of undulatory motions of pectoral fins that increase in amplitude toward the posterior, along with bobbing of the head up and down and lateral movements of the tail. These movements fluidize the sediment to aid in burial, along with excavating motions of the head and tail. While they use different anatomical structures, their burial is similar to flatfish.

## Impacts of capture-handling on reproductive success and behavior in western bluebirds

*Valerie Brewer, Jamie Cornelius, Suzanne Austin*

Predation pressure can strongly influence prey animal behavior. During the breeding season, adults must balance behaviors that promote their survival with behaviors that promote their reproductive success. Even a simulated increase in perceived predation pressure may cause breeding adults to alter their behaviors to optimize this balance and promote fitness. Capture-handling may be perceived as an acute predation experience by captured adults. Here we examine the effect of capture-handling on differences in reproductive success and behavior in western bluebirds (Sialia mexicana). We monitored a network of nestboxes across an urbanization gradient and followed the nests from lay to fledge to determine reproductive success of captured and uncaptured bluebird pairs. This examination of reproductive parameters and behavior will contribute to the understanding on how capture-handling may influence parental investment in birds.

## Polydactyl precursors: Insights for early tetrapod terrestrial locomotion from polydactyl alligators

*Trevor Brewington, Roshna Wunderlich, Masaya Iijima, Victor Munteanu, Savannah Swisher, Amanda Kellerhals, Richard Blob*

Several of the earliest taxa of tetrapod vertebrates exhibited polydactyl hands and feet, with seven or eight digits rather than the typical five or fewer seen in extant lineages. How such digit arrangements might have been used during terrestrial locomotion is unclear, given the dearth of living models in which their performance can be studied today and limited evidence from fossil trackways. However, polydactyly occasionally appears in American alligators (Alligator mississippiensis), animals with body plans that broadly resemble those of early tetrapods. To test how polydactyly like that seen in early tetrapods might have functioned on land, we used high-speed video and an EMED-ST pressure mat to measure the limb movements and foot pressures of three polydactyl alligators (~1.5 m in length) during walking. Contrary to expectations, our data typically did not indicate significant pressure records from the supernumerary digits on the hands or feet of alligators. The limited role of extra digits in terrestrial body support or propulsion provides context for the evolutionary loss of these structures as tetrapods became more terrestrial, and may help to explain the lack of examples of polydactyly in fossil trackways.

## What's my age again? A comparison of bottlenose dolphin aging techniques

*Sophi Brice, Wayne McFee, Jamie Torres*

Knowledge of population demographic data, such as age, can be highly beneficial for understanding potential underlying causes and patterns of marine mammal strandings. However, accurately estimating ages of marine mammal species has proven to be consistently challenging due to minimal external signs of aging and asymptotic total length reached in adulthood. Several methods currently exist for calculating age estimates of dolphins. Sectioning and counting growth layer groups (GLGs) in mandibular teeth has been used traditionally for dolphin aging, but analyzing chronological bone ossification developments through pectoral flipper radiography (PFR) has emerged as a potentially more accurate method for older aged animals that is less invasive and applicable for live animals. This study aimed to assess the comparability of age estimates from both methods, while also discussing the benefits and limitations of each. Age estimates of 14 Tamanend's bottlenose dolphins (Tursiops erebennus) stranded on the South Carolina coast were obtained using both GLG and PFR techniques to compare these methodologies. Results showed that the age estimates from GLGs were more consistent with morphological data than PFR estimates, which highlighted areas of improvement for using PFR on frozen samples. These results suggest that GLGs may remain the preferred method for obtaining bottlenose dolphin age estimates of deceased animals, and that PFR may be preferred for use during health assessments of live animals.

## Multiscale functional adaptation in rodent jaw muscle; from the musculoskeletal to molecular level

*Robert Brocklehurst, Amber Abu-Zahra, Nicholas LaFave, Jeffrey Moore, Nicolai Konow*

Masticatory myosin (MM) is an ancient isoform expressed in the jaw closing muscles of some vertebrates, associated with increased muscle force and power output. However, muscle is a hierarchically organized structure, and it is unclear how adaptations for force production at one scale correlate with those at another. We use rodents as a model system to test these relationships, comparing species which do (grey squirrel) and do not express MM (rats, guinea pigs), and which represent each of the major rodent cranial muscle morphotypes (sciuromorphs, myomorphs and caviomorphs). We combine fascicle-scale force-velocity data from in situ sonomicrometry and ergometry experiments with dynamic muscle moment arms measured through ex vivo XROMM (X-ray reconstruction of moving morphology). Our in situ data shows the highest specific muscle tension in grey squirrels, and different fascicle architectural gearing for force vs velocity amplification between species. Our moment arm results showed grey squirrels possessed the highest muscle leverage for jaw closure, across all gape angles. This is despite myomorph (rat) jaws being more kinetic, with propalinal joint translation correlating positively with muscle moment arms. We show generally consistent adaptation to high force production at the musculoskeletal, whole-muscle and molecular levels in grey squirrels, suggesting that selection for ecologically relevant traits – including MM expression - occurred at multiple levels of organization within the rodent craniofacial system.

## Not so dainty damsels: leg spur patterns provide insight into damselfly predation patterns

*Christofer Brothers, Victoria Lopez Campos, Rex Nepstad, Stacey Combes*

The order Odonata (dragonflies and damselflies) contains highly successful predators of other insects. Capture success and prey preferences have previously been examined in dragonflies - however, the hunting patterns of their smaller relatives, the damselflies, are less well explored. Unlike dragonflies that exclusively hunt flying prey, damselflies display two different predation strategies: "salliers" specialize in capturing flying prey, while "gleaners" pluck prey from solid surfaces. Regardless of foraging strategy, damselflies capture prey with their spiny legs, coming together to form a "capture basket" that grasps or traps their prey. Each leg possesses 2 parallel rows of chitinous projections (spurs), which differ among species in number, shape, and spacing, particularly on the tibiae. However, the range of variation in morphology and the functional implications of these differences for prey capture remain unexplored. We determined foraging modes for 20 species of damselflies from existing literature and field observations. Using light microscopy and Scanning Electron Microscopy (SEM), we examined whether foraging mode (sallier vs. gleaner) is related to tibial leg spur density of damselfly species across 8 families. Broadly, we find that gleaners, which pluck prey from surfaces, have a greater density of tibial leg spurs compared to salliers, which trap flying prey in mid-air. This provides insight into the functional implications of leg spurs in damselflies, and suggests that tibial spur arrangement is linked to predation mode.

## Yellows & purples of Yellow Island: characterizing the Hemigrapsus spp. on Yellow Island

*Benjamin Brown, Christine Mantegna, Camille Gaynus, Tiara Moore*

In the Pacific Northwest region of the United States there are two Hemigrapsus species, the Purple Shore Crab (Hemigrapsus nudus) and the Yellow Shore Crab (Hemigrapsus oregonensis). Shore crabs are intertidal trophic linchpins, consuming intertidal algae and detritus, and serving as a food source for shore birds, sculpin and anemones. These closely related species are differentiated by a few striking differences; most identifiable are the spotted claws in the purple shore crab and hairy legs on the yellow shore crab. General field observations contradicted the literature as many crabs were observed lacking and/or having one or both of the major identifying features along with contradictory and/or undocumented color variation. Morphological methods of identification require updating and inclusion of and habitat preference to increase reliability. Working on Yellow Island, an island in the San Juan Islands of Washington state, crabs were sampled across various substrate types and tidal zones. Size, gender, carapace color and identifiable characteristics were recorded and analyzed. Statistical analysis revealed significant positive correlation between tidal zone and several characteristics despite only 15% of the crabs confirmed as either H. nudus or H. oregonensis. These species, while sometimes overlapping in habitat, do have habitat preferences. A change in the distribution or range of these crabs may be an indicator of changing habitat suitability thus possibly indicating changing distribution for other intertidal species.

## Jumping mechanics of desert kangaroo rats (Dipodomys deserti): The role of the tarsometatarsal joint

*Christian Brown, Jordan Cannon, Marie Schwaner, Craig McGowan, David Lin*

Desert kangaroo rats (Dipodomys deserti) can jump vertically to over 10-times their standing hip height. Previously, inverse dynamics analyses revealed that net joint work is not evenly distributed across the hindlimb during vertical jumping and is higher at the ankle and tarsometatarsal (TMT) joints where there is relatively little muscle but a dense assembly of connective tissue. To study this phenomenon, we revised a model of D. deserti in OpenSim using high resolution CT scans of the foot, which improved definition of the skeletal geometry and muscle paths. Furthermore, the model has been updated to feature the plantaris and flexor digitorum tendons wrapping around the bony prominences of the TMT joint across different leg postures and joint angles. To validate the model, we estimated the moment arms and muscle length changes across a gradient of joint angles and found realistic ranges for both across the physiological range of motion at the metatarsophalangeal (MTP) and TMT joints. Relative to excluding it, adding the TMT joint renders our biomechanical model of D. deserti more realistic, decreases the estimated moments at the MTP and ankle joints, and reduces the net joint work contribution of both by $\sim$10%. With this more realistic model, we will use musculoskeletal modelling in

OpenSim Moco to determine how the inclusion of the midfoot joint affects predictions of muscle activations patterns during vertical jumps.

## Vascular and osteological morphology of digit tips in wandering salamanders (*Aneides vagrans*)

*Christian Brown, William Goldenberg, Olivia Hinds, Mary O'Donnell, Nancy Staub*

For over a century, researchers have hypothesized about large blood sinuses within the square-shaped toe tips of climbing salamanders (Genus Aneides). Wandering salamanders (Aneides vagrans) exhibit exquisite locomotor control within the redwood canopy. Here, we describe the cellular, vascular, and osteological structure of and blood circulation through the toes of A. vagrans using histological approaches in tandem with live-animal videos. Specifically, we sectioned the toes of preserved A. vagrans at $1\mu$m, embedded in Spurrs resin, and stained with toluidine blue; for confirmation, we sectioned three toes at $10\mu$m, embedded in paraffin wax, and applied Verhoeff and Quad stains. In live salamanders, we recorded real-time videos of blood flowing within individual toes upon a translucent surface oriented first horizontally then vertically, then analyzed the image sequences using ImageJ. We found that the vascularized toe tips have one large sinus cavity that separates more proximally into two chambers via a connective tissue divider, and we report large mucous glands in the dorsal-dorsolateral toe dermis. Live-animal trials revealed variable and heterogeneous sinus-filling both within and between toes, seemingly associated with variable pressure applied to the substrate when standing, stepping, clinging, and climbing. We conclude that A. vagrans, and likely other climbing salamanders, could functionally fill, drain, and trap the blood in their vascularized toe tips to optimize attachment, detachment, and complex arboreal locomotion (e.g., landing after gliding flight).

## The Sunda node: hints of non-torpid heterothermy in Bornean squirrels

*Eric Brown, Claudia Saldaña DeCamillis, Mohd-Azlan Jayasilan, Danielle Levesque*

Sciurids (ground, tree, and flying squirrels) have long been a model clade for studying mammalian heterothermy due to their near-global distribution and ecological and thermophysiological diversity. Squirrels exhibit the full range of endothermic phenotypes from strict homeothermy to hibernation. What remains is to resolve the geographic and phylogenetic gaps in our understanding of sciurid thermophysiology. Our notions of heterothermy have long been shaped by phenotypes that are more readily characterized, i.e. hibernation and torpor, as opposed to non-torpid heterothermy which is not as self-evident. We are finding that heterothermic phenotypes are more the norm than homeothermy, even among low-latitude species which have thus far tended to be nocturnal (e.g. bats and primates) or belonged to geographically cloistered lineages (e.g. monotremes and marsupials). Here we investigate how biogeography relates to mammalian thermoregulatory phenotypes and present preliminary findings on the phenotypes of three diurnal species of Indomalayan squirrels (subfamily Callosciurinae) which range in body size and degree of arboreality – Callosciurus notatus, Lariscus insignis, and Sundasciurus lowii. Collected from western Sarawak, Malaysia, preliminary data indicate that these species exhibit flexibility in normothermic body temperatures, resting metabolism, and water loss at various ambient temperatures. These initial data support the notion that flexible normothermy is a plesiomorphic trait in small tropical mammals.

## Studying animal behavior underwater with remotely deployed video

*Korrie Brown, Catheline Froehlich, Miranda Gibson, Rachel Gunn, Ryan Earley, Alex O'Brien, Benjamin Titus*

The study of animal behavior has been a fundamental pursuit in the biological sciences for well over 100 years and has been key in shaping evolutionary and ecological theory. Video has transformed the study of animal behavior and has become a prevalent method for observing natural behaviors. However, studying animal behavior with video underwater remains challenging because standard video cameras have limited battery life, which may not adequately capture an organism's behavior, and requires multiple SCUBA dives to replace a single battery. Thus, underwater behavioral research must contend with sample size, replication, observation time, and logistical tradeoffs in their experimental design. How do we balance these tradeoffs while still capturing the "true" behavior of interest? We sought to tackle these challenges using well-studied cleaning symbioses on Caribbean coral reefs as a model system. We deployed GoPro cameras in custom underwater housings to extend battery life to record cleaning behavior of Ancylomenes pedersoni. Cameras were deployed at individual cleaning stations and left to record A. pedersoni and its behavior for upwards of six hours. Cameras were re-deployed at the same station once per week for 6 weeks for replication. In total, we recorded $> 500$ hours of video across $N = 30$ A. pedersoni cleaning stations. Our dataset offers valuable methodological insight for studying animal behavior underwater and for researchers using videography as a tool broadly.

## Parental neophobia and innate immune function in House Sparrows (*Passer domesticus*)

*Sarah Brown, Hailey Freeman, Emily Regier, Elizabeth Cochrane, Samuel Lane, Britt Heidinger, Lindsey Willingham, Alexander Hoxie, Heather Mathewson, Jennifer Grindstaff*

To defend against disease, organisms may proactively use avoidance behaviors to prevent infection or if they become infected, individuals can activate an immune response to control an infection. Neophobia, or the fear of novelty, is one mechanism through which organisms may minimize exposure to pathogens, but neophobia may also reduce the ability to find and utilize novel food sources. This may be especially important during the breeding season as the demands for finding food increase. The relative importance of behavioral and immunological defenses against infection is likely to vary across latitudes as both the risk of pathogen exposure and the host pace-of-life vary. Within the United States, at northern latitudes, pathogen exposure is likely to be lower and host life span is likely to be shorter than at southern latitudes. As a result, we would expect individuals in the north to be less neophobic and to invest less in innate immunity than individuals in the south. We tested these ideas in wild populations of House Sparrows (Passer domesticus) by conducting novel object trials on adults at nest boxes during the breeding season. Latency to enter the nest box in the presence of a novel object was used to determine neophobic behavior. We then collected blood samples from birds to quantify bacterial killing capacity as a measure of innate immunity.

## Multi-individual tracking to investigate behavioral sexual conflict in Opiliones (Arachnida)

*Tyler Brown, Emily Marinko, Sophia Nawaz, Megan Ramirez Cuenca, Mercedes Burns*

Sexual conflict is a primary driving force in the evolution and manifestation of mating behavior. Reproductive behavioral studies are effective for investigating these interactions, however, manually scoring multi-individual interactions can be difficult, time-consuming, and error-prone. To combat this, we combined manual and automated scoring approaches to analyze behavioral sexual conflict in leiobunine harvesters (Arachnida: Opiliones). Temperate Leiobunum species vary greatly in reproductive phenology and have repeatedly lost nuptial gifts, resulting in two primary mating syndromes. In sacculate species, males produce high-investment nuptial gifts and females lack pregenital barriers, while in nonsacculate species females possess pregenital barriers and males produce low-investment nuptial gifts. These factors combine to provide the ideal system in which to explore behavioral sexual conflict. We first investigated whether increased behavioral antagonism compensates for reduced-investment nuptial gifts. We found significantly higher sexual conflict in nonsacculate species, indicating that a reduction in nuptial gift quality may contribute to increased behavioral sexual conflict. We additionally tested whether female receptivity varied with reproductive experience using Leiobunum vittatum, which is among the most widespread temperate opilionids. Contrary to theoretical expectations, we found no effect of female mating experience on receptivity and sexual conflict. We also established that our automated scoring metrics did not vary significantly from their manual counterparts despite opilionid morphology presenting numerous challenges, indicating our behavioral scoring approach may be broadly applicable to arthropod systems.

## Manipulation of a polyphenism-switch network reveals the molecular canalization of a threshold trait

*Justin Bryant, Erik Ragsdale*

Biologists recognize both genetic and environmental components as instructive agents in the development of an organism. However, how molecular genetic mechanisms channel environmental signals to predictable, developmental decisions remains an enduring question. Such decisions are exemplified by developmental polyphenism, whereby environmental cues are translated through a threshold to canalized, alternative forms. Here, we test how a developmental switch transcriptionally ensures the robustness of alternative phenotypes. The nematode Pristionchus pacificus, a model for developmental polyphenism, has been used to identify genes in which mutants fix either wild-type or intermediate phenotypes. Using single- and double-mutants for these genes, we performed transcriptomic contrasts throughout environmentally sensitive stages of ontogeny. From these contrasts, we identified overlaps among the genes and co-expression modules targeted by different components of a polyphenism-switch network. Further, our temporal schedule of target-gene expression revealed when and how, during an environmentally sensitive window, this decision is made and then executed. In summary, we offer a molecular explanation for how a developmental switch results in the canalized gene-expression needed to produce alternative, stereotypical phenotypes.

## Linking phenotypes, physiology, and fitness to track how climate change drives butterfly evolution

*Lauren Buckley*

Characterizing how exposed and sensitive organisms are to climate change is needed to understand their responses. I will synthesize research using mechanistic niche models to examine how the interaction of phenotypes and environmental conditions mediates physiological, performance, and fitness responses. Two functional resurvey projects for Pierid butterflies are repeating historical laboratory and field experiments to test the models and assess the interplay of plastic and evolutionary responses to several decades of climate change. The temperature dependence of larval development and growth constitutes an important mechanistic link between phenotypes and the environment. Adult wing melanization, which influences the absorption of solar radiation to alter body temperature and flight activity, responds plastically to development environments. We have detected evolutionary shifts in both larval and adults traits, particularly in response to thermal extremes and extended thermal opportunity. Plasticity plays an important role in reducing variation in selection in response to climate variability to facilitate evolution. Repeating historic experiments to test the predictions of phenotype-based models is a promising strategy for uncovering the mechanisms underlying climate change responses.

## Cross-scale drivers of nematode co-infection in bank voles

*Sarah Budischak, Hannah Chan, Elizabeth Pellegrini, Alyssa Dunn, Finley Melnikoff, Jasmine Veitch, Katy Wearing, Kristian Forbes*

Infectious diseases play a critical role in populations, communities, and ecosystems, and are an increasingly important conservation and public health concern. Since human impacts on the environment are ever-increasing, it is important to understand how environmental conditions affect wildlife disease dynamics. To understand what environmental and within-host factors shape parasite infections, we conducted a population-scale field experiment to determine the effects of food availability (supplemental feeding) on infection prevalence and co-infection interactions. During the study, individuals were collected from twelve bank vole, Myodes glareolus, populations in southern Finland. We tested how host traits and environmental characteristics affect infection, body condition, and nematodes (specifically their fecundity and length), as well as co-infection interactions. We found that voles from food-supplemented sites are more likely to be coinfected and infected by more parasites. Female voles are more likely to be coinfected and infected by longer nematodes but are in better condition than males. Host body condition was also a significant factor in infection, where longer nematodes and coinfection probability were higher in poor-condition voles. This study provides insight into how anthropogenic changes that affect food availability (e.g. agriculture, food waste, habitat fragmentation, invasive species) might affect disease dynamics in wild populations.

## Conservation genomics of the eastern indigo snake

*Matthew Buehler, Jamie Oaks, Brian Counterman*

The North American Coastal Plain is a recognized biodiversity hotspot that stretches throughout the southeastern United States. The region is notable for its high level of diversity and endemicity, however, the habitat and its constituent flora and fauna have been in decline due to agricultural and urban development. A particularly enigmatic endemic species that has declined throughout its range is the eastern indigo snake, Drymarchon couperi. This species was listed as threatened under the Endangered Species Act in 1978, however, before it was federally protected it was extirpated from Alabama and Mississippi. We developed a reduced representation genomic dataset that has been used to detect population structure and estimate genetic diversity for wild populations found throughout the remaining range of D. couperi. Initial results reconcile previous evolutionary hypotheses based on mitochondrial and microsatellite data and provide insight into the connectivity of populations across the landscape. The results of this project are being utilized in a larger ongoing D. couperi conservation genomics project to inform management decisions for wild populations and a breeding colony of D. couperi being used to re-establish extirpated populations.

## Energy Allocation Among Early Life Social Environments In the Mangrove Rivulus Fish

*Merryn Bumpass, Jennifer Fortunato*

The social environment in which an organism lives can affect its morphology. In our research, we aimed to examine the impact of the early life social environment on the morphological development of the mangrove rivulus (Kryptolebias marmoratus). Past research has shown that the social environment is a large contributor to the development of various aspects of morphology, such as organ size. We hypothesized that the early life social environment of the fish will contribute to plastic changes in organ size and there will be variation in plasticity among genotypes. We predicted that isolated early-life environments would result in larger liver sizes and smaller gonad sizes, while more social environments would result in larger gonad sizes and smaller liver sizes. We dissected and weighed the liver and gonads of K. marmoratus from 19 genotypes ($N = 374$). We utilized generalized linear mixed models to test our hypotheses. Our research can further clarify the impact of early life social environments on the development of individuals and whether there is potential for evolution by natural selection.

## Climate vulnerability is driven by physiological diversity in woodland salamanders

*Isabella Burger, Nathalie Alomar, David Adams, Martha Muñoz, Eric Riddell*

Phylogenetic niche conservatism (PNC) is a likely mechanism for species divergence. When individuals of a species track similar environments, environmental barriers can result in reproductive isolation and the subsequent evolution of new species. Lineages associated with PNC are often assumed to share similar traits, yet these assumptions are rarely tested. As environments continue to change, lineage-wide trait diversity could result in differences in climate vulnerability between species. We investigated how climate vulnerability is structured across a lineage that exhibits PNC by incorporating physiological measurements for 30 species of woodland salamander (Genus Plethodon) in a hybrid species distribution model. The model forecasted annual changes in energetic costs, activity, and water loss based on the microclimatic conditions and physiological traits of each species. These estimates were combined with bioclimatic variables to predict range shifts based on species physiology and forecasted climate change. We found that climate vulnerability ($\lambda = 0$; $p = 1$) was not correlated with species relatedness and was instead best explained by physiological variation across species. Range shifts were also not correlated with species relatedness ($\lambda = 0$; $p = 1$) and were highly informed by the model outputs, with 93% of species relying on these variables to forecast future ranges. Our study demonstrates the importance of accounting for physiological diversity when estimating species' responses to climate change, even in lineages that exhibit PNC.

## Exploring the relationship between biodiversity and biotic interactions in fossil cephalopods

*Zachary Burman, Kenneth De Baets, John Huntley*

The nature and meaning of the relationship between biotic interactions and biodiversity at a variety of temporal and spatial scales has long been debated. Here, focusing on cephalopods, we quantify the relationships between antagonistic interactions and estimates of diversity, origination rates, and extinction rates. We have compiled a database of biotic interactions preserved on fossil cephalopods composed of 230 species occurrences and 41,190 specimens ranging in age from Ordovician to Quaternary. Shareholder quorum subsampling estimates of diversity and three-timer origination and extinction rates of cephalopods were calculated from the Paleobiology Database via the FossilWorks website. Predation occurrences were sparse in the Paleozoic with peaks in the Jurassic and Cretaceous. Parasitism occurrences display an older record with peaks in the Devonian and Jurassic. We constructed a generalized linear model relating predation frequency and parasitism prevalence (for samples whose $n \geq 10$) to the diversity proxies and best estimate age. All relationships were significant at $p \geq 0.001$. The strongest relationships were negative associations with origination and extinction rates followed by a slightly positive association with mean sampled diversity. There was a slight positive relationship between biotic interactions and geologic age. We suggest this indicates that the intensity of antagonistic biotic interactions peaks when diversity is elevated but, more importantly, stable. This makes sense given that many of these interactions are obligate and taxon specific.

## Lithology predicts repeated adaptive radiation of cichlid fishes

*Edward Burress, Maya Stokes, Maria Napolitani, Frederico Henning*

Most classic examples of adaptive radiation involve a physically discrete arena such as islands, lakes, or coral reef that provide novel resources or escape from antagonists upon their colonization. Rivers by contrast, are highly hierarchical networks, yet appear to host similar adaptive radiations. Here, we demonstrate that recent (< 1 My) parallel adaptive radiations of riverine pike cichlids (Crenicichla) throughout parts of the La Plata River basin (Uruguay and Iguazu Rivers) were catalyzed by shared basalt (mafic volcanic rock) lithology that enabled an expanded ecological repertoire. The exposure of basalt led to high productivity, facilitating algae growth and snail abundance, and ultimately supporting the evolutionary viability of several derived niches that are scarcely occupied in association with other lithologies. The proportion of basalt across the La Plata River basin was positively correlated with rate of speciation and phenotypic evolution. The repeatability of adaptive radiation among cichlid fishes may be due to widespread colonization of lake and river catchments underlain by basalt, including the African Rift Valley, Cameroonian and Nicaraguan crater lakes, as well as the Uruguay and Iguazu Rivers.

## Quantifying Dental Proteome Variation caused by Dietary Change

*Robert Burroughs, Natasha Vitek*

Organic tissues are formed of proteins and inorganic minerals. Quantitative proteomics (QP) is the field which quantifies the type and amount of proteins within a sample. When tissues are robust and readily preserved (e.g., teeth), QP could assess protein changes without direct observation of life history (i.e., QP could estimate life history traits). However, protein expression must first be characterized in controlled experiments (e.g., the cause of expression changes is unambiguous). I assessed the effect of lower-quality nutrition on protein expression in teeth, with a controlled feeding experiment of C57BL/6J mice. Pregnant and nursing mothers, and their offspring, were either fed a reduced protein diet of 10% (treatment) or a control of 20%. Offspring were collected 28-days post birth. I extracted the upper first molars (M1), which form prenatally. Proteomics analysis was performed at the Stony Brook University Proteomics Core Facility. Treatments had significantly reduced expression of proteins associated with tooth formation compared to controls. The M1 also serves as a reservoir for immune system and metabolic stress proteins. Expression of these proteins were increased in expression in treatments relative to controls. These results suggest that treatment individuals expressed fewer tooth-building proteins and were under higher stress because of dietary quality. In the future, this change in expression profile could be a signature of nutritional state used to understand organismal response in natural settings.

## Birds of a feather: Linking the evolution of emarginated primary feathers to flight function

*Lilia Burtonpatel, Hannah Wiswell, Aimy Wissa*

Emarginated primary feathers are found on certain terrestrial, coastal, and freshwater birds, and vary significantly in their shape and degree of emargination across the avian species. These feathers are hypothesized to have an aerodynamic role during flight, but knowledge of how they are linked to flight function is limited. This study develops a standardized measurement system to track the evolution of previously unexplored primary feather dimensions. Data is collected from groups that span separate clades and have different flight styles, with the birds in each group having comparable degrees of emargination. Preliminary results analyzed for two groups of birds (Cygnus and Pelecanus) show a correlation between longer, thinner, and more emarginated feathers and soaring flight and shorter, stockier, and less emarginated feathers and flapping flight. This supports previous hypotheses that more significant emarginations facilitate more efficient flight. By analyzing the strength of the correlation between feather dimensions and flight style through statistical models and expanding this data to a working database, we can better understand how different emargination morphologies evolved and how these feathers are linked to flight style. Additionally, we can enable the selection of morphological features based on the desired flight style for aircraft.

## Understanding mechanisms of developmental abnormalities in the imperiled Gopher frog (*Rana capito*)

*Anna Bushong, Kiersten Nelson, Stacey Lance*

Amphibians face diverse threats across their complex lifecycles, which has spurred the employment of a conservation technique, 'head-starting', to bolster populations of imperiled amphibians. In 2021, our head-starting program for the Gopher Frog (Rana capito) at the Savannah River Ecology Laboratory resulted in developmental abnormalities in nearly 100% of captive-reared metamorphs (severe edema, skin, jaw, skeletal, eye). We suspected that plant material used to stock head-starting mesocosms facilitated abnormal development. In 2023, we obtained experimental evidence that a native wetland grass, maidencane (Panicum hemitomon), can be deleterious to the development of larval Gopher Frogs with nearly 100% of individuals reared in this treatment developing abnormalities. We are investigating competing hypotheses regarding endocrine disruption arising from either (a) environmental retinoids produced from cyanobacteria associated with plant material or (b) secondary plant compounds leaching from plant material. Given that carryover effects of atypical development on juvenile fitness are not well understood, we must clarify mechanisms and sources underlying these abnormalities to identify strategies to minimize them. Our central objective is investigating whether abnormal larvae across multiple developmental abnormality events experienced endocrine disruption indicative of dysregulated retinoic acid signaling using an RNA-seq approach to generate organ-specific transcriptome profiles for analyzing gene expression. We expect our data to inform refinement of Gopher Frog head-starting and improve basic understanding for the teratogenic potential of Panicum genus to larval amphibians.

## High-altitude adaptation alters the innate immune response in deer mice

*Chloe Butler, Megan Hemmerlein, Kathryn Wilsterman*

Although oxygen is considered the most salient abiotic challenge of high elevations, elevational gradients can be characterized by changes in many abiotic and biotic factors, including changes in pathogen prevalence and type. However, there is little research on how immune function has been altered as part of adaptation to high elevations. To fill this gap, I examined the immune response and recovery of lowland- and highland-derived deer mice in a common-garden experiment. Deer mice are a tractable and appropriate model because they occupy the widest elevational distribution of any mammal in North America and they have well-characterized genetic adaptations to high elevations.

I induced a standardized immune response by injecting mice with lipopolysaccharide (LPS), a component of bacterial cell walls. Within 48 hours post-LPS injection, both highlanders and lowlanders lost similar amounts of body mass associated with anorexia. However, in the next 72 hours, highlanders recovered mass faster even though food consumption was comparable to lowlanders. Lowlanders also experienced a more robust fever and displayed a greater degree of sickness behaviors relative to highlanders.

To better understand the biological mediators of these differing responses, we are now characterizing gene expression within the spleen, a major immune organ. The results of this study will provide a novel perspective on the integrative physiology guiding the evolution of innate immunity to high altitudes.

## The legacy of Dr. Karen Maruska: do good science and be a good person

*Julie Butler*

The legacy of Dr. Karen Maruska lives on not only through her scientific contributions to the fields of behavior neuroendocrinology and sensory biology of aquatic species, but through her kindness to others, commitment to rigorous and reproducible science, and the countless students, mentees, and colleagues she had the pleasure to interact with. I am one of those students. In this talk, I discuss some of the research she built her career on. But Karen was so much more that the research she conducted. I also discuss the top ten lessons I learned from Karen during my PhD in her lab, highlighting her passion for equity and inclusion in academia, her creative and resourceful approach to research, and the deep empathy, understanding, and support she gave to her mentees and students.

## Modern taxonomy of Oreophryne: reconciling morphological conflict and incomplete lineage sorting

*Marguerite Butler, Allison Fisher, Ke Cao, Allen Allison*

Over 160 years of evolutionary biology since Darwin have solidified the notion that taxonomy should reflect phylogeny. While the PhyloCode names monophyletic clades (but not species), the Linnaean rank-based taxonomy remains in wide use, with many recent studies seeking to satisfy both systems. However, there is currently little guidance for what to do when these codes conflict, particularly at the genus level where overlap is unavoidable. We discuss the taxonomic resolution of the polyphyletic frog genus Oreophryne. Our phylogenetic results show that it is possible for ranked taxonomy and phylogenetic nomenclature to conflict, and indeed are not reconcilable for the two monophyletic genera Oreophryne and the newly named Auparoparo (which contains the genus Aphantophryne). We find that the traditional diagnostic characters of the pectoral girdles lead to polyphyly, and cannot find any synapomorphy for these nearly morphologically identical genera. We explored the robustness of phylogenetic classification based on subsets of the data which correctly classified the majority of taxa in relation to reference taxa. Nevertheless, we also find evidence of signal conflict and incomplete lineage sorting, which complicates the notion of monophyletic genera under either nomenclatural system. We discuss the complexity of modern phylogenetic interpretation of characters which may evolve modularly as well as the "tangled bank" of gene histories which may not be neatly bifurcating.

## House sparrow nestling size and fledging success are related to the materials making up their nests

*Michael Butler, Brooke Weiss, Olivia Asher, Travis Shoemaker, Michael McGuire*

Nesting behaviors of birds are ancestrally ancient, but access to human-made trash is relatively recent. Birds incorporate trash into their nests, with effects on nestlings that are still unclear. We collected data at a field site that has an uneven distribution of anthropogenic material, due to the presence of a road and heavier human traffic along just one side of the site. Using free-living house sparrows (Passer domesticus), we collected data on both circulating nutrient levels and various metrics of body size on 217 nestlings throughout development. After these nestlings had left the nest, we dissected 97 nests and identified plant-based, animal-based, and anthropogenic materials. As expected, we found that nests closer to the road had more anthropogenic materials. The composition of different materials in the nests was not associated with a change in egg size or hatching success, but nests with more animal-based materials (i.e., feathers or fur) had a higher fledging success. A greater amount of animal-based materials was also associated with nestlings that were larger both halfway through development, and at the end of the nestling period. Thus, while we did not detect negative effects related to the incorporation of anthropogenic materials into nests, the benefits of animal-based materials (i.e., feathers and fur) may be compromised by increased and ready access to anthropogenic materials.

## Cryptic species in marine animals: where do we find them and why does it matter?

*Abigail Cahill, Anne Chenuil*

Cryptic species (CS) are reproductively isolated units that are morphologically indistinguishable. CS have been increasingly identified in the marine environment with the rise of molecular markers. Overlooking or ignoring CS can mean misestimating ecological parameters, including estimates of biodiversity or connectivity. We conducted a literature review and identified over 900 CS complexes in free-living marine animal species. Comparing these CS cases to data on all free-living marine animal species, we found that scientific history and biogeographical factors both contribute to the likelihood that a taxon contains CS: earlier-described species and species in the polar zones were more likely to contain CS. Species containing CS also had larger ranges than those without. Biological factors also played a role, with hard skeletons, internal fertilization, and image-forming vision leading to fewer CS than expected within a taxonomic class. We then used this information to predict which taxonomic groups and oceans are more likely to contain missed CS complexes (e.g. where is overlooking CS more likely to lead to errors in parameter estimates). For example, although many CS have been identified in fish, a larger portion of CS are yet to be identified in other groups such as annelids or sponges. This information can be used to identify places or taxa in which connectivity may be misestimated due to the presence of CS.

## Energy-Efficient Paths and Power Law in Elephant Trunk Motion

*Yilin Cai, Man Wo Lui, David Hu, Yue Chen*

How elephants plan their trunk motion remains a mystery. To investigate this, we filmed a female elephant at Zoo Atlanta, capturing her trunk's 3D motion as she reached for objects positioned at varying distances and heights. We parameterized and modeled the elephant trunk dynamics using parallel extendable soft actuation units. Our analysis of the reaching paths in Riemannian configuration manifold revealed that these trajectories are energy-efficient and correspond to geodesic paths. Additionally, we explored the velocity profiles of these paths and found that they align with a minimized jerk model, which is mathematically equivalent to the power law trajectory. Specifically, the power law indicated that the speed of the tip scales as a 2/3 power law with the curvature of the paths, a relationship also observed in human arm motion. These findings may have applications to motion planning of pneumatic soft robotics.

## Ant triage: Target prioritization and division of labor in fire ant rescue behavior

*Paige Caine, Daniel Soto, Daniel Goldman, Michael Goodisman*

Rescue behavior occurs when an individual risks itself to aid others. In social species, rescue can be a collective action requiring cooperation. Additionally, when multiple group members are in distress, social animals may prioritize certain individuals. How labor is divided in these situations, and who is rescued first, has large consequences for both the individuals and the group. This study explores rescue behavior, decision making, and labor division in the fire ant Solenopsis invicta. We examined rescue of fire ant larvae in an artificial substrate, simulating the result of nest collapse. In each trial, we bury two rescue targets, and vary caste and mass to test how rescuing ants decide and coordinate group rescue. We measure speed, frequency of rescue successes, number of rescuers, and where rescuers spend the most time. We find that ants prioritize rescuing one reproductive larva over one worker larva. However, this pattern reverses when one reproductive larva is buried alongside a mass-matched pile of worker larvae. In general, the overall mass of the target has a greater impact on priority than caste. Furthermore, we note a remarkable ability to multitask when ants are presented with multiple rescue targets. Overall, our results show that colony investment may be more influential in triage decisions than potential reproductive output. These results deepen our understanding of collective rescue activities and social behavior.

## Localization and identification of insulin-like peptides in the brain of a nudibranch

*Laurenzcia Cairo, Kate Otter, Paul Katz*

Insulin-like peptides (ILPs), found in invertebrates, have diverse roles including as growth factors and neurotransmitters. Several ILPs have been identified across invertebrate species groups, resulting in the classification of three ILP types by structure: insect insulin-like peptides (IILP), mollusc insulin-like peptides (MIP), and vertebrate insulin-like peptides (VILP). In gastropods, seven MIPs have been identified. We identified and localized three MIPs that are expressed in the ring ganglia of the nudibranch, Berghia stephanieae. We also investigated if expression in identified neurons were dependent on hunger-state. Peptides were identified by BLAST-ing the genome of Berghia using MIP sequences from Lymnaea stagnalis. The sequences within Berghia were labeled MIP-A, MIP-B and MIP-D. MIPs were localized using hybridization chain reaction in the brain of a nudibranch, allowing visualization of which cells had mRNA expression. The number of cells expressing MIP-B in the cerebral ganglion increased in food-deprived animals, but decreased in the buccal ganglion. MIP-D was expressed in all ganglia in sated animals, but had no expression in the buccal or rhinophore ganglia in food-deprived animals. We have now localized MIPs, as well as IILPs and VILPs in the brain of Berghia. Ongoing work is analyzing the state dependance of expression of the other identified ILP types, as well as localizing ILP receptors in the brain and ILPs throughout the body of Berghia to further investigate their functions.

## A theoretical framework for understanding neutral urban eco-evolutionary change

*Aude Caizergues*

Understanding how urbanization impacts species ecology, evolution and more broadly eco-evo dynamics is becoming a pressing issue in the current context of worldwide urbanization. While a growing number of studies investigate how urbanization affects ecology and evolutionary processes, we still lack a theoretical framework to ground our predictions. In addition, because of the many biases and technical difficulties arising from the collection of empirical data, unraveling broad patterns of eco-evolutionary changes in urban habitats from empirical studies are not straightforward. Interestingly, simulations and mathematical modelling approaches allowed for the development of groundbreaking theories in both ecology and evolution, but remain still rarely applied to the new field of urban evolutionary ecology. Yet, because of their flexibility and putatively unlimited possibilities, modelling and simulations of evolutionary scenarios could provide unforeseen opportunities to disentangle evolutionary processes occurring in urban areas and their potential causes. For instance, empirical evidence of neutral evolution (i.e., gene flow, genetic drift…) being impacted by urbanization is accumulating, leading to two main opposite results. Indeed, while some case studies support the urban facilitation scenario (i.e. increased gene flow and decreased drift) in urban areas, others clearly support the urban fragmentation scenario (i.e. decreased gene flow and increased drift), and the proximal causes of such opposed patterns remain to be disentangled. Here, we used a modelling approach to build predictions on how urban environmental features (habitat quality, green space arrangement, and connectivity), as well as life history traits of species (reproductive strategies, lifespan, and dispersal distances), can affect neutral evolution patterns we observe in cities. Using SLiM, a forward evolutionary simulation framework, we simulated urban populations' evolution through time under different scenarios of city and organismal features to try to understand the importance of each factor and build a theoretical framework for urban neutral evolution.

## Using genomic tools to enhance biodiversity assessments in subterranean estuaries

*Fernando Calderon Gutierrez, Shari Rohret, Danielle Bragg, Elizabeth Borda*

Subterranean estuaries are coastal ecosystems characterized by vertically stratified groundwater. They are considered extreme environments for life, but also to conduct research requiring scientific cave diving techniques. Molecular tools allow non-invasive biodiversity assessments and metapopulations analyses through environmental samples, and particularly, genome skimming circumvents PCR bias, one of the biggest caveats in metagenetic studies. Our goal is to characterize benthic metazoan biodiversity via metagenomic analysis of environmental samples and evaluate the utility and shortfalls of current public molecular databases for documenting cave adapted fauna and poorly known taxa. In this study we compared sediment samples from four caves, and three sites within each, in Cozumel Island and the Caribbean Coast of the Yucatan Peninsula. We identified representatives of 11 phyla of aquatic invertebrates, including taxa not previously reported at the study sites. However, we also detected exogenic DNA from terrestrial and marine taxa. Exogenic DNA represents a challenge for future studies utilizing metagenomic tools, especially in caves with direct connection to the ocean, but also an opportunity to better understand connectivity with adjacent ecosystems. Although our analyses focused on metazoans, our data also allows for the evaluation of prokaryotes and single celled eukaryotes, thus, providing with the ability to conduct holistic biodiversity assessments within aquatic subterranean ecosystems.

## Incubation and overwintering conditions influence hatchling turtle righting ability

*Molly Caldwell, Daniel Warner, Matthew Wolak*

Conditions experienced during development and early life may influence an array of fitness-relevant phenotypes, especially in oviparous ectotherms. The pond slider (Trachemys scripta) has two life stages particularly vulnerable to the influence of ambient conditions: the egg and hatchling overwintering stages. We aimed to determine the influence of both incubation temperature and overwinter environment on hatchling turtle performance. In 2019 and 2020 we incubated slider eggs at five constant temperatures (24°C, 26°C, 28°C, 30°, 32°C). After hatching, turtles were distributed to two housing treatments: terrestrial (simulating hatchlings overwintering in the nest), or aquatic (hatchlings overwintering in water). The spring following hatching, we conducted righting response trials, which are frequently used performance measures that may be associated with neuromuscular coordination. We built linear mixed effects models to determine relationships between incubation temperature, overwintering environment, hatchling phenotypes, and righting response time. Incubation temperature, overwinter environment and their interaction influenced hatchling phenotypes (e.g., shell and tail dimensions, body mass) and righting performance (e.g., total righting response time, latency to right). Aquatically-overwintered hatchlings that were incubated at cooler temperatures righted themselves faster than those incubated at warmer temperatures. This relationship did not exist in terrestrially-overwintered hatchlings, which had faster righting times and performed similarly regardless of incubation temperature. Results suggest terrestrial overwintering may better equip hatchlings for dispersal, and highlight the importance of nest characteristics for hatchling survival.

## Are they ready? Immune priming against emerging infectious diseases in bumble bees

*Austin Calhoun, Brenna Long, Benjamin Sadd*

Pathogenic infection has led to the evolution of diverse mechanisms that alleviate host harm. Invertebrates have evolved a memory-like innate immune response, called immune priming, which increases protection upon secondary pathogen exposure within and/or between generations. Investigating the natural relevance of such protective phenomena is important for species of economic and ecological concern, like bumble bees, where novel pathogen exposure poses severe threats to health. We explore the specificity of immune priming against emerging infectious diseases (EIDs), specifically the honey bee virus Israeli Acute Paralysis Virus (IAPV). We hypothesize that prior pathogenic experience boosts resistance and tolerance to secondary pathogen exposure, however, differential exposures precipitate mismatch costs. We subjected worker bumble bees to different priming treatments, including field-realistic doses, heat-inactivated viruses, and non-infective double-stranded RNA constructs. Subsequently, we quantified measures of infection tolerance (survival assays) and resistance (pathogen loads via RT-qPCR) following a higher dose of IAPV either 2, 7 or 14 days post-priming. We find no evidence for beneficial immune priming in this system. A follow up showed that this holds true independent of the secondary exposure dose, but confirmation for the priming agents activating antiviral pathways is currently being verified via transcriptomic analysis. These results are concerning for native bumble bee health as they suggest evolved immune strategies demonstrated to be effective against bacterial pathogens are not effective against viral EID threats.

## The interaction between fish schools and turbulence: analyzing flow field modulation by giant danios

*Michael Calicchia, Rui Ni*

It has been shown that when fishes school, they are able to reduce their cost of transport especially when swimming through turbulence. However, it is still unclear how these fish can achieve such efficient swimming in turbulence. It is hypothesized that the group of fish can modulate the oncoming turbulence to generate a flow field, which is less costly to navigate through. To begin to test this hypothesis, experiments were performed using a school of giant danios (Devario aequipinnatus). The school was exposed to flow conditions with varying levels of turbulent intensity. The schooling dynamics were recorded by multiple cameras to reconstruct the school shape and size in three dimensions. Furthermore, the velocity field behind the school was measured by using high speed cameras to record the trajectories of tracer particles. The turbulence statistics of the school's wake will be reported and compared to the baseline flow cases where no fish were present. This direct comparison will provide insights as to how the fish are modulating the surrounding turbulence as they swim and how this modulation may help reduce their cost of transport.

## Using complexity metrics to quantify morphological variation in mammalian skull sutures

*Marco Camaiti, Yichen He, Marius Didziokas, Heather White, Alana Sharp, Enrico Grisan, Anjali Goswami*

The skull performs numerous distinct tasks essential to the evolutionary success of mammals. An often-overlooked but key important contributor to skull performance is the morphology of sutures, the fibrous joints that connect cranial bones, which accommodate both growth and biomechanical pressures from feeding, fighting, and other actions. Here, we detail the first ever three-dimensional quantification of suture morphology in mammals using 3D meshes of sutures generated from microCT scans. Due to their nature as interfaces between bones, sutures are highly irregular and lack distinctive homologous structures, making their shapes difficult to quantify with traditional morphometrics. For this reason, we apply alpha complexity to compare the shapes of sutures across a sample of mammals. We find that the vault and facial sutures of fast-developing animals (i.e., Mus musculus, the common mouse) are on average less complex than slower-developing ones (i.e., Procavia capensis, the hyrax). Additionally, sutures of faster-developing mammals possess lower ranges of both fine and gross suture complexity compared to slower-developing ones. Going forward, we will apply this novel approach to a broad dataset of living and extinct mammals and their stem relatives to reconstruct the influence of diet, brain size, and locomotion, in addition to life history, on suture complexity and skull shape, with the ultimate goal of elucidating how cranial sutures supported the incredible ecological diversification of this clade.

## Morphological diversification in the woodland salamander non-adaptive radiation

*Henry Camarillo, Nathalie Alomar, Kalisa Vazquez-Minas, Anne-Claire Fabre, Eric Riddell, Bhart-Anjan Bhullar, Martha Munoz*

North American woodland salamanders (Genus:Plethodon) have been classically characterized as a “non-adaptive” radiation due to low amounts of morphological diversity relative to species diversity. Previous work used key linear measurements to classify differences between species and the phylogenetic relationship between taxa has since changed with updated phylogenies. Here, we use micro-CT scan data to see if 3D geometric morphometrics can provide new insight into the morphological differences between species. We also combine this data with the most up-to-date phylogeny and revisit the patterns of trait diversification in the Plethodon radiation

## Diet of the great horned owl (*Bubo virginianus*) in a Chicago suburb

*Timothy Campbell, Jasmine Zhai, Ashley Lanzarotti, Alexander Delgado, Samuel Gutherz*

Great Horned Owls (Bubo virginianus - GHO) are large avian predators with a widespread distribution throughout the Americas and are found in all counties in Illinois. These owls are opportunistic generalists with one of the most diverse dietary niches of North American owls, although their diets generally consist of ∼90% mammals and ∼10% birds by biomass. Here we present results from an ongoing study of the vertebrate prey taken by GHO in the southwestern Chicago suburb of Downers Grove, DuPage County, IL. To date 458 pellets, partial pellets, and bone detritus assemblages have been recovered from Lyman Woods Preserve, Downers Grove Park District, with 271 having been analyzed. Mammalian craniodental and avifaunal humeri were utilized for identification to the lowest possible taxonomic level using published keys, dental formulas, and museum specimen images. Minimum number of individuals (MNI) were calculated using the most abundant sided element per pellet or assemblage. In total, 583 specimens have been analyzed with remains from the following mammalian groups recovered: Didelphidae (MNI=40), Leporidae (MNI=73), Soricidae (MNI=27), Rodentia (MNI=46), and Chiroptera (MNI=6). Avifauna (MNI=80) recovered represent at least seven families: Columbidae, Picidae, Sturnidae, Corvidae, Alaudidae, Cardinalidae, and Turdidae. The presence of GHO in Lyman Woods presents an opportunity to document their diet in suburban environments. Ongoing research will include an analysis of seasonal variation and further identifications using additional skeletal elements.

## Exploring morphologies of shark skin denticles across a shape gradient with geometric morphometrics

*Isa Campos, Ella Nicklin, Gianna Mitchell, Gareth Fraser*

Like most elasmobranchs, the small-spotted catshark (Scyliorhinus canicula) has tooth-like skin denticles covering it. The denticles in its gills display an extreme morphological gradient. To understand this difference, we ask how much variation exists between denticles in the same body region, and can we categorize denticles into discrete morphotypes sharing the same characteristics. Denticle form variations are essential to their purpose, suggesting that particular morphotypes perform specific functions for sharks. To document denticle shape changes, we used a 3D image computing platform (3D Slicer) to visualize, segment, and process catshark gill CT scan data. We individually segmented the denticles within a gill skin region, and used the SlicerMorph module to perform geometric morphometrics. Landmarks were placed in specific locations on three denticles from the gills, then automatically replicated via AI program (ALPACA) for a sub-set of other gill denticles. Following this, a GPA (Generalized Procrustes Analysis) determined how much variation occurs between these gill denticles. We found 27.2% of variation explained along the axis of width and 15.9% of variation explained along the axis of height. Through warped estimates produced by the GPA, we observed multiple morphotypes within the gradient. This suggests that shark denticles are somewhat plastic in their development and we predict that slight variations in developmental pathway regulation may account for these subtle shape-shifts to produce uniquely functional regions of the skin.

## Impacts of vasotocin on chemical communication in lizards

*Stephanie Campos, Janice Park*

Chemical communication is critical for establishing and maintaining territorial relationships in many animals, but the influence of the hormone arginine vasotocin (AVT) on chemical signaling is not well understood. AVT impacts territorial displays and responses across many sensory channels and recent evidence suggests that, within the chemical modality, AVT may enhance chemical cues and heighten the interest of competitors in these chemical cues. We hypothesize that arginine vasotocin enhances the chemical signals produced by territorial male lizards, which could influence territorial dynamics. We present behavioral evidence from these manipulation experiments on two species of lizards, Sceloporus variabilis (rose-bellied lizards) and Anolis carolinensis (green anoles). Briefly, we administered IP injections of arginine vasotocin (or a saline vehicle) into male signalers and measured behavioral chemosensory responses of receiver males in either live interactions (green anoles) or in chemical playback assays (rose-bellied lizards). We discuss our findings and the potential mechanisms used by vasotocin to influence chemical signals.

## Trends in the evolution of the skull in the Eulipotyphla

*Maddie Cannistra, Catherine Suitor, Tristan Stayton*

Evolutionary analysis of shape and performance in skeletal elements (including limb and vertebral elements) in the mammalian order Eulipotyphla has revealed surprising results: significant ecological trends but no allometric trends. These elements are substantially involved in locomotion, and thus expected to be subject to size-dependent selection pressures due to changes in mass relative to bone cross-sectional area. The skull and mandible are not involved in locomotion, thereby offering a comparison to other skeletal elements: although they may be subject to selection related to prey size, they can be at least somewhat divorced from the necessary connection between body mass and stresses. We photographed skulls and mandibles of 79 eulipotyphlan taxa, including the largest and smallest known species, and digitized 2D landmarks on dorsal, lateral, and ventral views of skulls and lateral views of mandibles. We examined relationships between size, ecology, and overall shape for all views, as well as for mandibular lever arms of jaw muscles. In contrast with results for postcrania, the cranium shows significant allometric signal, in ways expected from previous studies in mammals (e.g., smaller braincase, larger facial region in larger taxa), along with significant ecological signal. The mandible shows ecological signal and allometric signal for muscle lever arms but not for overall shape. These results suggest performance explanations for the lack of allometry in most eulipotyphlan postcranial elements.

## Cross-sexual transfer of pairing behavior in a female-dominant biparental cichlid, *Julidochromis mar*

*Willa Cantlon, Andrew Anderson*

Cross sexual transfer occurs when, the traits associated with one sex are expressed in the other sex and is hypothesized to occur by altering the hormonal signal to match that of the other sex The cichlid fish, Julidochromis marlieri, has a behavioral sexual heteromorphism in which they preferentially pair large females with small males and take on different roles during courtship and brooding. Females in a pair exhibit territorial nest guarding behavior, while males exhibit nest and egg tending behavior. These behaviors can be reversed by manipulating partner size such that the male is larger than the female, thus causing a cross-sexual transfer of behaviors. Our experiment quantifies these behavioral shifts and changes in circulating hormone levels when individuals are paired with larger or smaller partners in J. marlieri. Our results show how plastic these behavioral suites are in each sex and if individuals are experiencing hormonal shifts when engaging in the cross-sexual transfer of behaviors.

## The distribution of adhesive foot contacts in Argentine ants during vertical climbing

*Yakun Cao, Andrew Chacon, Agasthya Valluri, Nick Gravish*

Argentine ants have adhesive pads (Arolia) on their feet which enable them to climb on vertical and inverted surfaces. To resist falling off of a vertical surface, climbing ants must generate appropriate adhesion across all their contacting feet to resist gravity. To explore how ants distribute adhesion across their feet while climbing, we used a frustrated total internal reflection (FTIR) climbing surface which illuminates regions of close contact. When ants climb on the surface, their adhesive contacts can be visualized. We recorded high-speed (400Hz) videos of Argentine ants climbing and used automated tracking methods to identify kinematics and foot contact. We compared the experimentally observed distribution of adhesive contact with the adhesion forces predicted by a quasi-static model of a climbing ant. In the model, the ant body was simplified as a mass point with three weightless limbs, subjected to gravity and foot contact forces. The directions of normal forces on all limbs and their relative ratios were determined based on the foot locations. Even though the relative ratios of adhesive contact areas among different legs did not align with the required force ratios, the model's accuracy in predicting which leg shows adhesive contact is on average 94.1% for climbing up and 74.6% for climbing down. Our finding suggests that ants activate adhesive pads only on the limbs needed to generate adhesive forces.

## From plates to pixels: decoding biodiversity with ARMS

*Demi Carballosa, Sarah Tweedt, Christopher Meyer, Sheila Kitchen*

The Flower Garden Banks National Marine Sanctuary (FGBNMS) in the Gulf of Mexico, a critical biodiversity hotspot, harbors many cryptic organisms that contribute to its ecological complexity but remain understudied. To address this gap, two Autonomous Reef Monitoring Structures (ARMS) were deployed on the reef crest (∼30 m) of the East Flower Garden Bank (EFGB) nine years ago. ARMS units, composed of stacked PVC plates, are designed to capture marine life associated with coral reefs, particularly species difficult to detect through traditional survey methods. This study compared the diversity and abundance of organisms encrusting these recently recovered units with prior ARMS recovered from depths of 60 to 100 m at EFGB. Photographic analysis and semi-supervised neural networks were employed to identify and quantify organisms on each plate, providing insights into microhabitat preferences and potential spatial variability within the reef ecosystem. Additionally, trends in dominant sessile organisms were documented through the analysis of plates from ARMS deployed for varying durations, from less than a year up to ten years. By documenting patterns in colonization and succession, this study aims to deliver valuable data that can inform conservation strategies for FGBNMS and similar ecosystems, ultimately contributing to a more comprehensive understanding of coral reef ecosystems and the ecological processes that sustain them.

## Revisiting lateral line shape evolution in labrid fishes

*Marina Carbi, Samantha Price*

The lateral line is an ancestral mechanosensory system crucial for various ecological behaviors, including predator avoidance, prey detection, and schooling. Variation in trunk lateral line morphology within fishes is thought to be adaptive. Previous descriptive research in labrids identified three distinct trunk lateral line patterns and suggested that shape may be constrained by body depth. In this study, we revisit these ideas by quantifying the influence of phylogeny, ecology and body shape on trunk lateral line evolution using rigorous phylogenetic comparative methods.

We classified trunk lateral line patterns using previously established categories for 311 species of wrasse and parrotfish (Labridae), using digital photographs taken of the lateral view of preserved specimens from the Australian Museum and the Smithsonian National Museum of Natural History. The body shape of these specimens was quantified using six linear depth, length and width measurements taken with calipers. We compiled data on the trophic ecology of these fishes and their typical position in the water column from the scientific literature review. Utilizing a previously published phylogeny of Labridae and models of continuous and discrete trait evolution we estimate the tempo and mode of the lateral line shape evolution and test for an effect of ecology and body shape.

This research provides insights into the evolution of lateral line morphology and the role of ecology, phylogeny and body shape across labrids.

## Analysis of northern purple-faced langur calling behavior across Sri Lanka's dry-zone

*Sarah Carnes, Abby Parks, Alexandra Hofner, Roberta Salmi*

The Northern purple-faced langur (Semnopithecus vetulus philbricki) is an Endangered folivorous primate endemic to Sri Lanka's dry-zone. The calling behavior of this subspecies is relatively unknown. Non-invasive methods, like passive acoustic monitoring, help understand elusive primate species' ecology. These methods record vocalizations without a researcher present, reducing human influence and increasing detection likelihood. Recordings of S. v. philbricki loud calls can assess species distribution, population trends, and explore their vocal behavior, and the acoustic and temporal characteristics of their vocalizations. We are examining a dataset recorded with passive acoustic monitors in the Kaludiyapokuna Forest Reserve, Sri Lanka. Recorders were set to record from 4:00-19:00 at a 48,000 Hz sampling rate. We will examine 10 days (150 hours) of recordings to document call frequency and timing. Additionally, we will investigate individual distinctiveness in three males by analyzing the "whoop" call using Raven Pro software. Based on prior primate vocalization research, we hypothesize greater variations in the temporal patterns of langur calls (length and frequency) than in their acoustic characteristics. This project aims to create a comprehensive set of isolated calls to identify critical habitats for conservation efforts and provide insights into identifying individual callers.

## A study in fur: American marten energetics and distribution

*Kit Carpenter, Danielle Levesque, Sandra De Urioste-Stone*

Increasing temperatures from climate change are predicted to alter and constrain species distribution in unpredictable ways over time. For cold-adapted species, such as American marten (Martes americana), we have a limited understanding of what temperature ranges might have physiological impacts significant enough to affect their distribution. Our project will develop a mechanistic model of martens' heat balance and exchange with their environment, integrating functional trait and microclimate data to develop a model specific to our study area in Maine. Fur trappers in the United States have an established history of participating in research and conservation efforts for their species of interest. Through semi-structured interviews, we were able to gather rich qualitative data on trappers' lived experiences with our study species as well as irregular weather and climate patterns. The local ecological knowledge of trappers will help inform our modeling process at multiple stages by providing firsthand observations of species phenology and weather conditions, especially during the winter trapping season. This integration of biological and social sciences will support the development of a model with more specificity to the study system in which it is being used than development of the model in isolation. Through these interdisciplinary methods, we hope to produce a more complete understanding of the ways in which changing conditions affect marten energetics and distribution, with implications for conservation.

## Microbes as manipulators of egg size and developmental evolution

*Tyler Carrier, Matthew Kustra*

Marine invertebrates mainly reproduce by energy-poor eggs that develop into feeding larvae or energy-rich eggs that develop into non-feeding larvae. The factor(s) responsible for driving transitions in reproductive strategy and developmental mode remain elusive despite having been studied in detail. Microbes may be one such factor, as they are functionally beneficial to animal reproduction and have evolved mechanisms to override components of this host program. This talk identifies the first suspected reproductive manipulator in the ocean and then presents theoretical models that support the premise that this type of microbe could serve as the selective agent of these developmental transitions. Specifically, these models outline the predicted circumstances by which these microbes may spread within populations. They then predict that microbial manipulators would create a sperm-limited environment that selects for larger eggs by shifting the host's sex ratio towards female dominance and, as a result, serve as an evolutionary driver of transitions in the developmental mode for marine invertebrates. Lastly, this talk will suggest candidate marine invertebrate genera from throughout the world's oceans that fit the framework of a microbe-induced switch between these predominate reproductive strategies.

## Symbiont-mediated metabolic shift in the sea anemone *Anthopleura elegantissima*

*Tyler Carrier, Jason Macrander, James Dimond, Brian Bingham, Adam Reitzel*

Coral reefs and their photosynthetic algae form one of the most ecologically and economically impactful symbioses in the animal kingdom. Stability of this nutritional mutualism and this ecosystem is, however, at risk due to increasing sea surface temperatures that cause corals to expel their symbionts. Symbiosis with these microeukaryotes has evolved multiple times and non-coral anthozoans (e.g., sea anemones) offer insightful comparative systems due to their ease of husbandry in the laboratory and their ability to shuffle different strains of their photosymbionts to acclimate to thermal conditions. This breadth of symbiont shuffling is observed in the sea anemone Anthopleura elegantissima, which naturally occurs in symbiosis with the dinoflagellate Breviolum muscatinei (formally Symbiodinium) and the chlorophyte Elliptochloris marina, and it may also be aposymbiotic. Here, we use multi-omics to characterize multiple physiological levels of each symbiotic state. We find that A. elegantissima has symbiont-state specific transcriptional and metabolomic signatures, but a similar bacterial community that was dominated by a single Sphingomonus species commonly found in the coral microbiome. Symbiosis with either eukaryotic symbiont resulted in differential expression and metabolic abundance for diverse processes spanning metabolism and immunity to reproduction and development, with some of these processes being unique to either symbiont. The ability to culture A. elegantissima in the laboratory and experimentally manipulate the abundance of these phylogenetically divergent photosymbionts makes A. elegantissimaanother tractable sea anemone to decode this symbiotic conversation and aid in wider conservation efforts of this vital ecosystem.

## Effects of urbanization and temperature on the bill morphology of an insectivorous bird

*Aziza Carrillo, Sage Madden, Ian Haliburton, Thomas Hahn, Gail Patricelli*

Increased urbanization worldwide has led to changes in food availability and temperatures experienced by wildlife which may alter selection on morphological adaptations for feeding and thermoregulation. Previous studies on granivorous birds have found that new food sources in urban areas may favor stronger, stubbier bills with decreased length and increased width and depth. Higher urban temperatures may instead favor an increased bill surface area for heat dissipation. Little is known about how selection may act in insectivorous birds facing altered food sources and increased temperatures. To address this knowledge gap, we investigated how changes in urban land cover and temperature affect the bill morphology of an insectivorous songbird–the Black Phoebe (Sayornis nigricans). From March to August of 2023 and 2024, we monitored Phoebe nests along an urbanization gradient in the Sacramento Valley, California. We measured the bill length, width, and depth of nestlings (n = 340 nestlings, 65 nests) and tracked temperatures throughout the nesting period. We found that higher maximum nest site temperatures were linked to decreased bill width and depth relative to tarsus. However, we found no relationship between nestling bill morphology and the level of urbanization. These results suggest that thermoregulatory challenges during development may be an important force shaping bill morphology. Further analyses will be conducted to investigate how other factors, such as altered diet, may affect bill morphology.

## Downsizing: latitudinal and temporal Bergmann's clines in the butterfly, *Vanessa cardui*

*Amanda Carter, Fabio Machado, Erika Hingst-Zaher, Mikayla Struble, Ashlyn Trujillo, Jonathan Branco, Colton Roberts-Zaffiro*

Body sizes are decreasing, and these shifts are often attributed to climate change via Bergmann's Rule. Bergmann's Rule relates body size to ambient temperature and can be applied across spatial (e.g., latitude) and temporal (e.g., climate change) temperature gradients. While there is growing evidence that decreasing body sizes may be a universal response to climate change in endotherms, it is unclear if ectotherms should be similarly affected. Furthermore, we know relatively little about how these body size trends arise – via phenotypic plasticity or natural selection – which is key to understanding how these trends contribute to climate change responses. Using museum collections of a widely distributed butterfly, Vanessa cardui, we tested for Bergmann's clines across western North America over the past century. We found that wing and thorax sizes are decreasing over time and across latitude. To explore contributions of plasticity versus selection, we collected climate data at varying temporal and geographic scales to estimate the developmental temperatures of each specimen and the temperatures across the population's range in multi-generation intervals. Preliminary findings suggest that selection may drive decreasing body sizes more so than plasticity, which is surprising in an insect with pronounced temperature-dependent phenotypic plasticity. Our results emphasize the importance of parsing mechanisms underlying biogeographic trends in diverse taxa to enhance climate change predictions.

## Developing an Inexpensive Materials Testing System (MTS) for Organismal Biology Research

*Joshua Carter, Stacy Farina*

Comparative studies of animal and plant tissues are core activities in the field of organismal biomechanics. These tissues are often complex, composite materials that require direct testing to determine their properties. However, testing systems used to determine these properties can be expensive and inaccessible, especially when conducting research at a primarily undergraduate institution. We will present a Materials Testing System that is both easy to assemble and affordable. By relying solely on easily available and inexpensive parts, we aim to create a system capable of applying vertical tensile and compressive stresses onto test materials and record their tensile and compressive strength. This will be done using stepper motors attached to wheel chassis that move vertically on aluminum frames. Force transducers will be employed to measure the exact forces being applied to the tested material which will be neatly transferred to an excel sheet to be graphed. Given the price of most Materials Testing Systems, an inexpensive one for smaller simpler tasks would prove exceptionally useful to research labs with a small budget or for classroom use.

## The aerodynamic effects of leading-edge ear tubercles of the Mexican free-tailed bat

*Richard Carter*

Mexican free-tailed bats (Tadarida brasiliensis) is a fast-flying species that experiences airspeeds exceeding 10 m/s. Along with wing morphology associated with fast flight, this species has ear tubercles along the leading edge of their wing-shaped ears. The hydrodynamic effects of leading-edge tubercles on humpback whale pectoral fins are understood to decrease drag, increase lift, and delay or prevent stall at certain angles of attack. Here, I used finite element computational fluid-dynamics to assess if the tubercles found on the bat's ear play a similar aerodynamic role during flight. Ear geometry was extracted from μCT data and processed in CAD software, yielding a "tubercled" and smoothed ear. Both ear geometries were then cut into an air column at different angles of attack, resulting in an ear shaped void in each. Air was moved over the ear shaped surfaces at 10 m/s and lift and drag data were generated from these. Air velocity, pressure, and turbulence data were also generated at various planes through the air column to capture fine scale flow differences due to the tubercles. The tubercled ear performed approximately the same or better in lift generation at the different angles of attack. This appears partly due to different patterns of streamwise vortex shedding along the leading edge and the effect these vortices have on the aerodynamic force of the ear.

## Effects of adult butterfly exposure during caterpillar stage on Bicyclus anynana mating preferences

*Jason Cartwright, Yiting Ter, Erica Westerman*

Mate choice learning is a critical tactic that many animals deploy. One form of mate choice learning, imprinting-like mate preference learning, allows sexually immature individuals to learn to prefer a specific phenotype via exposure to sexually mature adults. While this form of learning occurs in a number of animal taxa, it is relatively unexplored for the juvenile stage of animals that undergo complete metamorphosis. Here, we use the butterfly Bicyclus anynana, a species where adult females generally prefer males with two spots on each dorsal forewing but can learn preferences for males with four spots, to test whether females can learn this preference during the larval stage (as caterpillars). Using a split family design, we raised caterpillars with male butterflies painted to have four spots. To determine when learning occurs if it does, caterpillars were exposed to painted males for two different time windows – either during their entire larval development or only during their final caterpillar instar. Control caterpillars had no adult exposure. After emerging and maturing, female butterflies were then given a choice between two male butterflies, one with two and one with four spots. Preliminary data suggest that exposure to adults for the full larval period may influence adult female mate choice, but exposure during final instar may not. This suggests that larval social experiences may influence adult mate preferences in a butterfly.

## Is anti-müllerian hormone sex-specific in neonate sea turtle blood?

*Gabriella Carvajal, Jeanette Wyneken, Itzel Sifuentes-Romero*

Imperiled sea turtle species with temperature-dependent sex determination (warm female-cool male) are especially vulnerable to climatic changes. A small increase in nest temperature can produce highly female-biased primary sex ratios, potentially threatening population stability due to a lack of males. Establishing primary sex ratios is challenging because there are no simple or non-invasive methods that accurately identifies sea turtle hatchling sex. Finding a "user-friendly" method has not been an easy task. A recent study identified the Anti-Müllerian Hormone (AMH), to be sex-specific in blood plasma of male loggerhead (Caretta caretta) and red eared slider (Trachemys scripta) hatchlings using Western blots and a human AMH antibody. However, when replicating the methods, we found the "AMH" band was present in both sexes. Further, we developed a sea turtle specific antibody based on a partial AMH sequence obtained using male green turtle neonate gonad biopsies. The "AMH" band using this antibody was also present in both sexes. Together, these results together suggest that AMH likely is not a reliable sex-specific marker. Using immunoprecipitation and mass spectrometry we aim to identify if the initially detected protein is AMH or another member of the TGF-$\beta$ family.

## An experimental investigation of resonance and wing hinge dynamics in flapping wing insects

*Cailin Casey, Braden Cote, Chelsea Heveran, Mark Jankauski*

Many flying insects have evolved an adaptation known as indirect actuation to reduce the energetic costs of flight. Indirect flight muscles act to deform the flexible thorax, and small thorax deformations are converted into large wing rotation via an intermediate wing hinge. However, the extent to which wing hinge deformation contributes to the wing stroke angle is not well understood. This study investigates the role of the wing hinge in the performance of a wing stroke by quantifying its torsional stiffness, damping, and resonant frequency in insects with asynchronous and synchronous indirect flight muscle types, specifically the army cutworm moth (Euxoa auxiliaris) and the honeybee (Apis mellifera). Using a novel experimental approach, we measured the linear frequency response function relating thorax compression to wing stroke angle. We then derived a model to implement our experimental values and evaluate the nonlinear frequency response at large flapping amplitudes. Our findings suggest that while both species flap at frequencies higher than the mechanical resonant frequency of the wing/wing hinge subsystem, wing hinge stretching contributes more in honeybees compared to moths. This research provides insights into the dynamic contributions of the wing hinge and its implications for flight efficiency, maneuverability and resonance of the flight motor.

## Biodiversity-centered teaching: insights on how to teach a more accurate and socially just biology

*Aramati Casper, Yoon Ha Choi, Antonio Duran, Sarah Eddy, Linda Fuselier, Zuleyma Tang-Martinez, Karen Warkentin*

Undergraduate biology courses often focus on simplified content, excluding the broad diversity of life and complex interactions that occur across levels of biological organization and unintentionally supporting harmful narratives such as binary sexes, sexism, and racism. A Biodiversity-centered teaching approach can present biology more accurately while simultaneously being more inclusive. In this collaborative autoethnography (CAE) five biologists and two education researchers used the teacher-centered-systemic-reform model to understand how the biologists have engaged in transforming our courses to encompass the diversity of sex and reproduction and other topics to promote biodiversity centered pedagogy. We identified key points important in our change processes: 1) being dissatisfied with existing content that motivated us to change; 2) independently learning about the history and socio-political contexts of science and complexity of biodiversity; 3) engaging in small changes to build confidence and develop course materials; and 4) overcoming fear and accepting feelings of vulnerability. In our continual engagement with change we each use different entry points to teach diversity relevant to our individual experiences, knowledge, and social contexts; are always learning; and remain motivated through creating more inclusive and interesting courses and building community with others. Through our CAE we gained insights that may help others working to transform teaching through dismantling multiple hierarchies, deconstructing false discrete categories, and foregrounding multiple dimensions of biodiversity to develop more socially just biology education.

## Engaging with interdisciplinary teaching in ecology using a jigsaw activity

*Aramati Casper, Jay Falk*

Understanding and teaching about ecosystem interactions often requires engagement across scientific fields. Yet, introductory biology courses often focus on simplified, siloed content. To navigate the challenge of teaching interdisciplinary we developed, taught, and assessed a pollination ecology jigsaw activity in a large introductory undergraduate biology course. In this process we realized that the jigsaw was not just a helpful teaching tool, but also helped us explicate interactions and integrate knowledge across our animal evolution, plant ecology and science education backgrounds. In the activity students learned about animal movement ecology and social selection and plant reproductive evolution, including self-incompatibility. They then developed hypotheses about how the differences in animal behavior, particularly nectar feeding behavior in different morphs of the white-necked jacobin hummingbird, could influence plant pollination, and plant evolution, particularly in relation to self-incompatibility. Students completed readings we synthesized from primary literature articles prior to class and integrated their knowledge during in-class small group work to develop testable hypotheses. We used reflexive thematic analysis through the thematic lens of systems thinking to analyze student responses. Students' abilities to effectively engage with the problem varied greatly, from thoughtful data-driven hypotheses to overwhelmed confusion. Our analyses of student hypotheses and reflections on their experiences and our own experiences developing and teaching the activity provide insights for others who want to develop similar activities for their own courses.

## Pirates of sensory biology: mapping the olfactory receptor neuron density in Pacific spiny dogfish

*Gabriella Castillo, Aubrey Clark, Marianne Porter, Tricia Meredith, Lauren Simonitis*

The elasmobranch olfactory system consists of two paired olfactory capsules housing the olfactory rosettes. The rosette is comprised of multiple plate-like structures, known as lamellae, overlain with a sheet of epithelium with primary and secondary folds. As sharks swim, dissolved odorants flow through their nares, into the capsules, and pass over the lamellae of the rosettes. Lamellae contain regions of sensory and non-sensory epithelium. The sensory regions of lamellae contain ciliated supporting cells, which move mucus, and olfactory receptor neurons (ORNs), which bind to odorants in the water. Olfactory information is then sent to the brain for further processing. Previous work has used percent lamellar sensory area as a proxy for olfactory sensitivity without quantifying ORN density. In this study, we compared lamellar sensory surface area quantification data with ORN density to explore their relationship. Our goal is to better approximate olfactory sensitivity using morphological proxies. We analyzed the microstructure of Pacific spiny dogfish olfactory lamellae (Squalus suckleyi; N = 5) using scanning electron microscopy (SEM) and histology. We identified ORNs both within sensory epithelium and the transition zones of secondary fold nonsensory epithelium intrusions. These data challenge the appropriateness of using sensory epithelial surface area as a proxy for olfactory sensitivity but rather focus specifically on sensory surface area.

## The evolution of the muscle-tendon unit in mice selected for high levels of voluntary wheel running

*Alberto Castro, Allyn Nguyen, Theodore Garland, Saad Ahmed, Natalie Holt*

Skeletal muscles, often enhanced by elastic tendons, power animal movement. Muscle-tendon unit properties are thus important determinants of locomotor performance and hence Darwinian fitness. However, evolutionary adaptation is rarely directly demonstrated. Here we used an artificial selection experiment in which 4 replicate lines of mice selectively bred for high levels of voluntary wheel running are compared to 4 control lines. In situ muscle physiology experiments were performed, and morphological measurements made, on the triceps surae complex to determine contractile speed and endurance, and muscle and tendon length and mass. We expected selection to result in small, slow muscles with high endurance, long tendons, and a speed-endurance trade-off. Mice from selected lines had significantly lighter ($p=0.0027$) and shorter ($p=0.0039$) muscles, and longer tendons ($p=0.0016$), than those from control lines. Selectvie breeding had no effect on absolute muscle shortening velocity ($p=0.3399$). However, normalized shortening velocity varied across selected lines and was, unexpectedly, significantly higher in selected than control lines ($p=0.0086$). Muscle speed and endurance were negatively correlated across selected ($r=-0.980$, $p=0.0033$), but not control, lines. These data provide the direct evidence for the evolution of long distal tendons under selection for endurance running, a potentially interesting co-adaptation of muscle and tendon that may explain the lack of reliance on long, energy-saving, tendons in small-bodied species, and a speed-endurance trade-off that is only apparent under strong selection.

## Stable isotope fundamentals of jellyfish: tracking nutrient flow through the Monterey Bay Aquarium

*Vanessa Castro, Mariam Keshavjee, Jacinta Kinyunzu, Gloria Manga-Ebengue, Tommy Knowles, Sora Kim*

The foraging ecology of animals can vary with environmental processes, food web dynamics, and ontogenetic stages. Increasingly, ecological studies are using stable isotope analysis to track origins, pathways, and fate of organic matter within ecosystems. Jellyfish are gelatinous members of the Medusazoa subphyllum and present in all marine ecosystems, but their role in food webs changes throughout their life cycle. This study opportunistically sampled the culturing process of jellyfish at the Monterey Bay Aquarium to determine the trophic transfer of carbon and nitrogen isotopes, which could vary with growth rate, nutrient availability, and protein quality. All diet items were sampled, including aliquots of nutrient supplements, algae, and zooplankton. When necessary, diet items were mixed with seawater and vacuum filtered for 3-4 replicates. All jellyfish tissues were rinsed 3 times with filtered seawater to remove mucus, unless the tissue integrity was too fragile with agitation. All samples were stored frozen, then freeze-dried before stable isotope analysis at the Stable Isotope Ecosystem Lab of UC Merced. The $\delta$13C and $\delta$15N values were normalized and corrected for linearity and drift with reference materials. The $\delta$13C and $\delta$15N values reflect predator-prey relationships and indicate the isotopic fractionation with trophic level. This understanding of stable isotope variation under lab conditions will support future research on the diet and ecology of jellyfish, especially as ocean conditions change due to human influence.

## Predictive modeling of adaptive variation in tiger sharks across the western North Atlantic

*Eloise Cave, Anna Weber, Michael Criscitiello, Jeannine Ott, Toby Daly-Engel*

Adaptive variation plays a key role in the ability for species to persist in the face of changing environmental conditions. Seascape genomics explores how spatial relationships and environmental factors within the ocean impact the geographic distribution of genetic patterns in marine organisms. Here, we aim to uncover adaptive genetic variation across a seascape in tiger sharks (Galeocerdo cuvier) across the western Atlantic, northern Caribbean, and Gulf of Mexico (GOM). We generated single nucleotide polymorphisms (SNPs) on 283 tiger sharks by Double Digest Restriction Site Associated DNA sequencing (ddRAD-seq) and sequenced on a Nextseq 550 and a Novaseq 6000. A redundancy analysis (RDA) identified outlier SNP loci that exhibited significant associations with environmental factors. We then applied a genomic prediction of adaptation model to predictively map current adaptive variation and genomic vulnerability across the seascape. Of 3,833 SNPs, 21 candidate SNPs showed signals of environmental selection: 13 were associated with sea surface nitrate, six SNPs with salinity, one with long-term minimum temperature, one SNP with phosphate. The RDA identified three genetic clusters (northern GOM, Big Bend of Florida and Atlantic) by correlating SNP data with environmental factors and genomic variation differed across the environmental gradient. This study reveals how tiger sharks adapt to local environmental conditions and explores their genetic response to climate change, providing insight for conservation management of locally adapted populations.

## Nanoscale ultrastructures increase the conspicuousness of signalling traits in cleaner shrimps

*Eleanor Caves, Sonke Johnsen, Alexander Davis*

Signal theory predicts organisms should evolve signals that are conspicuous to intended receivers in natural signalling environments. Cleaner shrimps are small tropical crustaceans that remove and eat ectoparasites from their reef fish 'clients,' and many species signal their intent to clean by whipping long, white antennae. Since white is a reliably conspicuous colour in aquatic environments, we hypothesized that selection has acted to increase broad-spectrum (white) antennal reflectance in cleaners. We used Scanning Electron Microscopy, optical models, and reflectance measurements, and found that the antennae in three obligate cleaner species from two families (Palaemonidae and Lysmatidae) had either thick (~6μm) chitinous layers or densely-packed high refractive index spheres (300-400nm diameter), which are likely composed of isoxanthopterin, a reflective material normally found in the visual system. Optical models showed that these structures increase reflectance (400-700nm) substantially over chitonous exoskeleton alone. By contrast, two facultative and non-cleaning species had no visible antennae ultrastructure beyond chitinous exoskeleton. Calibrated color photography showed that antennae reflectance was significantly higher in the three obligate cleaner species than either the facultative or non-cleaning species. Overall, our results suggest that some obligate cleaners may have evolved ultrastructures that increase the conspicuousness of the antennae as signals.

## Avoidance of moving obstacles in Harris's Hawks

*Henry Cerbone, Graham Taylor*

Birds often fly through cluttered environments that involve moving obstacles both in the natural case, moving branches, and the built environment, wind turbines. Although previous work has examined birds' response to stationary obstacles, little has been done to understand how birds respond to moving obstacles. Furthermore, when performing known flight patterns like perch-to-perch flight, it is not known how birds balance planning and reactivity. Through the introduction of a padded, moving bar within the flight trajectory of Harris's hawks, Parabuteo unicinctus, we are able to further explicate the behavioral and kinematic response to moving obstacles. Four hawks outfitted with motion capture markers enabling tracking of the center-of-mass and head were flown perch-to-perch through a tunnel transect located halfway between the perches containing a vertical and horizontal moving bar respectively. The bar was programmed to move either left or right at a set delay once the bird had taken off, forcing the bird to reactively contend with the obstacle. Through 3D reconstruction from motion capture data, we model both high-level behavior, gap selection, and lower-level kinematic responses such as reaction time, pitch angle, and lateral deviation. We construct a decision matrix based on the symmetry of the obstacle, i.e. as one gap gets smaller, the complementary gap becomes proportionally bigger. Overall, our results provide insight into how birds balance planning and reaction during simple flight trajectories.

## Does it hurt ? Quantifying damage inflicted by Stingray barbs with a pressurized gas gun

*Jules Chabain, Philip Anderson*

Myliobatiformes are cartilaginous fishes which possess a hypertrophic dermal denticle shaped into a serrated spined called a barb. The diversity of this tool is compounded by the fact that it is not just at the species level. Similar variation in form is seen between barbs within species and even within individuals. A tool that has a uniquely described function, stabbing your predators, raises some questions. Do these variations influence the success of damage inflicted? Does barb shape influence defensive performance ? The objective of this study is to quantify the defensive performance as damage dealt by preselected barb shapes, and analyze the influence of the serrations in particular. For that, I perform high-speed puncture experiments using 3D prints of the barbs of 4 different species, Paratrygon aiereba, Gymnura altavela, Aetobatus narinari and Pteroplatytrygon violacea. Unlike previous experiments with drop tester and Particle Tracking Velocimetry methods, this study uses a pressurized gas gun to shoot the barbs into a pdms cube (10:1),filmed by a high-speed video camera. Polarized filters are employed to track the energy wave propagation. The range of that energy wave and the speed it is moving at will be used as damage proxy, in addition to the depth of puncture. Results indicate that Paratrygon aiereba outperform species similar to what was found in the previous experiment with the drop tester.

## The gift of water: can males improve females' fitness in arid environments?

*Chloé Chabaud, Natasha Tigreros*

Water availability is one of the major factors influencing the survival and reproduction of organisms under future climate change scenarios. To cope with dry environments, organisms have evolved various mechanisms, such as reducing metabolic rate to minimize water loss or increasing the consumption and catabolism of nutrients (e.g., proteins) to enhance water intake. These water-stress coping mechanisms may trade-off with the acquisition of essential macronutrients, including amino acids. In this study, we investigate how an increased need for water impacts the acquisition and allocation of essential amino acids in Pieris rapae, a widespread butterfly that experiences variation in relative humidity within its habitats. During mating, P. rapae females receive a nitrogen-rich nuptial gift, consisting of over 70% water, which they use for egg production. Specifically, we tested how the consumption of this nuptial gift benefits females in dry environments and how coping with water stress by consuming this resource affects the utilization of nuptial gift-derived amino acids. To do this, we manipulated relative humidity in their environments and used stable isotopes to track the metabolic fate of nutrients from the nuptial gift. Additionally, we compared the physiological hydration state of mated and virgin females in environments with high or low relative humidity. Our results revealed that the nuptial gift supports both metabolism and egg production, and enables females to better cope with dry environments.

## Parental feeding patterns and offspring corticosterone levels in Leach's storm-petrels

*Tori Chace, Kayla Lichtner, Jack Dziubek, Sarah Chapman, Nicole Joseph, Robert Mauck, Patricia Jones, Mark Haussmann*

During the reproductive season, pelagic seabirds balance time between care for their offspring and foraging flights. On any given night during the chick-rearing period, Leach's Storm-Petrel (Hydrobates leucorhous) nestlings may be fed by one, both, or no parents, resulting in relatively unpredictable periods of fasting punctuated by intense feeding bouts. The natural variation in food delivery caused by biparental feeding may affect corticosterone levels, a hunger and satiety regulating hormone. We explored how the duration of the fasted periods and the amount of food provided during the fed periods affect corticosterone levels. To determine feeding frequency, chicks (n=20) were massed daily from day 8 to 30 post-hatch. Plasma corticosterone levels were measured using an enzyme-linked immunosorbent assay from blood samples on days 10, 20, and 30. When chicks were not fed (30.2% of nights), they lost -4.0$\pm$1.3g, when fed by one parent (47.6% of nights), they gained 3.6$\pm$1.0g, and when fed by both parents (22.2% of nights), they gained 12.3$\pm$1.5g. We will discuss how the length of the fasting period and the amount of food delivered affects nestling plasma corticosterone levels. The substantial natural variation in both the timing and amount of food delivered to pelagic seabird chicks provides the opportunity to study how a range of feeding patterns affect nestling physiology.

## Controlling noisy herds

*Tuhin Chakrabortty, Saad Bhamla*

Individual sheep instinctively flee from shepherd dogs, yet in larger groups, they adopt a 'selfish herd strategy,' clustering together to minimize risk. This well-known collective behavior falters in small groups ($N<5$), where sheep unpredictably oscillate between fleeing and clustering. In this talk, we will discuss the physics of controlling such small N, noisy collectives, using the interaction between sheep and shepherd dogs as a case study. We focus on two key tasks: 'the drive,' which involves herding the group of sheep together, and 'the shed,' the act of splitting the group into two subgroups. Through mathematical modeling and field observations, we show that the key to controlling these erratic small groups lies in exploiting their inherent stochasticity. Our mechanistic framework not only offers a deeper understanding of animal herd dynamics but also provides valuable insights into controlling dynamic and heterogeneous systems across various disciplines, from swarm robots to public policy.

## Termite soldiers shoot liquid lassos to defend their nests

*Elio Challita, Jacob Harrison, Pankaj Rohilla, Daniel Ames, Christina McDonald, Prateek Sehgal, Jochen Mueller, Saad Bhamla*

The soldier caste of Nasutitermes spp. employs a unique defense mechanism to protect their nests from larger predators, such as ants. They eject a large, sticky liquid lasso from their cone-shaped heads to entangle these predators. Using high-speed imaging and rheological measurements conducted in the Amazon rainforest and Panama, we characterized the fluid dynamics of these termite jets, which are ejected at a speed of $0.32 \pm 13$ m/s. We demonstrate that termites utilize the phenomena of liquid rope coiling and a fluid sewing mechanism to effectively cover their targets. Our data reveal that the termite spit exhibits strain-hardening properties, enabling it to resist deformation under stress. Moreover, beyond the fluid properties, we found that the nozzle geometry of the termite head, as observed through micro-CT scans, reduces the pressure required to eject the viscous fluid at small scales. Inspired by these findings, we developed a 3D-printed nozzle based on the termite's nozzle geometry, which demonstrates similar efficiency in fluid ejection.

## Conserved patterns of modularity in an adaptive radiation of San Salvador Island pupfishes

*HoWan Chan, Emma Colaco, Kory Evans, Christopher Martin*

Adaptive radiations exemplify rapid speciation along ecological lines, often coupling fast lineage and morphological diversification. While ecological drivers are well-studied, structural constraints' role in trait diversification patterns is often overlooked. Trait covariation may guide evolution through increased integration between traits or strengthened modularity within traits. We examined skull modularity in an endemic pupfish adaptive radiation on San Salvador Island, Bahamas, featuring generalist, snail-eating, and scale-eating species. We assessed morphological disparity, integration strength, and modularity patterns across the radiation, lab-reared hybrids, and outgroup species. Results revealed unexpected uniformity in modularity patterns across species, supporting a five-module functional hypothesis: oral jaw, pharyngeal jaw, neurocranium, hyoid apparatus, and hyomandibula. Despite conserved modularity, species showed weak but significantly varying overall between-module integration strengths and significant disparity across cranial regions. Our findings suggest rapid morphological diversification can occur with conserved modularity patterns. We propose that broad-scale modularity patterns are more conserved, while between-module associations are more evolvable across species.

## A new neuroscience model for distributed computation, brain regeneration, and evolution

*Vikram Chandra, Libby Tseng, Karl Hill, Mansi Srivastava*

Our understanding of brain development and function derives primarily from the study of a few model organisms. These animals share features of brain organization that are not universal; many marine invertebrates have fundamentally different brains. Understanding these unfamiliar forms may reveal new principles for neuroscience, and how animal brains might have first evolved. We are developing as a neuroscience model a marine invertebrate with such a brain: the acoel worm Hofstenia miamia.

Hofstenia is a model for whole-body regeneration, and can rebuild a complete brain from virtually any initial tissue configuration. Its brain is primarily a cylindrical network of anastomosing neurites, with no major landmarks or regionalization. Exact brain shape varies substantially across worms and over time, hinting at the absence of stereotyped circuits. Hofstenia is an aggressive predator. Its complex foraging behavior is not affected by amputation of large fractions of the brain or while it reorganizes and regenerates. This suggests that most or all foraging computations occur in a distributed, decentralized manner. How such a brain could function is not well understood.

To study how such distributed computations could be implemented, we are developing high-precision tools to visualize neural circuit wiring, and to measure and perturb neural function and behavior. Together, this enables a research program studying the organizing principles of this diffuse brain, and will inform our understanding of early brain evolution.

## Shark's fin-ger print: Fine scale 3D characterization of shark fins for biomimetics & conservation

*Kanmani Chandra Rajan, Ruien Hu, Viktoriia Kamska, Benjamin Flaum, Mike Schindler, Mason Dean*

The stiffness of shark fins is correlated with species' ecology and the extent of skeletal support (fin radials) at the base of fins. The distal fin, however, is not supported by radials and instead contains collagenous, needle-like structures called ceratotrichia. Though ceratotrichia seem to offer a combination of structural support and flexibility to fins, there is little known about their functional morphology. We characterised the internal anatomy of fins from six carcharhiniform species with focus on anatomical features of ceratotrichia; their interaction with other fin tissues; and their finescale architecture. Ceratotrichia are slender gel-like rods organized in dorsal and ventral layers relative to the fin's bending plane, attached to the skin by a loose connective tissue. Extracted ceratotrichia are broad at the base with tapering tips, with radii ranging from few micrometres in small species (pacific spadenose) to 1 mm in large species (blue sharks). Regardless of animal size, our Dice-μCT and SEM results reveal ceratotrichia in three size classes of different cross-sectional radii (e.g. 100 μm in Pacific spadenose). The radii classes are stacked hierarchically, like wood in a pile, suggesting this arrangement may play a role in controlling dynamic flexibility. This finescale anatomical and structural data can inform species identification (e.g. against illegal trade) and applications in biomimetic hydrofoil design.

## Effects of simulated client color change on cleaner shrimp behavior

*Darcy Chang, Eleanor Caves*

While a rich literature exists on signaling within species, many questions remain about the ecology and evolution of interspecific signals. Reciprocal signaling appears to mediate the mutualism between the cleaner shrimp Ancylomenes pedersoni and "client" reef fish, in which shrimp remove and eat ectoparasites and dead skin from clients. Cleaner shrimp signal their intent to clean by whipping their antennae, and many clients undergo a rapid change to a darker morph after posing for cleaning. Preliminary work indicates that darkening increases a client's likelihood of receiving a cleaning if the cleaner has not yet signaled itself. To investigate client color change in a controlled environment, I simulated client brightness change for live Ancylomenes pedersoni in aquaria. Using black and white laminated paper fish, I simulated changes from white to black, black to white, white to white, and black to black and quantified the effect of color change on various aspects of cleaning behavior, including number of cleaning attempts and cleaning duration. I found that the white to black treatment produced the highest rates of cleaning, providing more robust evidence that rapid darkening is part of a reciprocal communication system, specifically inspiring cleaners to provide cleaning services. This finding suggests further questions about the possible signaling function of the observed variability in client darkening magnitude and pattern, both within and between fish species.

## A dynamically scaled model to study form-function relations in bladderwort, a carnivorous plant

*Nari Chang, Ulrike Muller, Otto Berg*

Carnivorous plants in the genus Utricularia have suction traps that range widely in size and shape, both within and between species, especially the trap entrance. This trap entrance serves as a nozzle, which conditions the suction flow. To explore form-function relations, we examine how nozzle shape relates to suction flow characteristics. However, the naturally small scales of distance (1mm) and time (1ms) present challenges when trying to quantify hydrodynamic performance. Using published data from 130 species, we found that aspect ratio (nozzle diameter to nozzle length) and flare (ratio of outer to inner diameter of the nozzle) correlate with conventional habitat categories (aquatic, terrestrial, epiphytic, and epilithic). Aquatic species have shorter nozzles than terrestrial species, and epiphytic species are more likely to have expanding nozzles. Laboratory measurement on mechanical models furthermore show that nozzle shape affects flow fields under biologically relevant conditions. Velocity and pressure profiles are flatter in flared nozzles than in straight or short channels, but are unaffected by nozzle shape at unrealistically low flow rates. Flow fields (in the absence of prey) were examined by means of a dynamically scaled model with interchangeable nozzles, which allowed for high temporal and spatial resolution particle image velocimetry. Noise was further suppressed by averaging over the artificially uniform suction conditions. Studying factual and counterfactual scenarios provides insights into the functional morphology of small suction feeders.

## Transcriptomic analysis of immune system ontogeny in a temperate coral

*Isabella Changsut, Erin Borbee, Lauren Fuess, Koty Sharp*

Coral diseases have been on the rise globally. Though disease pressure has been hypothesized to impact coral recruitment, the effects of disease on coral recruitment have been largely understudied. In part, this is due to a lack of understanding of baseline coral larval immunity. Here we leveraged the temperate coral, Astrangia poculata to track the development of larval immunity through developmental stages from zygote through planula via gene expression. We collected samples throughout developmental stages during spawning season (peak gametogenesis) in August of 2022. Gene expression patterns suggest a shift from maternal transcription to larval transcription of immune genes. We investigated this pattern by analyzing expression of specific genes associated with maternal and larval transcription. One of the first studies of its kind, our results allow for a greater understanding of the molecular development of the cnidarian immune system throughout development.

## The role of chick development on early-life telomere dynamics in a long-lived seabird

*Sarah Chapman, Kayla Lichtner, Tori Chace, Nicole Joseph, Patricia Jones, Robert Mauck, Mark Haussmann*

The conditions experienced early in life can have physiological effects in both the short and long-term. The biomedical literature has many examples of how variation in food delivery in early-life can have long-lasting effects on health. However, this variation is not generally studied in natural populations. Telomeres—the protective, terminal caps on chromosomes—may act as a physiological indicator of how early-life environment can affect cellular health and biological aging. In nestling Leach's Storm-Petrels (Hydrobates leucorhous) chicks may be fed by one, both, or no parents on any given night. Thus, the nesting ecology of storm-petrels make them an ideal system to better understand how early-life food availability affects telomere dynamics. In the field, chicks were massed daily after reaching 8 days post hatch to quantify food provided during the previous night. Blood cells' telomeres were measured on day 10 and day 30 post hatch using the telomere restriction fragment assay. The proportion of nights in which chicks were fed was $0.72\pm0.06$, receiving $6.40\pm1.12$g of food on average with an average of $1.25\pm0.49$ days between feeds. While telomere length is relatively stable over time in adult animals, telomere's change more quickly during development. This study improves our understanding of how food delivery affects growth and telomere dynamics during early-life, which may have long-term implications on organismal physiology.

## Doubling down on decentralization: visuomotor coordination in the bay scallop *Argopecten irradians*

*Daniel Chappell, Martin (Ric) Wehling, Daniel Speiser*

Complex behaviors are commonly thought to arise from a central condensation of sensory information to form sensory representations, from which information is distributed across the body to guide muscular responses. Can complex behaviors be found in animals without highly centralized sensory-motor network topologies? Vision is commonly thought of as a modality exclusive to cephalized animals, but some taxa deviate from this trend by having numerous visual organs dispersed across their bodies combined with varying degrees of neural centralization. These animals demonstrate surprisingly complex behaviors, but it is unknown if these nervous systems employ visual-motor circuits similar to those found in cephalized animals or if they use novel strategies to efficiently form neural representations and enact behaviors. Bay scallops (Argopecten irradians) have distributed visual systems consisting of dozens of eyes dispersed across their mantle tissues. It was previously thought that scallops peripherally downsample information gathered by their high-resolution eyes to ease the processing burden on their simple nervous systems. We found that bay scallops demonstrate interactive visual behaviors requiring high-resolution neural maps of their surrounding environment which are likely embodied in the somatotopically organized lateral lobes of their visceral ganglia. Scallops serve as a unique model system in which to study the neural basis of distributed vision and to learn how animals effectively sense, process, and behave using a balance of centralized and distributed network topologies.

## C-PHAST: Community phylogenetic analysis at speedy time

*Maya Chari, Michael Alfaro, Jonathan Chang*

The emerging field of spatial phylogenetics allows scientists to understand biodiversityand community ecology with the added lens of deep time. Biodiversity metrics that account for the shared evolutionary history in an ecosystem can give insight into the environmental filters that drive patterns of community assembly, and can help guide conservation efforts toward preservation of functional diversity. Here I present a new method: Community Phylogenetic Analysis at Speedy Time (C-PHAST), which builds on existing frameworks to produce a comprehensive pipeline for analysis of large-scale phylogenetic dispersion and community assembly. I apply this new method to characterize the phylodiversity of birds, plants, squamates, mammals and butterflies that are endemic to California. I create high resolutionvisualizations of the distribution of phylogenetic diversity across these clades within California, and find that patterns of over- and under- dispersion have low relative cross-clade correlation. Cumulative evolutionary history across clades reveals patches of overdispersion in northeastern California, in the southern Palm Springs desert regions, and in select coastal areas. I use the findings of this pipeline to pinpoint unmanaged regions harboring exceptionally high evolutionary history across taxonomic groups as recommendations for future conservation efforts.

## The scaling of anatomy and biomechanics in morphologically disparate domestic dog breeds

*James Charles, Eithne Comerford, Lucy Roberts, Anjali Goswami, Karl Bates*

Selective breeding has made the domestic dog an incredibly morphologically diverse species. However, the degree of geometric similarity between the vast array of breeds, and how this is related to inter-breed differences in gait biomechanics is poorly understood. Here, marker-based motion capture and force plates were used to measure gross body proportions and trotting biomechanics of several breeds including Labradors (n=23), Spaniels (n=21), Shepherds (n=15), Dachshunds (n=9) and Deerhounds (n=7). Computational models of each dog were created in OpenSim to generate spatiotemporal outputs, joint kinematics and moments. While body proportions scaled close to isometry between Labradors, Spaniels and Shepherds (i.e. geometric similarity), Dachshunds and Deerhounds diverged into negative and positive allometry respectively. Significant differences were also seen in terms of both kinematics and spatiotemporal parameters, with Dachshunds trotting with straighter fore and hindlimb postures, longer relative stride lengths and greater Froude numbers than the larger breeds. Overall, these data highlight the need for breed-specific considerations in regards to canine musculoskeletal health, and also suggest that some dog breeds may diverge from typical morphological and biomechanical scaling relationships seen across other vertebrate species.

## Functional organization of two neck muscles driving head movements in flying *Drosophila*

*Payel Chatterjee, Serene Dhawan, Bradley Dickerson*

Gaze stabilization helps animals extract relevant stimuli by minimizing motion blur of the visual field, a particularly important task for flying insects. These animals exhibit minimal eye movements relative to their heads and thus rely on head motion for maintaining a stable gaze. In flies, gaze stabilization is mediated by sensory feedback from both the visual system and the mechanosensory halteres at the level of neck motor neurons. However, previous physiological studies were limited to immobilized flies, leaving open how these modalities combine for both gaze stabilization and redirection maneuvers. To address this, we performed 2-photon imaging of a genetically encoded calcium indicator expressed in the neck muscles of tethered flying Drosophila melanogaster. We specifically imaged from two dorsal neck muscles: the adductors (AD), which may drive head roll; and the oblique horizontal (OH) muscles, which may drive head yaw. Our results reveal that both muscles are active during close-loop stripe fixation and are functionally distinct. Our findings lead to the hypothesis that OH muscles are phasically active, and the AD muscles are tonically active. We further find that most of the flies show a strong positive correlation between the right and left OH muscles, suggesting that these muscles ensure head fixation about the yaw axis by coordinating bilateral activity. Our study therefore provides mechanistic insights of gaze control in flying Drosophila.

## Variation in color perception under sexual selection

*Soumyadeep Chatterjee, Chris Clark*

Tuning of vision to particular wavelengths of light is called spectral tuning. Hummingbirds in the clade, Mellisugini, are sexually dimorphic. Males display their colorful throat feathers, the gorget, to females during courtship displays, which is an important sexual signal. If hummingbirds have undergone spectral tuning to match the peak sensitivity of their eyes to the respective gorget color of the males, this can translate to better perceptual ability in that range of colors. For instance, does a Costa's hummingbird with a purple gorget perceive purple shades better than an Allen's hummingbird with an orange gorget? I am studying differences in perceptual ability between Costa's and Allen's hummingbirds through operant conditioning, color discrimination experiments. Birds are trained to associate a particular shade of color to a food reward and then their ability to discriminate this shade against close shades of the same color is studied. Preliminary data from this study suggests that a bird is better at discriminating conspecific colors. This study will help to determine if spectral tuning under sexual selection leads to a differentiation in color perception. Differentiation in visual signal perception is a driver for rapid speciation. Hence, differences in signal perception between species might have contributed to the rapid speciation seen in this clade.

## Investigating the impacts of elevation on eastern red-backed salamander density and demography

*Isha Chauhan, Stephen Bredin, Priscila de Souza Rothier Duarte, Caroline Goldstein, William Hooker, William Ryerson, Andrew Orkney, Brandon Hedrick*

Climate change has rapidly degraded global biodiversity and environmental health. Mitigating the intensity with which biodiversity is impacted is integral to conservation efforts and maintaining species diversity. Protection is particularly important for amphibians which are especially sensitive to changes in environmental conditions and have suffered substantially as climate change impacts have accelerated. Among amphibians, Plethodon cinereus (red-backed salamander), a species of lungless salamander, has been characterized as a model system for exploring these environmental impacts and ecological shifts. Red-backed salamanders range across a broad latitudinal gradient and survive in a range of macro- and microclimatic regimes. We investigate how microclimatic changes across elevational gradient in Ithaca, New York impact dispersal, range size, density, and space-use of P. cinereus using a spatial capture-recapture framework. We show that salamanders at lower elevations have a temporal shift relative to those at higher elevations and that both groups have the highest activity rates under the same microclimatic conditions. Initial analyses indicate P. cinereus have high prevalence during cooler temperate conditions and rapid declines at higher temperatures. This finding remains consistent with physiological preferences and suggests that P. cinereus may be capable of accommodating temperature increases by shifting its surface activity. Ultimately, the results elucidated from these spatial and temperate differences across elevations offer an understanding of P. cinereus species range and dispersion among climate change for future conservation.

## The tail of myliobatid stingrays: function for controlling body stability

*Julia Chaumel Cerda, Connor White, George Lauder*

Myliobatid stingrays (manta, devil, eagle and, cownoses) swim by oscillating their large pectoral fins and possess a long and slender tail that can reach three times the animal's body length in some species. Although the tail is a defining feature of myliobatids, its effect on locomotion and body stability has not been previously analyzed. This study aims to test whether the elongated tail has a stabilizing effect during myliobatid gliding behavior. We measured tail length relative to body length across myliobatids and, for most species, tails are similar in length to disc width. We then tested the effect of different tail lengths using 3D-printed myliobatid models in a flow tank with increasing flow speeds. Model stability, based on changes in roll, pitch, and yaw, was measured using an accelerometer inserted into the model. We tested three tail lengths: double of the model's disc width (2:1), equal to disc width (1:1), and no tail (0:1). Models with tails were more stable, especially at lower speeds, with no differences between 2:1 and 1:1 tail length. In contrast, models without tails were highly unstable, with increased roll and yaw movements. We conclude that the tail of myliobatid rays can play a significant role in passively stabilizing the body. Understanding the biological roles of ray tails is crucial to discern the principles for efficient oscillatory swimming, gliding, and maneuvering underwater

## Can Large Language Models Help Generate Comparative Structure-Function Relationships?

*Itzel Chavez Martinez, Dhruv Bhate*

In comparative biology, the study of structure-function relationships presents multiple challenges, such as differences in terminology, the time-consuming process of synthesizing literature across different species and biological systems, and the vast and disparate sources that this information is contained in. With Artificial Iintelligence (AI) tools such as LLMs, we can now, in principle, address these challenges. Specifically, LLMs have the potential to perform automated literature reviews, generate hypotheses, and integrate domain knowledge across multiple disciplines. However, the use of LLMs poses questions about the quality and interpretability of the generated data, as well as ethical concerns. In this work, we propose a framework showing how LLMs can play a vital role in the bio-inspired design of engineering materials by generating Knowledge Graphs (KG) that relate Structure to Function to Application. A precursor to abstracting a design principle for a particular engineering application is the formulation of a validated hypothesis relating structure to function. Towards this end, we selected scales, which have evolved in reptiles, mammals, birds, insects and even some plants and fungi, and assessed if LLMs could generate a comparative Structure-Function KG. We did this in three phases: the first was a manual development of this KG by reading literature, the second by prompting ChatGPT as it is widely available today, and the third by controlling the information ChatGPT was permitted to query.

## Micro- and Nanoscale Morphological Features in the Hair of Apis Mellifera

*Itzel Chavez Martinez, Cahit Ozturk, Dhruv Bhate*

In contrast to what is known about flower characteristics that attract pollinators, far less is known about traits that influence pollen transfer directly, which includes pollen and pollinator hair morphology. Bees collect pollen using hairs that cover their bodies, and many have specialized hair structures for pollen capture, cleaning, and storage. The intertwined physical mechanisms that govern pollen-hair interaction include electrostatics, Van der Waal's adhesion, capillary action and mechanical interlocking. In this work, we report results from our high resolution Scanning Electron Microscopy (SEM) study of the hair of Apis mellifera. We image and measure micro- and nanoscale features of the hair, with an emphasis on differences and similarities across hair at different locations on the body of the bee. These features include the base junction of the hair, the nature of its branching and the shape of its terminal end, as well as some previously unreported observations concerning the nature of ridges on the hair shaft. We perform a shape and size comparison of these morphological features between the hair of queen, drone, and worker bees. With an aim to abstracting design principles for bioinspired design of particle trapping hair-like materials, we formulate structure-function hypotheses for the observed nano- and microscale morphological features, setting the stage for the model-driven study of how these features influence the mechanisms of pollen capture, cleaning and storage.

## The potential for short-term acclimatization to daily temperature range (DTR) in tropical corals

*Adrian Cheh, Peter Edmunds*

Thermal priming is a form of acclimatization altering organism phenotype in response to initial thermal regimes that improves survivorship to subsequent thermal stress. This study tested for acclimatization to daily temperature ranges (DTR) in corals as a mechanism supporting thermal priming as a response to high temperature. In 2023, Porites rus and massive Porites spp. from two back reef sites with contrasting DTRs of 0.625°C and 1.040°C in Moorea, French Polynesia, were incubated at 26.71°C and 29.93°C to test for thermal priming associated with DTRs at their collection site. Massive Porites spp. from the high DTR site displayed acclimatization of maximum photochemical efficiency of open RCIIs (Fv/Fm); at 29.93°C, Fv/Fm of corals from the high DTR site was unaffected, but it was reduced 5% in corals from the low DTR site. In 2024, corals from one back reef site were incubated at stable (29°C) versus DTR treatments (2°C and 4°C oscillations) to test for acclimation. After 24 hours, Fv/Fm was depressed 14% under 4°C-DTR relative to 29°C but was indistinguishable between 4°C-DTR and 29°C after 18 days, showing acclimation through Fv/Fm recovery under 4°C-DTR, but not in 2°C-DTR. DTR can reduce impacts of thermal stress on corals by diminishing the reduction in Fv/Fm, but the small effect size and short persistence ($< 18$ d) are unlikely to translate to effects on survivorship under tested regimes.

## Robots for Neuroethology: Robotic Infiltration of Poison Frog Families

*Tony Chen, Lauren O'Connell, Billie Goolsby, Mark Cutkosky, Loranzie Rogers, EmJ Rennich*

Biomimetic robots offer a treasure trove in understanding neuroethology. These robots can mimic the behavior of various animals to act like reliable and repeatable stimuli for neural and behavioral studies. For instance, mimic poison frog (Ranitomeya imitator) tadpoles vibrate intensely to signal nutritional need, yet little is understood about the mechanics of begging behavior or how vibration is neurally processed in amphibians and vertebrates generally. Thus, we developed a tractable method to identify and modify vibrational signals through the use of robotics. First, we identified a characteristic frequency and amplitude specific to tadpole begging. Using measurements of this characteristic motion, we designed and built a tadpole-mimetic robot, TadBot, that mimics this "begging" behavior accurately enough to convince poison frog parents to care for it as they would for a living tadpole. To achieve this goal, TadBot is designed to i) mimic the overall size of tadpoles (ii) isolate any actuator noise and vibrations to reduce disturbances to the poison frog parents, and (ii) have easily modifiable characteristics for behavioral study. More broadly, we present the use of robotics as a method to infiltrate and decipher neural encoding of species-specific signals.

## Out of the dirt: fabrication of cicada-inspired nanostructured engineered surfaces

*Yutao Chen, Marianne Alleyne*

Cicada wings have nanoscale patterns – nanopillars - that were found to convey antibacterial properties. The nanopillars kill bacteria by exerting mechanical forces, however the mechanism behind this phenomenon is still unclear. Previously, inspired by cicada wings, nanopillared polystyrene templates with nanopillars of different heights were fabricated via a nanoimprinting lithography process. Antibacterial testing techniques such as scanning electron microscopy (SEM), LIVE/DEAD staining, and luminescence assay, were then used to test the efficiency of the bacteria killing property of bioinspired polystyrene samples. To determine the killing mechanism we used (1) Focused ion beam (FIB)-SEM on nanopillared polystyrene samples after bacteria inoculation. The bacteria on nanopillared surfaces were sequentially sliced and then 3D reconstructed, revealing the mechanical process behind bacterial deaths; (2) Reactive oxygen species (ROS) were measured to determine the oxidative stress of the bacteria after interacting with nanopillared surfaces; (3) Microfluidic devices incorporating nanopillared surfaces were designed and fabricated to test the shearing force exerted on bacteria by the nanopillars, and observe the killing mechanism in real-time as bacteria in solution come flow through the device. This research shows how surface nanostructure dimensions affect antibacterial properties, and will help us design a robust protocol for testing antibacterial efficiency on engineering samples.

## Bumblebee gobies use vision and their reduced lateral line canal system to find prey

*Shrija Chhetri, Violet Anderson, Djurdjina Jovanovic, Margot Schwalbe*

The lateral line system plays a crucial role in several behaviors, including prey detection. This mechanosensory system helps fish form hydrodynamic images of flow disturbances around its body, allowing the fish to detect nearby flow, and signals emitted by mobile prey. Five types of lateral line canal patterns are found among teleosts, and the functional roles of most of these patterns remain unexplored. Reduced lateral line canal patterns can be found in gobies (∼1360 species) and have a partial or complete absence of bony canals on the skull, no trunk canal along the body, and extensive proliferation of superficial neuromasts on the body. Species with this reduced canal pattern tend to occupy hydrodynamically quiet and/or low-light environments, including some gobies. Here, we describe the reduced lateral line system of bumblebee gobies (Brachygobius sp.) and its role in prey detection. Individual gobies were tasked to find live, mobile prey under light and dark conditions and with an intact or gentamycin-ablated lateral line system. Bumblebee gobies detected prey in both light and dark conditions, and feeding was reduced, especially in the dark, with a disabled lateral line (confirmed by fluorescence microscopy). Thus, we continue to support that the search strategy changed depending on the available sensory systems. This study provides important insights into the functional and ecological significance of lateral line-mediated behavior in species with reduced lateral line canals.

## Flexible coordination of leg muscles in walking Drosophila

*Raveena Chhibber, Lili Karashchuk, Chris Dallmann, Elliott Abe, John Tuthill, Bingni Brunton*

For many animals, legged locomotion is crucial for survival in unpredictable environments. To move the body, premotor circuits coordinate activity in motor neurons, driving muscle contraction. It has previously been challenging to measure the temporal dynamics and functional role of fly leg muscles during walking. Here, we combined the genetic toolkit of the fruit fly with 3D joint tracking to investigate how premotor circuits generate leg kinematics. Using wide-field fluorescence imaging, we measured muscle calcium activity in two antagonistic coxal muscles during walking. We found relative changes in the phase of calcium activity between the two muscles correlated with left and right turns, where larger shifts correlated with larger turns. Unexpectedly, during forward walking, the phase relationships between the coxa muscles varied widely while generating similar kinematics. Specifically, the swing muscle was consistently recruited before the onset of swing, whereas the stance muscle was activated in-phase, non-phasically, or anti-phase with the swing muscle. Our findings suggest that motor neurons driving stance muscle activity may be controlled independently from the swing muscle. We hypothesize that the swing muscle is activated at a fixed phase within the step cycle, while the stance muscle may be flexibly recruited for fine-tuning of kinematics or force production. We are now leveraging a synapse-level EM dataset of premotor circuits to understand how neural circuits implement the flexible control of coxa muscles.

## Analyzing turning dynamics of a sea turtle-inspired robot on terrestrial environments

*Nnamdi Chikere, Frank Fish, Yasemin Ozkan-Aydin*

Sea turtles are renowned for their maneuverability across varied aquatic and coastal terrains. While turning behavior is crucial in aquatic environments, it is equally vital for terrestrial locomotion by hatchlings that must quickly navigate obstacle-rich terrain on their way to the sea. This study introduces a robotic prototype that emulates the turning strategies of sea turtles to optimize turning rate and energy consumption across diverse terrestrial surfaces. We explored two turning methods: using only the foreflippers and engaging all flippers. On dry sand, using all flippers significantly improved the robot's maneuverability, achieving faster and more stable rotational movements than foreflipper-only actuation. With all flippers engaged, the robot achieved a mean rotational speed of 18.36 ± 0.16 deg/s compared to 11.40 ± 0.28 deg/s using only the foreflippers. The robot's maneuverability increased from 15.89 ± 0.41 deg/cycle with foreflipper-only actuation to 40 deg/cycle when all flippers were engaged. The cost of transport (P/mgv) was slightly higher when all flippers were used, at 2.47 ± 0.03, compared to 2.36 ± 0.05 when only the foreflippers were actuated. Similar patterns were observed on various rocky terrains, indicating a trade-off between enhanced maneuverability and increased energy cost consistent across different environments. These findings contribute to understanding hatchling sea turtle locomotion and developing robots with enhanced navigational capabilities, making them equipped for effective deployment in diverse and challenging real-world environments.

## Sea turtle-inspired adaptive gait strategies for multi-terrain robotic locomotion

*Nnamdi Chikere, John McElroy, Yasemin Ozkan-Aydin*

Inspired by sea turtles' navigation through diverse environments using their flippers—gliding effortlessly through oceans and traversing rugged shores—we developed a servo-driven, 3D printed sea turtle hatchling-like robot (L=12.5cm, W=10.8cm, six joints, 513gr) with four flippers of varying stiffness to study how different morphological parameters and gait patterns impact performance on complex terrains. We evaluated the performance of various gaits on surfaces ranging from sandy shores to rocky trails, using both soft and rigid flippers. The results show that adapting gait patterns and flipper stiffness to terrain types consistently achieved enhanced forward displacement compared to trials using fixed gaits with both soft and rigid flippers. With soft flippers, we obtained 0.66 ± 0.01 body lengths/cycle (BL/cycle), with the adaptive gait surpassing the alternating 'diagonal gait' at 0.59 ± 0.01 BL/cycle and the synchronous 'all together gait' at 0.40 ± 0.01 BL/cycle. This pattern was consistent even when employing rigid flippers, with the adaptive gait configuration leading at 0.67 ± 0.01 BL/cycle. These findings highlight the advantages of integrating adaptive gait patterns and appendage stiffness into robotic designs, markedly enhancing navigation and endurance in unpredictable and complex environmentsspired by sea turtles' navigation through

## A bioinspired zoospore robot for high speed locomotion in low Reynolds number environments

*Nnamdi Chikere, Quang Tran, Sofia Lozano Voticky, Yasemin Ozkan-Aydin*

At low Reynolds numbers, where viscous forces predominate over inertial forces, traditional locomotion strategies become ineffective [Purcell, 1977]. Microorganisms have evolved specialized structures, such as cilia and flagella, to maneuver efficiently within these viscous environments. Among these organisms, Phytophthora zoospores demonstrate unique locomotion mechanisms that allow them to rapidly spread and attack new hosts while expending minimal energy [Tran et al., 2022]. In this study, we present the design, fabrication, and testing of a biflagellated zoospore-inspired robot, focusing on its forward locomotion at low Reynolds numbers. The robot's design incorporates flexible appendages and oscillatory propulsion mechanisms, emulating the swimming behavior observed in zoospores. Our experiments and theoretical model demonstrate that increasing the oscillation frequency from 2.05 Hz to 5.28 Hz significantly increases propulsion speed, with the highest speed reaching 3.41 cm/s. Our findings also suggest that flagella length strongly influences forward speed; 12-cm flagella beating at 4.41 Hz achieve a speed of 3.32 cm/s, 3.5 times faster than 6.5-cm flagella. Additionally, the anterior flagellum was found to have a greater impact on propulsion speed than the posterior flagellum. Our study not only contributes to the development of advanced microscale robotic systems with applications in medical, environmental, and industrial fields but also provides a valuable platform for studying biological zoospores.

## The evolution and development of arthropod tagmata

*Ariel Chipman*

The segmented body plan is one of the hallmarks of the arthropod body plan. Morphological segments are formed during embryogenesis, through a complex procedure involving the activation of a series of gene regulatory networks. The segments of the arthropod body are organized into functional units known as tagmata, and these tagmata are different among the arthropod classes (e.g. head, thorax and abdomen in insects; prosoma and opisthosoma in arachnids). Based on embryological work on segment generation in a number of arthropod species, coupled with a survey of classical descriptions of arthropod development, I suggest a new framework for the evolution of arthropod tagmata. The ancestral condition involves three developmental tagmata: The pre-gnathal segments, a tagma that is formed within a pre-existing developmental field and a tagma that is formed through the activity of a segment-addition zone, that may be embryonic or post-embryonic. These embryonic tagmata may fuse post-embryonically to generate more complex tagmata. This framework is consistent with the evolution of tagmosis seen in the early arthropod fossil record. It also calls for a re-thinking of the decades-old division of arthropod development into short-germ vs. long-germ development, as this distinction highlights a relatively minor aspect of the segmentation and tagmosis process.

## Integrating non-invasive endocrine sampling into conservation monitoring

*Helen Chmura, Mattina Alonge, Creagh Breuner*

Conservation monitoring programs often face the challenge of evaluating the status of species that are rare and cryptic. Non-invasive samples, from hair, scat, and other sources, can provide datastreams that guide managers in the absence of direct contact with target species. These samples can be used not only to determine presence/ absence of species of interest, but also evaluate the physiological status of individuals. While information about an individual's health, reproductive status, or other physiological markers can augment assessments of population status, there remains a gulf between academic studies identifying promising approaches and implementation of these tools in routine management activities. We focus on one tool utilized by conservation physiologists, endocrine panels built from non-invasively collected samples, and review the literature to identify suggested and actual applications of this approach to conservation and management. We describe our ongoing work to integrate endocrine sampling into an existing monitoring program for rare forest meso-carnivores in the Rocky Mountains. Approaches that leverage multiple data types from non-invasive samples will be important for the conservation of rare and cryptic species.

## Non-invasive 3D tracking of Water-Hopping Mudskippers in natural habitats

*Daehyun Choi, Nami Ha, Ulmar Grafe, Saad Bhamla*

Obtaining 3D trajectories of animal locomotion in their natural habitat is challenging due to limitations in camera setup, calibration, and lighting. Additionally, complex equipment and researcher-animal interactions often cause animals to flee, leading to unnatural behavior. To address this, our study aims to develop a minimalistic, non-invasive technique for capturing 3D trajectories of water-hopping mudskippers in the field using two wide-angle commercial cameras, two calibration pads, and a smartphone. Using 3D reconstruction software (Polycam) with a smartphone (Samsung), we reconstructed 3d position of cameras, calibration pads, and the surrounding terrain. Two wide-angle cameras (GoPro 12) captured the mudskippers' hopping kinematics at 240 Hz. The 3D position at each time step was estimated by the 3D reconstruction algorithm (SMART-MLOS) with known positions, using calibration pads and an in-house camera locating algorithm (Matlab). This technique was validated through field research in Incheon (South Korea) and Brunei Bay (Brunei) with two species of mudskippers: Periophthalmus modestus and Periophthalmus argentilineatus. Our findings indicate that the direction of escape is consistent across species. The present technique can be extended for broader application across various aquatic species, enabling more detailed behavioral studies in diverse environments and offering potential advancements in conservation efforts by providing accurate, non-invasive monitoring of animal behavior in their natural habitats.

## Effects of Genipin on Tendon Mechanical Properties

*Hanna Chow, Kelli Chung, Miles Valencia, Manny Azizi*

Genipin is an exogenous crosslinking agent that has been shown to change the mechanical properties of collagenous tissues like tendons. These changes in tendon properties are similar to maturation effects, and paired with its low cytotoxicity, genipin is a promising compound for applications in tendon rehabilitation and the development of phenotypic models for maturation and aging. To explore the effects of genipin tendons in animals just past skeletal maturity, we collected tendon fascicles from young adult (6-months) rat tail tendons and stored them at -20 degrees until mechanically tested. One group of tendons were incubated in genipin for 4.5 hours, and another group was included without treatment to act as controls. All tendon fascicles were secured to an experimental rig and subjected to a series of mechanical tests including cyclic loading, stress relaxation, and ramp to failure tests. Preliminary results suggest that both groups had similar failure strain but that the treatment group showed higher hysteresis and lower failure strain compared to the control group. Our results suggest that genipin has variable effects on tendons in early adulthood. Future research will include an advanced aged group to further understand how aging impacts the effects of genipin on tendon mechanical properties.

## In vivo muscle-tendon dynamics in response to a novel substrate perturbation during bipedal running

*Brooke Christensen, Monica Daley*

The natural world is complex. When an animal steps on a soft substrate, such as sand or mud, mechanical energy can be dissipated. Substrate energy dissipation creates an energy imbalance and a stability challenge. Here, we develop a simple, physical model of linear substrate energy loss, enabling us to perturb mechanical energy in the stance phase of running without altering the preceding flight phase or initial contact dynamics. Using this framework, we collected in vivo muscle data as guinea fowl (Numida meleagris; N = 10) ran across an enclosed, custom trackway under several perturbation conditions. We surgically implanted the digital flexor muscles of digits II and III with sonomicrometry crystals and EMG electrodes to record fascicle length and muscle activation, respectively. To record tendon force, we surgically implanted a force transducer onto each digital flexor tendon. We expect both of these muscles to function primarily as brakes to dissipate mechanical energy in steady locomotion. Based on the hypothesis that these muscles help regulate energy at the leg-substrate interface, we predict that the magnitude of energy dissipation rapidly decreases during perturbed steps to accommodate substrate energy loss. Preliminary results support our hypothesis and indicate a shift from brake like function during level, steady locomotion to strut-like function during strides perturbed by rapid energy loss. NSF DBI-2319710.

## Reduced energy expenditure facilitates mass gain in brown bears

*Amelia Christian, Charles Robbins, Troy Tollefson, Anthony Carnahan, Jessie McCleary-Smith, Perry Barboza*

Brown bears (Ursus arctos) fatten before winter, but mass gain depends on the difference between energy expenditure and digestible energy intakes. We hypothesized that energy expenditures would increase with food intake due to diet-induced thermogenesis (DIT), and with the metabolism of excess N from diets of high protein content. We fed adult female bears three protein concentrations (10, 20, 40% of dry matter) at two intakes (100% and 200% predicted maintenance) in three periods (May, July, and September). Bears were dosed with doubly-labelled water ([2H]2[18O]) to measure energy expenditure at low physical activity in small indoor-outdoor enclosures. Bears gained more mass at higher digestible intakes (100%—6.8 ± 0.8, 200%—18.6 ± 0.9 g/kg75/day), but also expended 30% more energy that was probably associated with DIT. Digestible energy intake was similar on the low and high protein diets (0.92 —0.96 MJ/kg75/day) but higher on the medium protein (1.04 MJ/kg75/day). Energy expenditure declined over summer (May—1.01 ± 0.08, July—0.70 ± 0.05, September—0.46 ± 0.07 MJ/kg75/day) without any effect of diet. The difference between energy intake and expenditure therefore increased over summer. Brown bears can gain mass throughout summer, but are most efficient at fattening when energy expenditures decline in late summer, especially if they can select moderate protein concentrations from abundant foods such as berries and salmon.

## Echinobase: an orthology resource for echinoderm research.

*Nicholas Christodoulides, Veronica Hinman, Macie Chess, Cheryl Telmer, Kamran Karimi, Peter Vize, Sergei Agalakov, Stanley Chu, Troy Pells, Dong Zhou Wang, Vaneet Lotay, Bradley Arshinoff, Charles Ettensohn*

Echinoderms, such as sea urchins, sea cucumbers, and sea stars, have long been model organisms in developmental biology and gene regulatory research. Echinobase (www.echinobase.org) supports the echinoderm research community by hosting genome assemblies, functional genomic data, and other resources. It shares servers and databases with Xenbase, utilizing open-source systems like Ubuntu, Apache Tomcat, and PostgreSQL. Over 38,000 gene pages offer search and BLAST tools, gene model names, curated reagents, related publications, GO terms, expression data, and multispecies orthology built on prediction approaches used in the DRSC Integrative Ortholog Prediction Tool (DIOPT). Orthology is crucial not only for understanding evolutionary relationships within echinoderms but also for accurate gene naming and effective comparisons across species in broader studies. Genomic resources from newly sequenced species are continually being integrated, with updates to annotations and orthology data. For instance, recent analyses between Lytechinus variegatus and the newly added Lytechinus pictus revealed that 92% of orthogroups contain orthologs in both species, while species-specific orthogroups highlight genetic divergence within the genus. Additionally, the Echinoderm Anatomical Ontology (ECAO) has been developed with standardized anatomy terms for developmental stages and parts organized into a hierarchy, with a visualization tool to graph relationships between anatomical structures and label associated functional genomic data. Echinobase's collaboration with Xenbase serves as a model for establishing advanced, cost-effective organism databases. Echinobase is funded by NICHD P41 HD095831.

## Material Properties of Kangaroo and Lab Rat Tail Tendons

*Kelli Chung, Hanna Chow, Miles Valencia, Craig McGowan, Manny Azizi*

Tendons are primarily composed of collagen fibers that stretch and release elastic energy from muscle contractions to bones during locomotion. Utilization of these elastic mechanisms vary between species, but the translation from variation to function is still being explored. We use variation in tail function to better understand variation in mechanical properties of tendons. We compare tendon properties of two rodent species: lab rats (Rattus sp. BNx344) and kangaroo rats (Dipodomys deserti). Kangaroo rats have been observed to swing their tail while airborne during escape jumps to stabilize their bodies. To assess tendon materials properties, we conducted cyclic-loading, stress-relaxation, and ramp-to-failure tests on isolated tail tendon fascicles. Preliminary results show that kangaroo rats reach failure at higher strains compared to lab rats. Additionally, lab rats generally have a higher stress-relaxation than kangaroo rats highlighting differences in viscoelastic properties. The results of this study aim to reveal the changes in the mechanical properties of tendons associated with changes in function.

## Coping with rapidly warming temperatures: the roles of plasticity and adaptation in a coldwater frog

*Amanda Cicchino*

As a consequence of climate change, global temperatures are continuing to increase in mean and in variance. Furthermore, extreme climatic events (e.g., wildfires and heatwaves) are becoming more common and more severe. To physiologically cope with these temperature changes in situ, populations can respond via plasticity or evolution in physiological traits. Therefore, quantifying the magnitude of plasticity and evolutionary potential in thermal physiological traits among populations is key to understanding their ability to cope with warming temperatures. However, it remains unclear how these responses may constrain or facilitate future responses to temperature change. Here, we present the results of our studies investigating the physiological coping capacity of a coldwater frog (Ascaphus spp.) to warming temperatures and demonstrate the impacts that two extreme climatic events had on these populations. Specifically, we estimate plasticity and evolutionary potential in upper thermal tolerance limits (CTmax) among tailed frog populations occupying varying thermal environments. We then demonstrate the differing roles of plasticity and evolution in the persistence of populations through two extreme climatic events – a wildfire and a heatwave. Lastly, we highlight the lasting impacts these responses have had on estimates of physiological vulnerability to warming temperatures among these populations and show how populations may respond to future extreme climatic events.

## Adaptations for extreme ventilatory mechanics in whale lung airway morphology and flow patterns

*Robert Cieri, Robert Shadwick, Marina Piscitelli-Doshkov, Merryn Tawhai*

The pulmonary systems of Cetaceans are the largest in evolutionary history and tell a fascinating story about adaptation to marine life. Challenges to lung design in cetaceans include extreme body size, the repeated collapse and reinflation of lungs due to external pressure during diving, and extreme ventilatory dynamics due to exceptionally short breaths and high tidal volumes. Using morphological analysis of pulmonary airways segmented from computed tomography (CT) scans of inflated lungs from 13 species, we show that airway morphology differs substantially from terrestrial mammals and varies among cetacean species. One main finding is that the conducting airways in deep-diving, slow-ventilating beaked whales (Ziphiidae) are relatively larger than those in shallow-diving, fast-ventilating dolphins (Delphinidae), suggesting that the need to store lung gas in the primary airways during diving may be a more important selective pressure than maximizing flow rates. By using computational fluid dynamics simulations built using one-dimensional tree-growing algorithms to extend the pulmonary tree down to the acini, we show that branching angles and diameter ratios evolved to enable extremely fast and short ventilation in cetaceans. Combining our airway sophisticated models with LiDAR/photogrammetry models of lung anatomy from species which are too large to CT scan, we can perform an allometric analysis of airway shape and size in cetaceans and simulate how breathing works in the largest lungs of all time.

## Fighting-related injuries do not affect mate choice in the giant mesquite bug

*Lauren Cirino, Zachary Emberts, Isaac McEvoy*

Females often choose high-quality mates as they may confer benefits to the female. One way male quality may decline is due to the injuries that they can acquire during male-male combat. Females might assess males based on injury since injuries place energic demands on the body that could reduce their reproductive output. Thus, females might make mating decisions based on whether males have acquired these fighting-related injuries. Here, we tested this injury-mediated female mate choice hypothesis using the giant mesquite bug, Pachylis neocalifornicus (Hemiptera: Coreidae). This hypothesis predicts that females will choose uninjured males over injured males. We simulated non-lethal injuries that males could acquire during male-male contests and assayed mate choice. We compared mate choice of the injury group to a control group and found that fighting-related injuries did not affect mate choice. However, females were more likely to mate with males that had large weapons while males were more likely to make mating attempts with large-bodied females. Our results do not support the injury-mediated mate choice hypothesis. Thus, other factors, besides fighting-related injuries, appear to have a larger role in determining mating behavior patterns in this species.

## Burying Batoidea: impact of body shape, rigidity, and sediment size on batoid burial performance

*Kaitlyn Cisz, Charbel El Khoury, Cassandra Donatelli, Matthew Kolmann, Olivia Hawkins, Sarah Arnette*

Batoidea (skates and rays) is the most diverse group of Chondrichthyans. The nearly six-hundred species are dorsoventrally flattened and occupy diverse habitats varying in salinity, depth, and substrate type. Although swimming behaviors and kinematics have been explored in several morphologically diverse batoid species, burial is seemingly a pervasive behavior. Benthic batoids bury to avoid predation and to shield themselves from abiotic assaults like extreme wave action. Pelagic batoids exhibit modified burial via "pitting" behavior for feeding on buried bivalves. The purpose of this study is to understand the mechanisms impacting burial performance; quantifying 1) body shape, 2) body rigidity, and 3) sediment size on burial and the extraction force once buried. 3D- printed skeletons cast in EcoFlex-50 were inspired by radiographs from five species, and a linear actuator was used to simulate burial; an IMADA force transducer was used to measure extraction forces. Results indicate that body shape and rigidity, both positively impact extraction forces. Additionally, in fine-grain sediment (i.e, mud-like), the extraction force for each model increases, yet body shape and rigidity are not statistically significant. For benthic batoids burying using high frequency undulations, the extraction force and overall burial performance are high, indicating a positive tradeoff in the energy required to bury and unbury. For pelagic batoids, semi-burying to feed, the extraction force and overall burial performance is lower, indicating energy-efficiency.

## The evolution of an owl-like auditory system in harriers

*Sara Citron, Cristian Andres Gutierrez-Ibanez, Aubrey Keirnan, Vera Weisbecker, Douglas Wylie, Andrew Iwaniuk*

Hearing is crucial for predators to detect hidden prey. Owls are perhaps the best example of predators with extreme auditory abilities and anatomical specializations that enhance prey localization by sound alone. Such specializations include enlarged acoustic meatus (bony ears), asymmetrical ears, and enlarged auditory brain nuclei. Harriers (Accipitridae, Circus spp.), medium-sized diurnal hawks, have similar sound-based hunting strategies and abilities to localize sound, but whether they have the same anatomical specializations as owls remains unknown. We provide a quantitative analysis of the harrier's auditory system, combining histology and microCT scanning to analyze both brain and skull anatomy. Harriers greatly differ from other hawks in having enlarged acoustic meatus and expanded auditory brainstem nuclei (nucleus magnocellularis and nucleus laminaris, which are up to 3x and 12x larger than in other hawks) that are comparable to that of owls. However, harriers do not show obvious ears asymmetry, nor expansion of other auditory nuclei that are enlarged in owls. We integrate hunting behaviour, activity pattern and known hearing mechanisms to investigate the reasons behind these differences. Overall, our data support the convergent evolution of the auditory system in owls and harriers, but also underscore the complexity of the relationship between sensory specializations and behaviour.

## Turn around: every now and then fish turn a little bit differently

*Andrew Clark, Eric Tytell*

When turning, fish experience a physical dilemma: by keeping their body straight, they are able to generate larger amounts of torque using their tail because their lever arm is long, but they also have a larger rotational moment of inertia. Alternatively, by bending their body, they are able to reduce their moment of inertia, but also reduce the lever arm for generating torque. To better understand this tradeoff, we studied turning in bluegill sunfish and asked whether slow and fast turns are kinematically distinct, or whether a fast turn is simply a slow turn at a higher speed. Using a system that elicits repeatable turns at a controlled speed, we recorded 75 slow and 75 fast turns across 5 individuals. In fast turns, fish maximize torque first and then minimize moment of inertia, while in slower turns, the pattern is more variable but they often reverse the fast turn pattern, with minimum moment of inertia first followed by maximum torque. Thus, the turns appear to be kinematically distinct from each other. We also quantified the relationship between moment of inertia and angular velocity and explored how fish anchor their caudal fins while maximizing their anterior angular velocity.

## Wing sounds of the Bearded Tachuri: flutter with a twist

*Chris Clark, Juan Areta, Emilio Jordan*

The Bearded Tachuri (Polystictus pectoralis) is a flycatcher that breeds in the Pampas of Argentina. Males defend territories acoustically, by producing a combination of vocalizations and a loud wing sound that sounds like a loud bleating. While this wing sound is usually produced during aerial displays that are hard to video record, they sometimes produce it while perched, in full sun. Therefore, it was possible to film their displays at $>$ 30,000 fps. Acoustic analysis of the bleating sound revealed three frequencies of interest: a dominant frequncy of about 3kHz, an interaction frequency of about 300 hz, and the sound is pulsed at 33 Hz, the wingbeat frequency. The ultra-high speed videos taken in the field revealed that wing feathers P5, P6 and P7 flutter with a precise phasic relationship at 300 Hz, thus flutter is the source of the interaction frequency, but did not reveal the 3kHz sound. Wind tunnel tests of just the feathers reproduced the sound and revealed acoustic interactions between the feathers, representing yet another way that aeroelastic flutter can generate loud sounds in bird wings.

## Fitness plasticity tradeoffs under temperature extremes: linking epigenetics and microbial load

*Mikayla Clark, Marie Strader*

Environmental changes in marine ecosystems pose risks of population decline and extinction for many cnidarian species. Cassiopea spp., however, exhibit remarkable phenotypic plasticity allowing them to persist and thrive within a broader thermal range than other symbiotic cnidarians, although the underlying mechanisms remain unknown. We find that polyps reared at ambient (28°C) and high temperatures (33°C) prioritize asexual proliferation through budding and strobilation at the expense of growth. In contrast, polyps reared at lower temperatures (20°C) prioritize growth and lose the ability to strobilate, reproducing solely through budding. We also observe that microbial load, when combined with heat stress, impacts fitness by reducing total asexual reproduction, the size of ephyra produced, and survivability post-strobilation. As microbes can influence both host physiological traits and epigenome, we additionally present an initial exploration into the epigenome of Cassiopea polyps, the role that temperature and microbial load play in shaping its landscape, and how it links to temperature-mediated fitness traits. Together, this study characterizes the mechanistic links between temperature, microbes, and organismal fitness at the molecular level, ultimately offering insights into how marine organisms cope with global change.

## Mechanisms of extreme survival: Uncovering how tardigrades can tolerate extreme radiation

*Courtney Clark-Hachtel, Jonathan Hibshman, Tristan De Buysscher, Evan Stair, Leslie Hicks, Bob Goldstein*

Tardigrades can survive remarkable doses of ionizing radiation (IR), up to about 1000 times the lethal dose for humans. How they do so is incompletely understood. We found that the tardigrade Hypsibius exemplaris suffers DNA damage upon irradiation, but damage is repaired. We used RNA sequencing to identify H. exemplaris genes induced by IR and found that these tardigrades massively upregulate specific DNA repair pathway components in response to IR. This upregulation is extreme – making some DNA repair transcripts among the most abundant transcripts in the animal. These results suggested that increased expression of these genes might contribute to an organism's survival in the face of IR. To test this hypothesis, we expressed some of these DNA repair pathway genes in E. coli. We found that increased expression of some repair genes can suffice to increase radiation tolerance. We also show that at least one such gene is important for tardigrade radiation tolerance. These findings suggest that tardigrades have mechanisms for sensing IR-induced DNA damage and for robustly increasing the expression of specific DNA repair pathways in response. We are currently expanding our IR tolerance research beyond traditionally used tardigrade species – an endeavor that will expand our understanding of the mechanisms that animals use to maintain DNA integrity under destructive conditions and provide potential new routes forward to improving DNA stability in other systems.

## Effects of acute stress on liver insulin-like growth factor-1 (Igf1) pathways in black rockfish

*Eva Claussen, Zoey Dale, Julianne Santos, Janae Shew, Sean Lema*

Elevated cortisol contributes to reduced growth in stressed fishes, and yet the mechanisms by which cortisol exerts growth-inhibiting effects are not fully clear. Somatic growth in fishes and other vertebrates is controlled by several hormones including insulin-like growth factor-1 (Igf1). Here, we examined how acute stress affects Igf1 pathways in black rockfish (Sebastes melanops), a nearshore marine groundfish. Rockfish were maintained for 56 days under two feeding amounts: an ad lib food ration (6% dry feed mass per fish mass per day), or a restricted feed ration (0.5% feed mass). Fish in both feeding groups were then either sampled directly from their tanks (baseline, pre-stressor treatment), or netting and handled, returned to their tank, and then sampled 70 min after initial netting (stressed treatment). Rockfish under restricted food showed slower mass-specific growth, lower body condition, and reduced liver hepatosomatic index (HSI) values. While liver transcript abundance of the igf1 gene was unaffected by food availability or acute stress, gene expression for the Igf1 binding protein (Igfbp) igfbp1a was elevated in the liver of fish experiencing restricted food. Liver igfbp1a mRNA levels also increased after the acute handling stress in both food ration groups. Igfbp1a is thought to have inhibitory effects on Igf1 action. These findings suggest that shifts in inhibitory Igfbp expression may modulate Igf1 regulation of somatic growth following acute stressor exposure.

## Plasticity of upper thermal tolerance varies with latitude in brown anoles (*Anolis sagrei*)

*Ian Clifton, Leah Bakewell, Noah Gripshover, Elizabeth Hoffman, Kelly Wuthrich, Christian Cox*

Due to the range of temperatures experienced in seasonal environments, selection should favor organisms with more labile physiologies. Interspecific comparisons between tropical and temperate congeners largely support this prediction, with tropical species generally exhibiting less thermal plasticity than more temperate congeners. Brown anoles (Anolis sagrei) present a unique opportunity to explore the evolution of thermal plasticity due to their wide latitudinal distribution. We compared the upper thermal tolerance limit and plasticity of thermal tolerance in brown anoles from three populations along a latitudinal gradient in FL, USA. As brown anoles encounter more seasonal environments in their northern expansion, the ability to modulate thermal physiology becomes more important for fitness. We therefore predicted that lizards from the northern population would be more plastic than more southern populations. While we found no differences in upper thermal tolerance limits among the three populations, we did find that anoles from the three populations differed in their responses to acute heat stress. Brown anoles from the northern-most population displayed a significant increase in their upper thermal tolerance after experiencing acute heat stress while brown anoles from the southern-most population exhibited a slight decline in their upper thermal tolerance limit. Our results suggest that plasticity has evolved rapidly as brown anoles have pushed northward, and this plasticity may play a role in their continued northward expansion.

## Dormant but Stressed: Transcriptomic Responses of Diapausing Embryos Exposed to Anoxia

*Patrick Clouser, Jason Podrabsky*

Diapausing embryos of the annual killifish Austrofundulus limnaeus have been shown to survive anoxia with an LT50 of 65 days at 25°C, making them one of the most anoxia tolerant vertebrates on the planet. Diapause dormancy occurs under conditions conducive to normal development, and stress tolerance almost always co-occurs with diapause. It is assumed diapausing embryos "prepare" for stress as part of a gene expression program as they enter dormancy, and there is substantial evidence supporting the accumulation of molecular and chemical chaperones, and the alteration of metabolic pathways during the entry phase of diapause. However, few studies have profiled global responses in gene expression to stress in diapausing embryos. In this study we challenge diapausing embryos with anoxic stress to test the hypothesis that diapausing embryos are already poised to survive stress and will lack a canonical gene expression response to anoxia. RNASeq and gene ontology analysis of diapausing embryos exposed to 24h of anoxia and 24h of aerobic recovery from anoxia was performed. Results indicate a robust transcriptomic response to anoxia that activates several molecular pathways such as heat shock response, integrated stress response, and p38MAP kinase signaling. We identify regulator of G protein signaling 2 (rgs2) and taxilin gamma (txlng) as immediate moderators of the anoxic response. These data provide new insights into the relationship between dormancy and stress tolerance during diapause.

## Swimming in early vertebrates: exploring the hydrodynamics of Sacabambaspis

*Samuel Coatham, Lauren Sallan, Marco Rosti, Alan Pradel, Ivan Sansom*

As one of the earliest known vertebrates, the Ordovician jawless fish Sacabambaspis represents a rare opportunity to understand life at the dawn of vertebrate evolution. Well-preserved specimens provide critical insights into its morphology but raise key questions about its locomotion. How did Sacabambaspis steer and stop while swimming, in the absence of any paired fins? Did its elongated horizontal tail lobe serve as a stabilizer? Could the broad, rounded head shield interact with the benthic substrate to generate ground effect forces, thereby influencing its ecology?

To address these questions, we employed a combination of computational fluid dynamics (CFD) and experimental particle image velocimetry (PIV). A 3D digital reconstruction of Sacabambaspis was modeled in a computational fluid domain, where simulations were performed evaluating hydrodynamic parameters across various angles of attack, substrate proximities, and flow velocities. Complementary experiments in a flume tank using a 3D-printed model enabled detailed PIV analysis of flow dynamics around the head shield. Additional turbulence modeling evaluated the potential stabilizing effect of the trailing lobe on a gliding bluff body, before specific application to Sacabambaspis.

This study represents the first investigation into the locomotion of Sacabambaspis, offering significant insights into ancestral swimming patterns and biomechanics of early vertebrates.

## Optimizing dietary reconstruction in fossil primates: a multivariate, machine learning approach

*Savannah Cobb, Darrell La, Siobhán Cooke*

In primates, diet is intrinsically linked with anatomy, behavior, and sociality. As dietary changes are hypothesized to drive major evolutionary changes, investigating dietary ecology is key to understanding the biology of both living and extinct primates. Historically, studies relied on singular dental elements (e.g., molars) to reconstruct diets of fossil primates based on established form-function relationships. However, each tooth evolves under distinctive ecological and functional pressures, offering unique insights into dietary ecology. We propose an integrative, multivariate approach incorporating multiple dental elements to optimize dietary reconstructions and enhance the information that we may glean about fossil dietary ecologies.

We measured ecologically-relevant traits on molars, premolars, and incisors (e.g., measure of sharpness, cusp height) for a sample (n>250) across 33 genera of crown anthropoid primates, the group containing the last common ancestor of monkeys and apes and all its descendants. We developed models to infer broad dietary category (e.g., generalized frugivore, hard-object feeder) and estimate annual consumption of tough foliage using machine learning techniques (e.g., Random Forest), which have revolutionized predictive modeling in other fields. Dietary classifications of extant primates were highly accurate (>70%) as were regressions inferring dietary foliage (MAE=11). Our models were used to reconstruct diet for a sample of fossil anthropoids.

Our study integrates evolutionary biology, anatomy, and computational methods, and offers new insights into the factors driving evolutionary radiations in primates.

## Effect of cold dormancy vs constant growth on mitochondria density and telomeres in gopher tortoises

*Chelsea Cochran, Anet Filipova, Ali Amer, Ericha Shelton-Nix, Jeff Goessling, Tonia Schwartz*

Headstarting is a conservation technique that raises animals in captivity to increase early-life survival. The gopher tortoise (Gopherus polyphemus), a threatened species inhabiting the Southeast United States, is a keystone species to longleaf pine sand hill ecosystems. In efforts to support wild populations, headstarting is currently used on gopher tortoises where they are often maintained under constant warm, fast-growth environments for one or more years. Thereby, unlike their wild counterparts, headstarted gopher tortoises do not undergo their early-life cold dormancy. The long-term impacts of missing this physiologically significant event on metabolic parameters and life history trade-offs are unknown. We conducted a headstart experiment, splitting clutches between a (1) constant warm fast-growth treatment, and (2) a simulated cold dormancy treatment. We use qPCR to quantify the number of mitochondrial genomes and telomeric repeats before, during, 2 weeks after, and 3 months after treatment for both groups. We predict that the fast-growth treatment will have a lasting effect to decrease telomere length and increase mitochondrial density, relative to the cold treatment. We discuss the results in the context of growth trajectories for each treatment group and the implication for effects on life-history and population trajectory. By investigating early-life effects on energy dynamics, we aim to optimize headstarting procedures and improve conservation methods.

## The effects of *Mycoplasma gallisepticum* on plumage coloration of eastern bluebirds

*Elizabeth Cochrane, Hailey Freeman, Taylor Kinchen, Jennifer Grindstaff*

For sexually dimorphic bird species, plumage coloration acts as an honest intraspecific signal of quality. Individuals with higher immunocompetence have more colorful plumage. However, when infected with a pathogen, an individual's physiology can be impacted with consequences for plumage coloration. Mycoplasma gallisepticum (MG) is an important pathogen most recognized for its effects on domestic chickens and wild House Finches (Haemorhous mexicanus). Individuals infected with MG may contract upper respiratory disease and conjunctivitis. However, other species, such as Eastern Bluebirds, do not experience symptoms, and it is unclear how MG may affect their physiology. We used a wild population of Eastern Bluebirds (Sialia sialis) in Oklahoma to understand the effects of MG on morphology and plumage coloration in adults and nestlings. Plumage coloration is costly to produce, therefore, infected individuals may prioritize health over coloration. We predict that Eastern Bluebirds previously infected with MG will be duller and smaller in comparison to non-infected individuals due to the allocation of resources dedicated to their immune system rather than to their plumage and growth. With this information, we hope to advance the understanding of how pathogens affect morphology and sexually selected traits such as plumage coloration.

## 3D PTV flow measurements around bluegill sunfish (Lepomis macrochirus) during suction-feeding

*Jensine Coggin, Duvall Dickerson-Evans, Erin Hackett, Roi Gurka*

Suction-feeding is a common method for capturing prey by aquatic organisms. This method allows for the adaption of predators by enabling them to consume a wide range of prey. Suction-feeding is a complex fish-fluid interaction governed by various hydrodynamic forces: inertia, unsteady, viscous and pressure gradients that are described by the coupling between the flow physics equations (Navier-Stokes) and the dynamic behavior of the fish (motion and forces). During several suction-feeding event sequences, we measured the 3D velocity fields in a volume surrounding the buccal cavity of a blue gill sunfish (Lepomis macrochirus), and used high-speed imaging for measurements of the fish buccal kinematics (period and amplitude). To measure the 3D velocity fields, we apply Particle Tracking Velocimetry (PTV). Measurements of the 3D flow field enables direct measurement of all the hydrodynamic forces governing the flow, which allows insight into the coupling effects between viscous, inertia and pressure gradient forces acting during the various phases of suction feeding. In particular, the 3D flow measurements enable a direct estimate of the pressure gradient terms in all three directions, which is not possible with 2D measurements utilizing, for example, PIV. These interactions are important because they govern the success rate and energy expenditure during the suction-feeding process.

## Drivers of material tradeoffs in vertebrate armor

*Karly Cohen, Andrew Schulz, EW Misty Paig-Tran*

Armor has convergently evolved in fungi, plants, invertebrates, and vertebrates alike and serves various functions — including, but not limited to, defense, offense, mechanical advantage, camouflage, temperature regulation, fluid retention, and/or sexual selection. Across vertebrates, protein fibers join mineralized blocks to build flexible yet strong composite armors. The effectiveness of armor is greatly influenced by habitat; for example, while the shells of leatherback turtles and tortoises are composed of similar materials, their performance varies significantly based on where they live. The rigid, dense shell of a tortoise provides blunt protection and aids in temperature regulation on land, whereas the flexible, porous shell of a leatherback turtle allows for greater maneuverability in aquatic environments. Armor in terrestrial animals is not bound by the same limitations as in aquatic environments, and vice versa. Keratin is a common material in both aquatic and terrestrial armors, but its composition and functions vary greatly. We examine the trends and tradeoffs between armor material, composition, and habitat, focusing specifically on its role in defense. We evaluated species based on their material composition, degree of armoring, and the known properties of the material building blocks (such as keratin, chitin, cellulose, or collagen) in wet versus dry conditions. We used phylogenetic comparative analyses to uncover the morphological and ecological factors that drive the evolution of armor in specific environments, providing critical insights for bioinspiration.

## Genetically integrated phenotypes define tolerance to ocean acidification in a coastal fish species

*Thea Cole, Alexis Lundquist, Darren Johnson*

Ocean acidification can have negative effects on many species. However, the long-term responses of species will depend critically on the degree to which populations can evolve to become more tolerant of high CO2/low pH conditions as the ocean environment changes. To investigate this phenomenon, we evaluated genetic variation in both feeding rates and growth rates for larvae of a coastal fish, the California Grunion. We combined breeding experiments (66 families in a half and full-sib breeding design) with experimental manipulation of seawater conditions (4 pCO2 levels) to examine heritable variation in sensitivity to CO2. Our results suggest that elevated CO2 can strongly impair feeding efficacy, but these results do not emerge until later in the larval phase when the supply of maternal yolk was exhausted. By 11 days post hatching, there was significant, heritable variation in sensitivity of feeding to CO2 (e.g., ~20% of families were unaffected; ~20% experienced over a twofold drop in mean feeding efficacy at the highest CO2 levels). Moreover, sensitivity of feeding rate to elevated CO2 was genetically correlated with sensitivity of growth rate to elevated CO2 ($rG = 0.29$). These results suggest that tolerance to ocean acidification conditions may be better understood by considering a suite of related, performance-based characteristics. For Grunion, genetic variation in tolerance may facilitate adaptation, offsetting some of the harmful effects of ocean acidification.

## The physiological mechanisms regulating spring fattening in the greater snow goose

*Maëlle Colin, Ilona Grentzmann, Frédéric Angelier, Charline Parenteau, Nicolas Flamand, Elizabeth Dumais, Gilles Gauthier, Cristoforo Silvestri, Pierre Legagneux*

In migratory birds like the greater snow goose, spring fattening is crucial to meeting the energy demands of migration and subsequent reproduction. It is hypothesized that this seasonal fattening is partially regulated by i) the endocrine system, with the key hormone corticosterone (CORT) involved in maintaining the birds' metabolism, and ii) the lipids of the endocannabinoidome (eCBome), sparking avian biologists' interest in recent years due to their known role in human obesity. The objective of our study is to explain spring body condition variation by examining the links between diet, CORT (basal levels) and eCBome lipids concentrations. Blood samples taken within 3 minutes after capture were collected from wild greater snow geese (Anser caerulescens atlantica) on spring staging area in 2019-2023. Goose diets was estimated using isotopic signatures of key food items. Blood concentrations of CORT and eCBome lipids were measured respectively with Radio Immuno Assay and Liquid Chromatography Mass Spectrometry. Contrary to expectations, neither the endocrine system nor the eCBome appear to be related to body condition. However, basal CORT decreased at the very end of the fattening period showing that increased basal CORT is related to hyperphagia. ECBome lipids varied according to the estimated amount of corn. This multidisciplinary study deepens our understanding of the physiological mechanisms driving migration in the greater snow goose and provides integrated information in a transitory obese species!

## The function of shark skin denticles studied using biomimetic models

*Jade Collins, Dakota Law, Molly Gabler-Smith, George Lauder*

Shark skin has long attracted attention due to speculation that their skin denticles aid in locomotory efficiency. Do the structural features present on shark skin actually reduce skin friction and reduce the resistance to motion through the water? There are a variety of biomimetic models with surface structures that mimic denticle surfaces. Our aim was to test the hydrodynamic function of real shark skin in comparison to biomimetic samples to determine whether these models are capable of reducing skin friction below that of shark skin. We mounted samples on a knife-edge plate within a custom flow tank. These samples consisted of real shark skin and a diversity of biomimetic samples. High-speed videos and particle image velocimetry (PIV) were used to visualize the flow of water in the boundary layer. Velocity profiles of these videos were used to calculate the shear stress within the viscous sublayer, representing friction over the samples. We also used 3D profilometry to quantify surface characteristics of each sample to help correlate these characteristics to the shear stress of each sample and between samples. Our results show that some biomimetic samples are more effective in reducing shear stress at high speeds than the natural shark skin samples.

## Illuminating the deep: Revealing the bioluminescent history of deep-sea shrimps

*Stormie Collins, Heather Bracken-Grissom*

Bioluminescence is estimated to have evolved independently 94 times across the metazoan tree of life, highlighting its ecological significance as a universal language of light. Understanding the evolutionary pathways of bioluminescence is crucial for revealing the adaptive significance and diversification of this trait in marine environments. In decapod crustaceans, autogenic bioluminescence has been positively documented in 157 shrimp species from 12 families within Dendrobranchiata and Caridea, but not in any other decapod groups. Despite this, the evolutionary history of bioluminescence in decapods remains unclear. Bioluminescence in shrimps may occur through specialized light-producing organs called photophores and / or defensive luminous secretions. Notably, all known bioluminescent modes are present in both Dendrobranchiata and Caridea, groups which diverged approximately 400 million years ago. Several instances of lensed photophores with unique structural morphologies restricted to certain families suggest multiple independent origins. This study synthesizes genetic data from 20 previous molecular phylogenies with newly generated sequences to construct the most robust molecular shrimp phylogeny to date, including 19 genes from over 700 taxa. Using Sanger sequencing and genome-skimming with dense taxon sampling, this effort aims to clarify family-level relationships across all shrimp groups. Furthermore, this study investigates the evolutionary history of bioluminescent modes using ancestral state reconstruction, providing insights into the mechanisms and evolutionary pressures shaping these adaptations.

## The Role of the Microbiome in Species Invasions: Insights from Large Constrictors in the Caribbean

*Timothy Colston, Alberto Puente-Rolón*

The rapid spread of invasive species, exacerbated by global connectivity and climate change, poses a significant threat to ecosystems worldwide. Island ecosystems in particular are especially imperiled, chief among them being the Caribbean Biodiversity Hotspot. The recent invasion of three large constrictor species (boa constrictors, reticulated pythons, and ball pythons) in Puerto Rico (PR) within the last 2-3 decades exemplifies this ecological challenge and represent an incredible overload of island ecology by large-bodied apex predators. Introductions of Boa constrictors from Brazil date to the mid 1990s in western PR, reticulated pythons from Indonesia were first reported in 2011 in east-central PR, and ball pythons from west Africa have recently been detected as established populations in the west. All three show exponential trends in abundance, representing invasive apex predators from different regions locked in hypercompetition, conflicting with each other and federally endangered native snakes and both terrestrial and sea birds. This unique three-species invasion on the island of Puerto Rico provides a compelling opportunity to understand the evolutionary processes associated with rapid adaptation and niche competition. Here we discuss the real-time sampling of the invasion fronts to document genomic signatures of adaptation, assess the role of microbiomes in adaptive potential, and understand pathogen co-evolution. We present preliminary data on the current spread of these invasion fronts and the potential roles microbes play in invasion success.

## Multi-dimensional kinematic data reveal efficient swimming and migrations in a keystone squid

*Seth Cones, Kenneth Shorter, T. Aran Mooney, Pedro Afonso, Jorge Fontes*

Animal swimming behaviors and associated movement costs dictate an individual's scope for activity and habitat use. Yet in situ measurements of movement often overlook key details such as whole-body kinematics and associated metabolic costs. Here we coupled novel magnetometry methods and swim tunnel respirometry to acquire multi-positional movement and energetic data of free ranging squid, an ecologically keystone taxon whose movements and behaviors have been traditionally difficult to measure. Squid (Loligo forbesii) were affixed with a novel biologging tag (accelerometer, gyroscope, magnetometer; ITag) and a magnet was equipped to one fin; the latter uniquely enabled fin-kinematic measurements via distortion of the magnetic field during swimming behaviors. Controlled respirometry experiments at multiple current speeds revealed a significant, predictable correlation between finning rate and oxygen consumption. Free-ranging squid enacted diverse fin and jet movements that varied on seconds time scales. Fin-mediated swimming and soaring behaviors dominated animals time budgets. While long-considered inefficient swimmers, the combined laboratory and field data revealed squid largely selected a low-amplitude fin movements that enabled energetically efficient vertical migrations and navigation of dynamic seamount habitats. Our study showcases the effectiveness of magnetometer-magnet coupling in augmenting biologging datasets to provide a more-detailed understanding of animal behavior in the wild.

## The genetic and developmental basis of extreme jaw morphologies in a Lake Malawi cichlid fish

*Andrew Conith, Milan Malinsky, Craig Albertson*

Extreme morphologies occur when natural or sexual selection pushes the distribution of a trait outside of a normal range, but how these traits arise and persist remains an open question. Here we examine a cichlid from Lake Malawi, Labeotropheus fuelleborni, with an extremely wide lower oral jaw. The extreme width of this jaw is thought to confer some advantage during feeding, permitting more algae to be cropped with each bite. We begin by measuring the width of jaws from cichlids across Lake Malawi and confirm that Labeotropheus exhibit the greatest width but do so by laterally extending the tooth-bearing region of their dentary bone rather than via a hyper-allometric growth pattern that impacts the entire oral jaw. These lateral 'wings' increases the area for teeth to grow and without them Labeotropheus jaws are similar in width to other closely related cichlids. We then cross Labeotropheus with a narrowed-jawed Malawi cichlid that lacks the tooth plate extension, Tropheops, to uncover the genetic basis of jaw width, with and without the 'wings'. We find different regions of the genome control each aspect of jaw width. 'True' width and 'wing' width reflect two separate modules. The ability to independently regulate jaw width from tooth plate width results in fewer functional trade-offs as efficient algae scraping is achieved without altering the underlying articulation mechanics of the lower jaw.

## Dietary isoleucine restriction increases lifespan and leucine and valine catabolism in grasshoppers

*Kerri Conklin, Haley Peters, Rebekah Sein, Morgan Tomlinson, Hayat Husein, Alicia Horton, Emma Kordek, Isabella Ihemis, John Hatle*

Decreasing dietary protein quantity or quality extends lifespan. Specifically, via an unknown mechanism, restriction of isoleucine (Ile-R) alone recapitulates some life-extending benefits of protein restriction in flies and mice. Our research explores how Ile-R potentially acts via reduced accumulation of branched-chain amino acid (BCAA), as restricting one essential amino acid can increase the catabolism of other amino acids. Reduced BCAA catabolism is linked to type II diabetes, heart failure, and cancer progression. Our previous data indicates that Severe Ile-R significantly increases leucine (Leu) and valine (Val) catabolism, in comparison to an isonitrogenous high-quality protein diet, potentially altering Citric Acid Cyle intermediates linked to longevity. This study investigates the impact of dietary Ile-R on lifespan and BCAA catabolism, using female Lubber grasshoppers. Grasshoppers were assigned to three isonitrogenous and isocaloric dietary groups: High-Quality, Moderate Ile-R, Severe Ile-R, or a control of Ad Libitum Lettuce. As of this writing, grasshoppers on the Moderate Ile-R diet have a median lifespan of 101 d, surpassing those on Ad Libitum (71d; $P=0.04$) and Severe Ile-R (74 d) diets, and trending longer than those on the High-Quality (87.5 d). For BCAA catabolism, the Moderate Ile-R diet significantly increased Leu catabolism ($P=0.02$) and tended to increase Val catabolism ($P=0.058$) compared to the Ad Libitum group, indicating altered metabolic processing. The data suggests a link between dietary Ile, Leu catabolism, and lifespan.

## Single-cell transcriptomics of polyps and medusae of the hydrozoan *Podocoryna carnea*

*Michael Connelly, Alberto Rivera, Matthew Travert, Marina Stoilova, Paulyn Cartwright, Andy Baxevanis*

The hydrozoan Podocoryna carnea possesses a complex life cycle featuring both sessile colonial polyp and free-living medusa stages, each with distinct morphological and functional characteristics. To determine the molecular basis of life stage-specific traits such as striated muscles in the medusa stage, we performed a comprehensive single-cell transcriptomic analysis using dissected P. carnea polyps and liberated medusae. Individual cells were dissociated and fixed using the acetic acid-methanol (ACME) method, sorted for viability by FACS, processed for library preparation on the 10X Genomics Chromium platform, and sequenced on an Illumina NextSeq 2000 instrument (~40 million reads per sample). Downstream processing using Cell Ranger and Seurat leveraged the draft P. carnea reference genome to identify distinct cell populations and reveal differential gene expression patterns that correspond to each life stage's unique physiological adaptations. Key regulatory genes and signaling pathways that drive the morphological and functional differences between polyp and medusa-specific cell types were identified, offering insights into the cellular differentiation trajectories and developmental processes that give rise to this hydrozoan's diverse life stages. This study also showcases how a novel cell dissociation method can advance our understanding of cnidarian transcriptomics at the level of individual cells, yielding valuable genomic data for the continued exploration of cnidarian cell type diversity and life cycle evolution.

## Evolution of brain morphology in lizards: Phylogenetic signal of regional volume

*Sophie Connolly, Michele Johnson*

Understanding patterns of phenotypic evolution provides insight into the ecological factors that may drive this evolution and the constraints that may slow evolutionary change. Phylogenetic signal, or the degree to which phenotypes are associated with phylogenetic relationships among taxa, has rarely been examined in the context of brain morphology. Lizards offer an excellent system for measuring signal in neuroanatomical traits because of their wide range of ecology, behavior, and physiology and the availability of robust phylogenies for the group. In this study, we are using nine diverse lizard species to measure the volumes of brain regions associated with sensory modalities, social behavior, spatial cognition, and autonomic processing. Using Pagel's lambda and Blomberg's K, we calculate the phylogenetic signal for the evolution of each brain region's volume. We predict lower phylogenetic signals in brain regions associated with highly variable ecological pressures (e.g., sensory modalities) than in those associated with basic body processes (e.g., involuntary physiological processing). These findings may offer insight into the factors driving evolutionary change in neural adaptations across vertebrates.

## 3D EM reconstruction provides evidence for olfactory glomeruli in a nudibranch mollusc

*Alexzander Cook, Harshada Sant (she/her), Sarah DeAmicis, Kriti Dhiman, Cheyenne Tait, Yuelong Wu, Richard Schalek, Jeff Lichtman, Paul Katz*

Glomeruli have long been considered basic units of olfactory processing, with conserved neural motifs in mammals and insects. They are characterized by afferent axons expressing the same odorant receptors converging onto dendrites of projection neurons in the olfactory bulb or antennal lobe respectively. However, it is not known whether molluscs also share this organization. We studied the neuronal organization of the chemosensory rhinophore ganglion (rhg) in the nudibranch mollusc, Berghia stephanieae. Neurobiotin fills show that some afferent axons terminate in the rhg and others project through the connective to the cerebral ganglion and into the contralateral rhg. From our volume EM dataset, we identified a region with distinct ultrastructural features and reconstructed several cell types. Notably, we found a cluster of projection neurons with overlapping dendrites in a confined area. These dendrites were contacted by axons projecting from both distal regions of the rhinophore ganglion (rhg) and the connective. The axons had vesicle-filled boutons localized to the dendritic region of the projection neurons. This exclusive convergence of axons onto the projection neuron dendrites suggests an olfactory glomerulus-like circuit. If this organization is consistently found in the rhg, it would imply that the glomerular organization of olfactory systems evolved independently in molluscs, supporting its universality across species.

## Ontogeny of the Virginia opossum temporomandibular joint and implications for mammalian evolution

*Emma Cooney, Peishu Li, Zhe-Xi Luo, Alec Wilken, Casey Holliday*

The evolution of the modern mammalian middle ear from the primitive jaw joint is a remarkable example of vertebrate evolutionary history. We have a deep understanding of how the bones of the ear and jaw have evolved from the fossil record, however the knowledge surrounding the evolutionary origins of soft tissues of the temporomandibular joint (TMJ), such as the pterygoideus muscle, articular disc, and the discomalleolar ligament (DML), is limited. Previous hypotheses have suggested the disc and DML are vestiges of the lateral pterygoideus muscle as the malleus is its primitive attachment, but these remain untested. Ontogeny of the Virginia opossum (Didelphis virginiana) TMJ resembles the evolutionary trajectory of mammalian jaw and ear bone, making it a useful model to study soft tissue development. We explored the soft tissue connections between the TMJ, middle ear, and jaw musculature in a neonate, weanling, and adult opossum using high-resolution DiceCT. In the adult, we identified that the TMJ articular disc is continuous with the lateral pterygoideus rostrally and the DML caudally, which continues through the petrotympanic fissure to attach to the malleus. Similar connections are identifiable in the neonatal and weanling specimens, suggesting evolutionary and developmental connectivity of the pterygoideus, disc, DML and malleus. These results further the understanding of opossum ontogeny and contribute to the overall understanding of mammalian cranial evolution.

## Acclimation effects on thermal dependence of tongue projection performance in chameleons

*Etti Cooper, Madison McIntyre, Krystal Tolley, Graham Alexander, Christopher Anderson*

Ectotherms are particularly dependent on temperature effects on the functioning of many physiological processes, including muscle powered movements. Populations, however, are known to adapt to the thermal environment in which they live, and acclimate in response to acute temperature changes. Chameleons present an opportunity to assess the extent to which adaptation and acclimation affect performance across a range of temperatures in disparate movement types. As their ballistic tongue projection is powered by the recoil of preloaded elastic elements, performance is largely temperature independent, while their muscle-powered tongue retraction is strongly affected by temperature. We compared temperature effects on tongue projection among species from different thermal environments before and after a two-month acclimation period to a common laboratory setting. Individuals from six species of Bradypodion and Chamaeleo were collected across South Africa

and brought into the lab. Feeding events were filmed at five temperatures between 15 °C and 35 °C using high-speed video immediately following collection from the field and again after the two-month acclimation to a laboratory environment. A significant effect of pre- versus post- acclimation on tongue projection performance was observed but varied directionally among species. These results suggest that elastic recoil-powered movements can acclimate to acute changes in thermal environment and that some of the population level differences in thermal performance may be short-term responses to temperature fluctuations rather than evolutionary adaptation.

## Using Xenopus laevis to Model Adaptation to High Hydrostatic Pressure.

*Mark Corkins, Tianyuan Hao, Anvita Bhattad, Lance Davidson*

The bottom of the oceans is an extreme environment with conditions such as near-freezing cold, low oxygen, and hydrostatic pressure reaching 100MPa (980atm). The organisms that live there have adapted to these conditions, and our work focuses specifically on how these organisms adapt to these pressures. High levels of hydrostatic pressure can result in increased cytoplasmic viscosity, disruption of membranes, gasses becoming solubilized into solution, and proteins miss-folding or denaturing, but little is known about how organisms overcome these problems. This project aims to take embryos of the shallow-dwelling aquatic organism Xenopus laevis, determine specifically which aspects of these problems fail under high hydrostatic pressure, and then identify a means to allow embryos to survive under this deadly pressure. We have designed a system to expose different embryonic stages of X. laevis to high pressures and observe its effects. We have found that pressure over 10MPa (98atm) results in a developmental stall that can be reversed by returning embryos to pressure at sea level (10kPA, or 1atm). Using bioinformatic approaches, we are screening to identify genes regulated by hydrostatic pressure and discover drugs and other treatments that could help embryos survive at these high pressures.

## Is heart rate anticipatory of flight duration in a free-living songbird, the red crossbill?

*Jamie Cornelius, Taylor Chapple, Travis Draud, Thomas Hahn, Jalyn Devereaux, Jessica Karr, Kathleen Hunt, Ben Sonnenberg, Alex Jahn, Martin Wikelski*

Heart rate is one estimate of metabolic rate in free-living animals and can elevate in response to oxygen demand, carbon dioxide accumulation, or sympathetic shift in autonomic tone. For example, heart rate may elevate in response to a perceived stressor or, in some mammals and contexts, in anticipation of a locomotion event. However, research describing cardiovascular physiology of free-living birds is limited. We have observed increased heart rate of birds wearing heart rate radiotransmitters just prior to flight. Here, we explore the changes in heart rate before, during and after foraging flights in free-living red crossbills (Loxia curvirostra) to determine how heart rate variability relates to flight duration. We also compare heart rates during normal foraging movements to that of an escape flight from an aerial predator. We predict that red crossbills minimize unnecessary cardiovascular effort by adjusting the degree of anticipatory increase in heart rate to flight duration. We further predict that heart rates during flight will reach an asymptote as flight duration increases, but that stress-induced heart rate during predator evasion will exceed this maximal value, similar to mammals. Autonomic control of heart rate may assist in rapid mobilization of oxygen and energy to muscles during flight. Further exploration of cardiovascular dynamics in free-living birds will help to better understand costs of transport and energy trade-offs during foraging in free-living animals.

## Thermal responses in Hawaiian volcano shrimp: active vs. passive plasticity across genetic lineages

*Mariangel Correa-Orellana, Ash Romero, Kendra Zwonitzer, Troy Sakihara, Cassidy Hawk, Erik Iverson, Justin Havird*

Climate change poses a significant threat to the planet's well-being, prompting organisms to respond through plastic physiological changes (e.g., acclimation), adaptive evolution (e.g., genetic change), or migration to habitats that match their climatic niche. Animals from volcanic habitats are underexplored and could be used to model physiological and evolutionary responses to warming temperatures. In this study, we focused on the potential of different lineages of the Hawaiian anchialine shrimp Halocaridina rubra as a model for understanding responses to temperature variations, including those from the warmer habitats formed during the 2018 eruptions of Kilauea. We observed that animals from warmer habitats have elevated thermal limits, but these limits decrease to match the thermal range of animals from older habitats after being maintained at room temperature. This suggests that the thermal limits might be shaped by acclimation. Additionally, there is minimal variation in metabolic rates across different genetic lineages. We discuss the possibility of elevated temperatures leading shrimp to seek cooler waters underground, citing instances of this behavior occurring in some habitats due to volcanic activity. Furthermore, we highlight the potential impact of climate change on anchialine habitats and suggest appropriate experimental designs for assessing and quantifying the thermal acclimation of biological rates.

## How do worms climb duckweed roots?

*Nicholas Correcha, Prathyusha Kokkoorakunnel Ramankutty, Harry Tuazon, Ivy Li, Saad Bhamla*

California blackworms (Lumbriculus variegatus) possess flexible, slender bodies that can inter- twine with each other and spontaneously aggregate into a "worm blob", providing collective protec- tion against external threats. Worms interact with their environment in intricate ways, using their ability to intertwine and aggregate to access floating vegetation on the water's surface, such as algae and duckweed, which reveals essential aspects of their behavior and adaptation. Our experiments observations demonstrate the blackworm can climb the dangling duckweed roots by entangling with roots of duckweed. Such collection of the duckweed and worms acts like a floating raft, enabling the worm to achieve faster collective locomotion. Inspired by this mechanism, we model the ensemble of California blackworms and duckweed as a system of active and passive polymers, respectively. We model the worm as an active polymer endowed with self-propulsion and active head motion that resembles the dynamics of worms and their entangling behavior. Duckweed is modeled as a polymer with finite stiffness, anchored or free at one end of the polymer. Our simulations demonstrate that the stiffness of the passive polymer and the active tangling strength of the polymer are deciding factors in the ascending behavior and collective motion. We believe our computational study, which investigates worm locomotion and climbing behavior, is vital for developing bio-inspired robots capable of replicating these natural movements across various habitats.

## Thermal acclimation studies in brook trout: hatchery vs. wild fish

*David Coughlin, Xavier Ernest, Evelyn Peyton*

Many studies of fish physiology have relied on animals raised in hatcheries, particularly for salmonids. Recent work in our lab suggests hatchery brook trout (Salvelinus fontinalis) show a robust thermal acclimation response, with significant shifts in swimming performance and muscle contractile properties with the temperature of acclimation. Fish exposed to warm water for several weeks have slower muscle contractile properties and slower maximum escape responses. The hatchery fish were from the Huntsdale Fish Hatchery, Carlisle, PA, but originated from a population in Virginia. We asked if native brook trout show the same thermal acclimation response. Wild brook trout were collected from Hayes Run and the East Branch of the Antietam Creek in Adams County, Pennsylvania. These streams are tributaries of the Potomac River. Temperature dataloggers were employed in the streams throughout the year, and wild trout were collected in late spring, summer, fall and early winter for comparison to our hatchery thermal acclimation studies. The wild fish displayed more modest variations in physiological function through the seasons compared to hatchery fish. As climate change alters the thermal environment of the planet, thermal acclimation is a key mechanism to mitigate the impact of rising temperature on the physiological function of ectothermic, cold-water fish like brook trout. Our physiology results suggest that this population of wild fish will face significant stress with climate change.

## Effects of migratory strategy on flight muscle mitochondrial physiology in songbirds

*Soren Coulson, James Staples, Christopher Guglielmo*

Endurance flight is a physiologically demanding life-history strategy used by migratory birds. The two main challenges of endurance flight are maintaining energy balance and avoiding oxidative stress, which are presumed to increase in importance with migration distance. Mitochondrial function mediates both challenges, yet how mitochondrial function varies with migratory strategy is unclear. We hypothesized that mitochondrial function varies with migratory strategy in birds and predicted greater flight muscle size, mitochondrial abundance, oxidative phosphorylation capacity and lower reactive oxygen species (ROS) emission in long-distance migrants relative to shorter-distance migrants. We tested this hypothesis with a comparative approach that included 19 songbird species that vary in migration strategy. For each species, we measured flight muscle size, mitochondrial abundance (via citrate synthase activity) and capacities for oxidative phosphorylation and ROS emission using high-resolution flurorespirometry in isolated mitochondria. Contrary to our predictions, we found that flight muscle relative to body mass was lowest in long-distance migrants, while mitochondrial abundance was unaffected by migration strategy. Oxidative phosphorylation capacity also declined with migration distance, while ROS emission was unaffected. In contrast to our hypothesis, our data indicate that long-distance migrants have evolved a low oxidative capacity. We surmise that long-distance migrants have evolved a lower oxidative capacity as part of a larger strategy that maximizes energy efficiency during flight.

## Do asymmetrical patterns increase survival of a cryptic reptile?

*Ross Couvillon*

Various animals can more easily detect, learn, and reproduce from memory symmetrical color patterns over those that are asymmetrical. This helps explain empirical findings that symmetrical color patterns are effective for signaling coloration (like aposematism) whereas asymmetrical color patterns are effective for cryptic coloration. This body of research has largely focused on insects or artificial prey selection by birds. There does not appear to be any research on symmetry of reptile color patterns. Eastern copperheads (Agkistrodon contortrix; hereafter, copperheads) have a color pattern consisting of blotches of various shades of brown, which no doubt provides superb camouflage against leaf litter of the forest floor. These blotches are often shaped like bowties centered along the dorsum and repeat down the length of the body. But copperhead color patterns exhibit intraspecific variability, and asymmetry of these bands is common. Copperheads may prove an effective model to test whether asymmetrical color patterns increase the fitness of a cryptic reptile. In this pilot study of copperhead pattern symmetry, I categorized the degree of blotch asymmetry of museum specimens from Louisiana. The goal is to see if certain characteristics about blotch asymmetry typify individuals that survived to maturity.

## Reasoning and methodology to use zooplankton as a water resource management tool

*Joseph Covi*

While zooplankton monitoring is standard in some areas of the United States, it is not conducted in states like North Carolina. This simple omission endangers important freshwater and coastal marine resources. Zooplankton are a critical asset for water resource management because healthy zooplankton communities help to mitigate algal blooms while simultaneously providing an important food resource for juvenile fish. The high importance of zooplankton to ecosystem health is sufficient reason to add zooplankton diversity and biomass to the list of variables monitored by any water resource managing authority. The path forward to using zooplankton as a management tool in states like North Carolina requires both education and the adoption of tractable methods for monitoring species that can remain dormant for centuries. Methods to monitor both the active and dormant subsets of zooplankton communities in lakes will be discussed. Data generated with these methods will be presented for two disparate lakes in North Carolina. These data demonstrate the value of monitoring both the active zooplankton community in the water column and the dormant zooplankton community in the benthos. Lessons from Antarctic zooplankton and methods to mitigate the negative impacts of anthropogenic chemicals globally will be discussed.

## Spatial and temporal dynamics of a signal polymorphism in a tropical lizard

*Christian Cox, Maria Alcivar, Leah Bakewell, Ian Clifton, John David Curlis, Anabarbara Gonzalez, Samir Gulati, Daniel Romero, Jessica Stapley, Claire Williams, Kelly Wuthrich, W. Owen McMillan, Michael Logan*

Understanding the origins of diversity in animal signals is a central goal of evolutionary biology. In particular, systems with polymorphic signals represent an excellent opportunity to study how evolutionary processes shape diversity, because genetically determined polymorphisms should drift towards fixation on either trait value if they are not under selection. Hence, the presence of signal polymorphisms is an opportunity to study how neutral and non-neutral forces interact to shape phenotypic evolution. However, only rarely is there an opportunity to study the evolution of signal polymorphism in natural populations over multiple generations, particularly in the tropics. We studied the ecological and evolutionary dynamics of a genetically determined color polymorphism in the dewlap of the Panamanian slender anole lizard. The dewlap is a colorful flap of skin that can be extended as a social and sexual signal. We compared both the presence and frequency of morphs across 24 populations and nearly 40 generations and correlated morph presence and frequency with climatic and landcover date. We found that the spatiotemporal distribution of dewlap morphs matched some predictions of neutrality, selection along an environmental gradient, and negative frequency dependence. Our results suggest that a complex mixture of evolutionary forces govern signal polymorphism in this species.

## Does ground invertebrate diversity correlate with breeding success in eastern bluebirds?

*Sophia Cox, Danae Diaz, Steve Nowicki*

Insects and other invertebrates have undergone significant decline, raising conservation concerns for both invertebrates and taxa that prey upon them, such as birds. Urbanization, which includes habitat loss, pollution, and the introduction of invasive species, is one cause for this decline. We investigated the effects of urbanization on invertebrate diversity and abundance at four study sites in central North Carolina varying in degree of urbanization and also looked at the impacts this might have on the fitness of insectivores that depend on them. Using pitfall traps, we collected invertebrates over two four-day intervals in late April and early July, 2024, at sites where Eastern bluebird breeding was studied in 2023 and 2024. We chose pitfall traps for their efficacy at sampling ground invertebrates, which previous work has shown to be a significant dietary component for both adult and nestling bluebirds. We predicted that pairs would experience greater nesting success at sites with greater invertebrate diversity. A higher diversity of prey may provide better nutrition to nestlings or simply reflect more abundant food resources overall. We measured reproductive success by checking nest boxes regularly and counting eggs and nestlings. We counted invertebrate samples from each site, identified them to family level, and then correlated taxonomic diversity and relative abundance of the samples with nesting success data across sites varying in degree of urbanization.

## Assessing the physiological response of sand tiger sharks (*Carcharias taurus*) to longline capture

*Chestina Craig, Kady Lyons, Bryan Frazier, Johanne Lewis*

In sharks, capture and handling can elicit a physiological stress response, often quantified by changes in blood chemistry associated with mobilization of fuel (glucose and ketones) and shifts in metabolic state (lactate). Stress responses are variable across species, sexes, and ontogeny, and can be influenced by other factors such as temperature and hook time. Carcharias taurus is a nearshore, migratory shark, that is popular in aquaria. The objective of this study was to characterize the physiological response of C. taurus to longline capture and identify factors that may influence plasma metabolite concentrations during capture and handling. Sharks were sampled off South Carolina, via longline, reeled to the boat, and a blood sample taken. Shark sex and length was recorded. Environmental factors and soak time were noted for each longline set. Plasma was analyzed for glucose lactate and ketone levels. Sex and length did not have a significant effect on glucose, or lactate, however they did have a significant effect on ketone concentrations. Soak time did have a significant effect on plasma lactate levels; as soak time increased so did plasma lactate concentrations, however lactate did not increase across handling time. These data suggest there may be sex difference in ketone concentrations and that C. taurus appears to be relatively robust to handling.

## Sex-specific consequences of juvenile dispersal for lifetime fitness in an island lizard

*Ashlyn Crain, Tyler Wittman, Rachana Bhave, Heidi Seears, Aaron Reedy, Robert Cox*

When the costs or benefits of juvenile dispersal differ between sexes, sex-biased dispersal should be favored, though such sex-specific consequences are rarely measured for lifetime fitness in the wild. Here, we use five years (generations) of mark-recapture data with lifetime fitness estimates from genetic parentage to measure natural selection on two dispersal phenotypes (binary dispersal propensity and continuous dispersal distance), in an island population of lizards (Anolis sagrei). Juvenile dispersal was consistently male-biased, with males exhibiting a higher propensity to disperse and dispersing twice as far as females. Males that dispersed had higher juvenile survival and lifetime reproductive success than males that remained philopatric, whereas fitness did not differ between dispersing and philopatric females. Although this result suggests that the fitness benefits of dispersal are sex-specific, we found no difference in fitness between dispersing and philopatric males after accounting for body size, which was positively correlated with dispersal. Likewise, we did not consistently detect direct linear selection on dispersal distance in either sex when including body size in multivariate selection analyses, nor did we find consistent correlational selection on combinations of body size and dispersal distance in either sex. We conclude that selection on juvenile dispersal propensity is sex-specific, but likely indirect and mediated through its positive association with body size in males.

## Landscape bee-havior: Automated monitoring to understand dynamics of plant-pollinator interactions

*James Crall, Matthew Smith, Olivia Bernauer, Rafael Salas, Acacia Tang, Ben de Bivort, Claudio Gratton, Brian Spiesman*

Bees and other pollinators show remarkable behavioral flexibility that allows them to respond dynamically to environmental conditions and resource availability. Similarly, interactions between plants and pollinators show significant flexibility over rapid time scales (e.g. days or weeks). While flexibility has important implications for plant-pollinator networks, generating empirical data on interactions between plants and pollinators at sufficient spatial and temporal resolution to characterize these dynamics remains a significant challenge. Here, we describe an approach for automated monitoring of floral visitation in the field to address these knowledge gaps. Our approach uses deep-learning-based detection to perform scalable monitoring of floral visitation and is implemented on low-cost, open-source, field-deployable hardware (Raspberry Pis). We demonstrate the potential of this approach in both natural meadows and agricultural ecosystems using dozens of cameras monitoring floral visitation over several months. We then use this system to quantify effects of short-term weather (i.e., temperature) fluctuations on activity and ecological interaction patterns (including species- and network-level specialization), as well as explore the importance of microclimatic variation for foraging dynamics in agro-ecosystems. Overall, our work highlights the potential of low-cost, AI-based tools for unraveling the dynamics of pollinator behavior at a landscape scale. Finally, we discuss the prospects for adopting similar approaches for both large-scale ecological monitoring and experimental approaches to insect behavioral ecology.

## Songbird telomere length reflects metal exposure and habitat degradation from mining contamination

*Bridger Creel, Lillian Krach, Benjamin Colman, Megan Fylling, Zachary Cheviron, Creagh Breuner*

Mining contamination (MC) is a widespread ecological disturbance with disproportionate effects on riparian ecosystems that host diverse breeding songbird populations. In these habitats, songbirds face risks from both metal exposure and habitat disturbance. However, few studies have disentangled the relative impact of these stressors on songbird health and fitness. Nestlings are particularly vulnerable to disturbance as their growth is rapid, energetically demanding, and fueled almost entirely by local insects that act as vectors for dietary metal exposure. Both metal toxicity and chronic stress from habitat disturbance can shorten telomeres and shortened telomeres during early development predict reduced lifespan in birds. Thus, relative telomere length (RTL) should be a useful biomarker to reflect negative effects of metal exposure and habitat disturbance on nestling health and future fitness. We measured body condition, RTL, and blood metal(loid) concentration in nestlings of four species across three contaminated sites with varying restoration treatments and one non-contaminated reference site. We find significant elevation in blood concentrations of lead, arsenic, and selenium at the most contaminated sites but only see a strong direct relationship between decreased RTL and selenium blood concentration. Nestlings at the reference site exhibit longer telomeres than those in all contaminated sites even when blood metal concentrations do not exceed established negative effects thresholds–suggesting that independent of metal exposure, nestlings experience increased developmental stress at contaminated sites.

## Robustness and resilience of biological systems: Introduction to system thinking

*Erica Crespi*

Why particular biological systems persist while others fail is a question that spans multiple disciplines within and outside the biological sciences. There has been an attempt to identify common rules that govern the robustness and resilience of biological systems as an important step toward answering this question; however, currently definitions of robustness and resilience vary across disciplines. Although there are multiple computational approaches to explore systems dynamics, here I focus on network theory, which serves as a framework for universal, scale-free mathematical models to describe robustness and resilience of systems and the relationship between them. This theory predicts that properties of systems, such as redundancy, diversity, and connectivity of networks, from the biochemical to the ecosystem level, will result in a system's ability to resist or bounce back from perturbation under dynamic conditions. In addition, expanding undergraduate and graduate training in biological sciences to include network theory as well as cross-cultural approaches that integrate both traditional indigenous knowledge and western science could also be applied to better understand how biological systems persist in the face of change. This new understanding of biological systems will allow us to derive predictive models of biological systems and revolutionize the study of robustness and resilience of biological systems.

## Impacts of warming temperatures and symbiont density on crayfish behavior

*Tara Cronin, Michael Childress, Sabrina Fernandez, Megan Taylor, Tess Abrams*

There are growing concerns about the impacts of climate warming on interspecific interactions. While studies focusing on competition and predation are common, much less focus has been placed on symbiotic interactions. Historically, symbiotic interactions were thought to have static outcomes, but recent work has shown that symbiotic relationship outcomes can shift based on environmental conditions. Understanding how temperature changes impact these relationship outcomes is vital for our understanding of the impacts of climate warming. Crayfish-branchiobdellid symbiosis is the ideal system to examine the impacts of climate warming on symbiotic relationship outcomes. Context dependent relationship outcomes have been previously shown, as well as grooming behaviors being important in regulation of these relationships. In this study, we examined how temperature and branchiobdellid density impacted the behavior of Cambarus bartonii and Cambarus latimanus. Crayfish were subjected to temperatures ranging from 68-78°F and their behaviors were recorded. After this each crayfish was examined to determine symbiont density. The results of this experiment indicate a significant increase in the frequency of locomotion/activity with increasing temperature as well as positive trends for both climbing and burrowing behaviors. Whereas grooming behavior were shown to significantly decrease as temperature increased. Preliminary results indicate no impact of symbiont density on grooming behaviors. To further explore this question we are examining a larger range of temperatures and continuing symbiont density measurements.

## Ontogenetic scaling of suction-feeding performance in axolotls

*Claire Crookston, Stephen Deban*

At extremely small size, suction feeding vertebrates may be unable to capture prey given the high viscosity of water (Re < 102). Their full-size adult counterparts or larger species can power suction in more inertial flow regimes (Re ∼ 104). Estimations of Re for first-feeding Ambystoma mexicanum larvae and mature adults reveal a limited range of Re values (∼300-7000) indicating these salamanders experience a laminar or transitional flow regime after hatching that becomes turbulent later in ontogeny. Preliminary analyses of the ontogenetic scaling of aquatic suction feeding across an 11-fold difference in SVL (8.14-86.20mm) and 1400-fold difference in body mass (0.021-30.66g), reveals geometric similarity of morphology and movement of first feeding larvae to full-grown adults, adhering to Hill's 1950 model of muscular dynamics. We quantify the scaling of mass-specific power necessary for prey capture by analyzing the flow profile in front of the mouth during suction feeding. Using axolotls as a model for amphibian suction feeding will serve as a basis for comparisons with extremely tiny, suction feeding larvae of other amphibian species, e.g., Eurycea sp.(salamanders) and Hymenochrius sp. (frog tadpoles).

## Flight energetics of Anna's hummingbirds

*Mauricio Cruz, Derrick Groom, Alejandro Rico-Guevara*

The energetic cost of locomotion is a primary determinant of animal behavior; therefore knowing the metabolic cost of an animal's movement can help predict its behavior over a wide range of ecological contexts. However, one of the biggest obstacles bird physiologists face is measuring the energetic cost of flight in a way that accurately represents natural conditions. Traditional methods require the attachment of equipment to the animal, which can disrupt normal flight behaviors or add additional energetic costs to flight. This project will address this obstacle by using the labeled sodium bicarbonate method to measure the energetic cost of short flights for Anna's hummingbirds in a wind tunnel across a broad range of speeds. The sodium bicarbonate method is a non-invasive stable isotope method in which 13C is incorporated into the animal's bicarbonate pool and the extinction rate of the 13C during the period of exercise is then used to estimate metabolic rate. Given the curve of the mechanical cost of flight and flight speed is U-shaped, I expect the curve of the metabolic cost of flight and flight speed will show that flight is least energetically costly at intermediate speeds for Anna's hummingbirds. However, given that hummingbirds have adapted to hover, the curve may be more J-shaped than U-shaped.

## Hanging parrots use traveling-wave micropumps to drink nectar

*David Cuban, Sunghwan Jung, Maude Baldwin, Alejandro Rico-Guevara*

Nectar-feeding animals have evolved a diverse variety of feeding mechanisms to efficiently ingest tiny amounts of liquid without damaging their replenishing flowers. Within nectarivorous birds, we have found several distinct feeding mechanisms despite morphological convergence in multiple feeding apparatus traits. Convergence is limited by constraints, however, and nature finds novel solutions accordingly. Parrots are one of the few bird groups that possess tongues with intrinsic musculature, and have a distinctive bill shape that, for nectarivorous parrots, has not turned into the quintessential elongated structure that most other nectar-feeding birds have. We show here that hanging parrots show an unparalleled method of consuming nectar by utilizing their fleshy, muscularized tongue in combination with their hooked upper bill to pump the liquid inwards. We collected kinematic data of the tongue, bill, and fluid meniscus from Blue-Crowned hanging parrots feeding from artificial flowers. We also made a 3D model of a hanging parrot bill and tongue by microCT scanning a preserved museum specimen. With the feeding apparatus geometry and its observed kinematics we generate a mathematical model for this parrot's nectar-feeding mechanism. We unveil and explain this novel feeding mechanism, highlighting another unique utilization of a muscular hydrostat within animals.

## Viral epidemic potential is not uniformly distributed across the bat phylogeny

*Caroline Cummings, Amanda Vicente Santos, Daniel Becker, Colin Carlson*

Characterizing associations between viruses and their wildlife hosts is critical due to the rising frequency of emerging infectious diseases in humans, which are usually zoonotic. Most analyses have evaluated zoonotic risk as binary, whether a pathogen can or cannot infect humans, but virulence and capacity for onward transmission in humans can vary dramatically. Recent work suggests bats harbor more viruses with high virulence in humans than other mammalian or avian orders. However, bats are speciose, and it remains unknown whether all bats harbor viruses of equal virulence and transmissibility in humans or if only particular clades harbor virulent and transmissible viruses. We analyzed the phylogenetic distribution of viral virulence and transmissibility in humans across mammals and within bats specifically, using phylogenetic factorization to flexibly identify clades with low or high viral epidemic potential. When assumptions about taxonomic order are relaxed, bats are not a uniformly virulent or transmissible clade of hosts. Instead, virulence and transmissibility predominantly cluster within specific subclades of bats, often cosmopolitan families found in both the western and eastern hemispheres. Lastly, we mapped the geographic distributions of high-virulence bat clades with spatial data on anthropogenic footprint, highlighting hotspots of zoonotic risk in South America, Southeast Asia, and equatorial Africa. Our results deepen understanding of the host–virus network and identify clades to prioritize for surveillance and future studies identifying mechanisms of viral tolerance.

## Characterizing the gut microbiome of North America's largest salamander

*Chloe Cummins, Alexander Rurik, Jason Dallas, Mitra Ghotbi, Kaitlyn Murphy, N. Reed Alexander, Lluvia Vargas-Gastélum, Joseph Spatafora, Kerry McPhail, Jason E Stajich, Taina McLeod, William Sutton, Sherri Doro Reinsch, G. Sandonato, Dale McGinnity, Donald Walker*

Hellbenders, the largest species of salamander in North America, have experienced persistent declines across their historic range in recent decades and are now listed as threatened or endangered in many states, including Tennessee. Recent declines in hellbender populations have been attributed to a myriad of anthropogenic and environmental causes, including reduced water quality, emerging infectious diseases, and habitat loss/degradation. Consequently, these declines have stimulated an increase in captive breeding and headstart programs as a management strategy for hellbender conservation. For instance, through the Nashville Zoo's headstart program, wild-collected eastern hellbender eggs are reared in captivity prior to release in Middle Tennessee streams. However, for effective implementation of such conservation approaches, comprehensive knowledge of the complex interactions in the hellbender gut microbiome must be established, especially considering that disturbance-induced dysbiosis of the gut microbiome can adversely impact host health. Through metabarcoding and high-throughput amplicon sequencing of the bacterial 16S rRNA marker, a better understanding of the composition and intricate microbial interactions within the gut microbiome of this imperiled amphibian was elucidated. Anticipated results will include a characterization of the bacterial gut assemblages of pre-release hellbenders in captivity coupled with post-release individuals in the wild and wild resident hellbenders (i.e., never reared in captivity) in order to inform headstart programs on the potential to rewild the hellbender gut microbiome.

## Nest defense of Eastern Bluebirds (*Sialia Sialis*) in response to competitors and non-competitors

*Katalina Cunningham, Jonathan Perez*

Appropriate threat detection and response is essential for both survival of an animal, but also for maximizing fitness by avoiding unnecessary energy expenditure. Two strategies an animal can use to identify threats are specialization and generalization. With specialization, an animal is selective in what threats they respond to, while with generalization it responds broadly to a category of stimulus and without close discrimination. Both strategies come with benefits and drawbacks – when an animal uses generalization, they have a greater ability to respond to novel threats, but can also waste energy reacting to non-threats. Conversely, specialization minimizes the amount of energy wasted, but limits the animal's ability to respond to novel threats thus carrying a higher potential risk (loss of resources, offspring, and even death) in dynamic or rapidly changing environments. In this study we explore whether Eastern

Bluebirds utilize a specialized or generalized approach to potential songbird threats to their nest. Using songbird models with corresponding audio for five minutes, we measure the difference in the defensive response of Eastern Bluebirds during incubation to a competitor (House Sparrow) and non-competitor (House Finch). Preliminary analysis of our data suggests that cavity nesting songbird threats elicit a stronger defensive response than do models of a non-cavity nester. This suggests that Eastern Bluebirds use a specialized approach to threat detection and response.

## Impacts of per- and polyfluoroalkyl substances on the behavior and physiology of an estuarine fish

*Rachel Cuomo, Isaac Ligocki*

Chemical pollutants in the environment pose widespread consequences for wildlife and human health alike. Per- and polyfluoroalkyl substances (PFAS) encompasses a large class of synthetic organic compounds known for their resistance to degradation over time. PFAS compounds fall into two general categories: long-chain ($\geq$8 carbons) and short-chain ($<$8 carbons). Long chain compounds are generally considered more toxic; many long-chain compounds have been replaced with short-chain successors. The purpose of this study was to determine if short-chain compounds are less toxic than their long-chain predecessors. Cohorts of Fundulus heteroclitus were exposed to either a high or low concentration of perfluorooctanoic acid (PFOA), a long-chain PFAS compound, or a high or low concentration of perfluoro (2-mthyl-3-oxahexanoic) acid (GenX), a short-chain PFAS compound. Behavioral trials were conducted to identify changes in activity levels and risk-aversion behaviors as a result of PFAS exposure. Additionally, plasma samples were collected post-exposure to determine the impact that PFAS may have on cortisol levels. Male fish exposed to high concentrations of either compound displayed an altered relationship between mass and time spent on the outer edge of an arena when compared to control fish. There were no documented differences in other behaviors or cortisol levels depending on history of exposure. Further understanding of these compounds and their influence on wildlife is critical to assessing environmental risks associated with chemical pollution.

## Mate guarding and pair bonding behavior in green salamanders

*Paul Cupp*

Male Aneides aeneus arrive at home crevices and establish territories through chemical deposits and often aggression with other males. Females usually follow soon after. Thus, male-female pairs are formed in single rock crevices or in adjacent crevices for periods of days or weeks mainly in May and October. Pair bonding occurs that likely involves chemical and tactile communication. Males and females may gain familiarity with each other. Male-female pairs are often in direct contact as males may have a limb or other body part resting on the back or tail of females. Also, heads of male and female may be oriented to opposite ends of crevice openings with posterior ends in contact. This may be a defensive response to predators. Pairing increases chances of courtship and mating, and allows for mate guarding thus reducing chances for polyandry and polygyny. Some aggression by males may occur such as biting and snout-pressing, which is similar to behaviors observed during courtship and mating. Males that have established and defended territories are likely more fit. Thus, mate-guarding behavior may be selected for in that females may choose more fit males. Aggressive defense of territories by males combined with the formation of male-female pairs and pair bonding indicates that mate guarding occurs in A. aeneus. This may enhance reproductive success of both males and females.

## Does a chameleon of arboreality conform to typical arboreal chameleon locomotor patterns?

*Michael Curran, Christopher Anderson*

Chameleons are a diverse clade of lizards that inhabit a wide range of habitats across the arboreality spectrum. Chamaeleo calyptratus has served as a primary model for studies on arboreal locomotion in chameleons. Studies including Chamaeleo dilepis, however, have scored their arboreality as terrestrial, semi-arboreal or arboreal depending on the species it was being compared to. Specific knowledge of the kinematics and performance of C. dilepis locomotion is somewhat limited, however, and the species is unlikely to simultaneously exhibit locomotor patterns adapted for all possible conditions along the arboreality spectrum. We performed locomotor trials with C. calyptratus and C. dilepis across substrates and orientations to compare kinematics between these two model chameleon species. Individuals were first filmed using biplanar high-speed video walking along a meter-long wooden dowel at three inclines (-45°,0°, 45°). Individuals were then filmed walking along on a 1-meter-long flat surface at 0° incline. We quantified morphology, kinematic, and performance variables including velocity, joint angles of the forelimb and hindlimb, stride length, and stride frequency from locomotor trials for each species. Our results provide insight into how an arboreal and terrestrial environment impacts the locomotor patterns and performance of these species to help establish the degree to which C. dilepis locomotion departs from a typical arboreal model chameleon.

## The importance of immunology in conservation science: the example of cheetahs in Namibia

*Gábor Czirják, Bettina Wachter*

The cheetah (Acinonyx jubatus) is a threatened species that suffers from human persecution, habitat destruction, and illegal wildlife trade. Their lack of genetic variability with possible consequences on reduced reproductive performance and disease susceptibility was suggested as additional threats. In our long-term research project in Namibia, we study the ecology and health status of this species. Here we show that free-ranging cheetahs are exposed to a wide variety of pathogens and mount an adequate immune response. They do this despite the low variability at their MHC (major histocompatibility complex) genes, which are associated with the adaptive immune system. They show an unusually competent constitutive innate immune system when compared to other sympatric carnivores including the leopards, a species with high MHC variability. By comparing the prevalence and co-infection patterns of hemoparasites of the two species, we found differences in their Th1 and Th2 responses. Furthermore, using proteomic and functional immunological tools, we describe various factors influencing the within-species differences in immune phenotype. Based on our results, we suggest that the immunity of cheetahs is equally successful as other species, their unusual innate response explaining how they cope well with diseases. We advocate the importance of the combination of immunogenetic and functional immune methods to fully understand the health status of endangered species and the role of immunology in developing research-based conservation strategies.

## Characterizing the variation in muscle force-length dynamics during in vivo non-steady locomotion

*Monica Daley, M. Janneke Schwaner, Caitlin Bemis, Kiisa Nishikawa*

It remains a challenge to characterize muscle function over realistic ranges of natural behavior, because in vivo muscle force-length dynamics have been measured in relatively few muscles, species and conditions. Here, we explore variation in force-length, activation and workloop characteristics in the guinea fowl lateral gastrocnemius muscle (LG, N=6) during treadmill locomotion with belt speed perturbations. We hypothesize that strain transients early in the stride will have a substantial influence on the force and work output over the full cycle. We collected in vivo muscle length, force, and activation data during trials at steady speeds and with belt-speed perturbations (decelerating by -0.5 ms-1and re-accelerating to the reference speed). We measured force, impulse, work, fractional length and velocity features during 1) passive swing, 2) force loading and 3) force unloading. We used principal components analysis (PCA) to analyze co-variance among strain, velocity, activation, force and work. The analysis reveals that PC1 captures a correlation between larger velocity transients during passive swing and higher peak force, average force during active shortening, and positive work output over the full cycle. PC1 exhibits a strong speed effect, which can be detected in the speed-perturbed steps although no significant change in EMG intensity occurs until 2 strides after the perturbation. These results suggest that nonlinear interactions between strain and activation strongly influence work output in non-steady locomotor tasks. NSF-IOS 2016049, DBI-2319710

## Interkingdom dynamics in the gut microbiome of an amphibian model system

*Jason Dallas, Kylie Moe, Mitra Ghotbi, Kaitlyn Murphy, Lluvia Vargas-Gastélum, Kerry McPhail, Joseph Spatafora, Jason Stajich, Donald Walker*

Experimental approaches to examine the impact of specific microbial taxa on the gut microbial community structure are limited to a small subset of model organisms. Basidiobolus species are ubiquitous members of the herpetofauna gut and are hypothesized to play an important role in fungal-bacterial interactions in the microbiome. We used a novel experimental system with wood frogs (WF; Lithobates sylvaticus) to identify how Basidiobolus affects gut microbiomes. Captive-reared froglets were fed fruit flies inoculated with one of two putative Basidiobolus species cultured from the feces of wild Plethodontid salamanders. Afterward, all WF were fed uninoculated fruit flies for three months, and WF feces were collected daily for amplicon sequencing of 16S and ITS1 rDNA. All Basidiobolus-fed WF tested qPCR positive following the single feeding while control frogs remained Basidiobolus-free. However, Basidiobolus residency was brief suggesting that this fungus requires consistent reinoculation for long-term persistence in the gut, likely reflecting the lifecycle of the fungus within the host. The gut bacterial composition was largely influenced by maternal effects ($r2 = 0.32$, $P < 0.001$) and the Basidiobolus treatment ($r2 = 0.11$, $P <$

0.001), while the latter had a strong effect on fungal assemblages ($r2 = 0.22$, $P < 0.001$). Utilizing our novel experimental system, we controlled the Basidiobolus inoculation into WF and were able to determine that Basidiobolus structures bacterial-fungal interactions in the gut microbiome.

## A comparative analysis of bacterial growth rates between anthropogenically disturbed and non-disturb

*Mark Daniel, Jason Davis, Joyce Caughron*

How do anthropogenic modifications to the environment impact not just bacterial diversity, but overall bacterial growth rates? Have urbanized environments selected for faster growth curves than undisturbed natural environments? To explore this, we collected samples of bacteria present at disturbed and non-disturbed sites in a range of locations including both North and South America. Our initial data collected in South America suggested that the rate at which bacteria grow is different between disturbed and undisturbed sites, with disturbed sites growing significantly faster. To explore this further, we collected additional data from North American sites along a gradient from unmodified, to recently modified, long-term modified, and re-wilded, as well as a gradient of frequency of disturbance. Bacterial density was estimated using spectrophotometry, while plate counts were used to estimate biodiversity between bacteria. Results of all studies and sites will be presented here.

## Three-dimensional in situ measurements of octopus crawling reveals elements of simplified control

*Joost Daniels, Christine Huffard, Paul Roberts, Kakani Katija*

Ocean animals have adapted to their underwater environment in a myriad of ways, developing sensory systems and biomechanical strategies unlike those found on land. Octopuses in particular, use their flexible arms to swim and crawl in ways not seen in other species. Their movements have garnered considerable interest from roboticists, who attempt to emulate this highly complex yet adaptable system. However, studies have not yet quantified three-dimensional arm movements during crawling in-situ, due in part to the complexity of obtaining these 3D data. We used the plenoptic imaging system EyeRIS, deployed by a remotely operated vehicle, to record the three-dimensional arm kinematics of Muusoctopus robustus at a depth of 3200 meters off the coast of Central California, USA. Using semi-automatic, markerless tracking of the arms, we quantified strain, as well as the radius and location of bends in the arms. Preliminary analysis supports the hypothesis that these octopuses prioritize simple, rotation-based arm movements to effect locomotion. Additional camera angles recorded by the remotely operated vehicle helped reveal conserved attributes in gait kinematics as the octopus crawled across the terrain. Despite moving over rocks of irregular sizes, their strides showed remarkable consistency, even across individuals. These results highlight the need for ideas based on laboratory studies to be verified through in-situ measurements.

## Branching Corals Alter Their Hydrodynamic Environment to Enhance Capture Rates of Evasive Prey

*Kelsey Daniels, Bradford Gemmell*

Hermatypic corals obtain nutrients through a symbiotic relationship with photosynthetic zooxanthellae and through heterotrophic feeding. Despite the importance of heterotrophic feeding, research on this type of resource acquisition for these corals is understudied compared to autotrophic resource acquisition. Thus, relatively little research exists on the predator-prey interaction with naturally occurring prey types. The goal of this study is to elucidate the role of branching coral morphology on the local hydrodynamic environment and how this may impact the capture of evasive and hydrodynamically sensitive, but highly abundant prey such as copepods. We used acrylic cylinder models to mimic branching coral colony structure of three natural branch diameters. High speed, high resolution video recordings measured contacts (i.e. captures) of either evasive copepod prey or non-evasive artemia on the models after being released upstream of the models in a recirculating flume at different flow speeds within the range coral would be exposed to in the wild. We found that branch arrays captured evasive copepods at higher rates than passive prey at all branch diameters at low (5 cm/s) flow speeds, but the advantage dissipates at the highest flow speeds tested (20 cm/s). This suggests that coral morphology has evolved to passively enhance evasive prey capture at flow speeds commonly encountered in nature. This has implications for coral ecology, evolution and restoration efforts.

## Architectural muscle changes in the rat hindlimb during pregnancy and lactation

*Nicole Danos, Adrien A. Arias, Ava Palma*

Hormonal changes during pregnancy and lactation contribute to architectural and morphological changes in the hindlimb muscles of mammals. Previous work in rats (Rattus norvegicous) show that gastrocnemius muscle mass and Achilles tendon stiffness both decrease during pregnancy and lactation. However, it remains unclear whether this pattern is observed in other limb muscles involved in locomotion. Differences in muscle architectural features are associated with changes in the mechanical function of hindlimb muscles during locomotion. Here, we quantify changes in muscle anatomy in the 36 hindlimb muscles of rats during pregnancy and lactation. For each muscle, we conducted gross dissections in virgin non-pregnant (n=3), pregnant (n=3), and lactating rats (n=3) to compare muscle mass, shape (length, depth, width), fiber length, and pennation-angle. We found that 25 out of 36 muscles decreased in mass in both pregnant and lactating females compared to non-pregnant females. Both hip extensors and flexors lost mass during pregnancy and even more during lactation compared to the non-pregnant condition. The same pattern was observed for knee extensors and knee flexors. We found no changes in pennation angle or fiber length as muscle mass decreased. However, all muscles had narrower widths. These changes will be used with a mathematical model of the rat hindlimb and a three-dimensional finite element model to predict muscle mechanics at these critical life stages.

## Mechanical properties of the ACL during pregnancy and lactation in the rat, *Rattus norvegicus*

*Nicole Danos, Alexa Gomez, Adrien A. Arias*

Knee ligaments play a vital role in limb stability and are one of the most frequent sports injuries in humans. Pregnancy and lactation in mammals is associated with several key morphological and mechanical differences in collagenous limb structures. However it remains unclear whether there are changes in the mechanical properties of knee ligaments during pregnancy and lactation that could jeopardize limb stability. Here we use female Sprague Dawley rats (Rattus Norvegicus) as a model system to test whether there are sex differences in mechanical properties and whether pregnancy and lactation affect the mechanical properties of the anterior cruciate knee ligaments (ACL). We use uniaxial material testing (Univert, CellScale Waterloo, Ontario Canada) to calculate the stiffness (N/mm), Young's modulus (MPa), toughness (J/m3) and other mechanical properties of the ACL in non-pregnant, first time pregnant, lactating female and in male rats. Our preliminary results show that ACL stiffness is higher in males than in any female group by nearly an order of magnitude. However, while male ACL tore at strains of 25%, the ACL of pregnant animals could be stretched past 38% before a drop in stress was visible. Combined these preliminary data suggest that pregnancy could lead to a ligament that requires more energy to rupture, making permanent damage less likely during large limb deformations.

## Rigidity, Resilience, and Robustness in Network-like Biomaterials

*Moumita Das*

Living systems exhibit unique emergent properties such as self-assembly, rigidity, resilience, and robustness. In this talk, I will present results from projects that underscore the importance of understanding these collective properties in network-like bio materials and help to address key questions in the rational design of biomimetic systems: Can we engineer composite soft matter based systems to display life-like emergent properties? How can we enhance the tunability and control of such systems? And, is it feasible to activate synthetic soft materials using biological processes? I will begin by examining potential physical mechanisms that underlie robust and resilient mechanical properties in biopolymer networks in cells and tissues. Utilizing rigidity percolation theory, we explore how the composite and heterogeneous composition influence cell and tissue mechanics and suggest design principles for artificial constructs with tunable and robust mechanics. Following this, I will discuss the formation and manipulation of colloidal networks using functionalized clock proteins—proteins that regulate biological clocks—to engineer robust self-assembly kinetics and material properties in colloidal systems. Leveraging such protein-based reaction networks allows us to endow synthetic systems with life-like properties. Our findings demonstrate how understanding the emergent structure-function properties in biological and bio-hybrid systems can support the development of biomimetic materials that not only mirror the robustness and adaptability of living systems but also offer enhanced control over their physical properties and functions.

## Threats and Opportunities: Control of Embryonic Development by the Environment

*Lance Davidson*

Species in the wild face a bewildering array of environmental threats that can narrow their ranges as well as opportunities that may expand their ranges. Typically, environmental effects on species ranges have been viewed through the lens of physiological performance and behavior of adults; however, embryonic stages are the first time in an organisms life cycle where these threats and opportunities may be impactful. Oviparous embryos are directly exposed to a wide variety of environmental stressors such as temperature, humidity, pressure. When eggs are laid in aqueous environments embryos may are exposed to additional stressors through osmolarity and pH. Evolutionary adaptation, constraints, and canalization can limit the ability of developmental programs of patterning and morphogenesis to compensate for these stressors. Alternatively, these programs can enable a species to thrive when competitors are stymied. This presentation is a perspective on the invasive ability of Xenopus laevis aquatic frogs to tolerate, and even thrive at both extremes of their permissive ecological ranges. Exploration of morphogenetic adaptations to these extremes and constraints on closely related Xenopus species (X. tropicalis, X. borealis, and X. muelleri) are likely to shed light on the threats and opportunities facing global animal populations facing rapid climate changes.

## Cis-regulatory dimensions of inter- and intraspecific variation in beetle horn development

*Phillip Davidson, Armin Moczek*

Nutrition-responsive and sexually dimorphic traits are among the fastest evolving phenotype classes, yet the contribution of cis-regulatory elements and associated gene networks in facilitating, biasing, or hindering such diversification is largely unexplored. This work aims to deepen current insight into the plasticity and evolvability of developmental gene networks in generating organismal diversity using beetle head horns. Using a combination of comparative genomics and ATAC-sequencing in the genus Onthophagus, we find largely discrete regulatory networks underlie two types of intraspecific variation in horn development, nutritional plasticity and sexual dimorphism, potentially permitting the extreme elaboration of this trait over evolutionary time. Moreover, we identify three distinct classes of cis-regulatory modifications associated with horn diversification within and between species: changes in 1) accessibility and 2) sequence of conserved regulatory elements and 3) acquisition of lineage-specific regulatory elements. We then focus on the exaggeration and loss of plasticity in O. taurus and O. sagittarius horn development, respectively, and identify an evolutionarily dynamic cis-regulatory landscape nearby candidate genes involved in horn development. Lastly, we validate our predictions by perturbing the function of BMP-signaling regulatory proteins in developing horns to show this signaling pathway has been co-opted during the diversification of this novel trait. More broadly, our results highlight the significance of cis-regulatory elements in mediating gene network interactions responsible for transducing genetic and environmental signals toward alternative or novel phenotypes.

## Molecular mechanisms underlying the formation of the nerve cord in the annelid *Capitella teleta*

*Johnny Davila-Sandoval, Neva Meyer*

Increasing evidence on developmental mechanisms and gene expression in emerging research organisms has ignited the debate on the origin of central nervous systems in animals. The neuroectoderm is specified by a gradient of bone morphogenetic protein (BMP) signaling and activation of the MAPK cascade in vertebrates (Deuterostomia) and insects (Ecdysozoa). However, this mechanism is unknown in Spiralia, including Capitella teleta. We previously showed that in C. teleta, the blastomere 2d, which forms the trunk ectoderm and the ventral nerve cord (VNC), can form neural tissue in isolation. However, isolating 2d in the presence of other animal cap micromeres at the 16-cell stage blocks VNC formation. This suggests that VNC specification in C. teleta relies on autonomous neural determinants and cell-cell signaling. To identify the genes involved in neural specification in C. teleta, we combined blastomere isolation and transcriptomics. In pilot RNA-seq experiments, we identified Spiralia-specific transcription factors and components of the canonical Wnt signaling pathway (cWnt). We perturbed cWnt signaling via small-molecule experiments and used in-situ hybridization of the neural marker Ct-elav1 to assay VNC formation. To identify additional clade-specific genes, we performed gene family analysis using metazoan genomes. These results provide insights into the molecular mechanisms underlying VNC formation. For future directions, we are planning to expand RNA-seq experiments to identify critical time windows for cell-cell signaling and additional candidates acting as neural determinants.

## Innate immune function across four conspecific turtle species

*Isabella Davis, Jen Terry, Lori Neuman-Lee*

The reptilian immune system is poorly understood, and few studies have made intraspecies comparisons. To address this gap, innate immune function across four conspecific freshwater turtle species was evaluated. Red-eared Slider Turtles (Trachemys scripta elegans), Mississippi Mud Turtles (Kinosternon subruburm hippocrepis), Eastern Mud Turtle (Sternotherus odoratus), and Common Snapping Turtles (Chelydra serpentina) are found throughout the southeastern United States and represent different ecological niches and life histories. In spring 2024, male and female aquatic turtles were caught using hoop nets, and blood samples were taken to assess immune characteristics. Microbial killing assays were conducted using multiple blood serum treatments (fresh, frozen, and frozen+ heat-treated serum) as well as three microbes that activate specific immunological responses: Gram-positive (Staphylococcus aureus), Gram-negative (Escherichia coli) and a fungus (Candida albicans). By using this suite of microbial assays, differences in immune prioritization can be observed across species and between sexes. Conducting intraspecies comparisons in immune function can provide valuable insight into the underlying patterns of physiological variability within wild organisms.

## How bulbs get swole: resource allocation patterns across bulbous plants

*James Davis, Cody Howard*

Geophytes are plants with belowground perennating buds and storage organs which allow for the plants to survive disturbances, such as frosts, droughts, or fires. Geophytism can be accomplished through different types of morphologies, such as tubers (i.e. potatoes), rhizomes (i.e. ginger), corms (i.e. crocus), and bulbs (i.e. onion). Of these, bulbs are unique in that leaf tissue performs most resource storage rather than stem or root tissue. The bulb storage organ is made up of swollen leaf bases called scales, arranged in concentric layers surrounding the apical meristem. These scales vary in size, shape, and number across species, even within members of the same genus, and these differences may reflect alternative resource allocation strategies. It is not fully known how variation in bulb and scale size contributes to the life history of a bulbous plant. To further our understanding of resource allocation patterns within bulbous plants, we measured the size of the plant and water content of the individual components of the bulb for 16 taxa. Overall, we found a positive correlation between bulb diameter and root mass, shoot mass and stem diameter. Additionally, in general, we found a decrease in water content from the outermost to innermost layers of the bulbs. This suggests that despite considerable variation in morphology across taxa, from few to many bulb scales/leaves, bulbous plants share resource allocation strategies.

## Artificial evolution: Patterns in interactions between human selectors and digital organisms

*Jason Davis, Birch Ambrose*

Genetic algorithms couple the speed of machine learning to the selective and mutative processes inherent in evolution to derive solutions to complex and dynamic problems. Using these algorithms we can create digital environments where patterns of selection and evolution can be played out at a rapid speed; moving through hundreds or thousands of artificial generations in minutes. In this project we created an algorithm in which digital organisms with observable phenotypes and underlying genotypes were acted on by human selectors, forcing them to evolve in response to human-induced pressures. This interaction rapidly recreated classical patterns seen in evolution such as camouflage, aposematism, and mimicry. It also allowed us to easily explore emergent patterns in other variables, including the evolution of mutation rate, interactions between evolution and population size, and the effects of organismic complexity on selection. In addition, the evolution of these digital organisms provided surprising insight into qualities of the selective agents themselves, with phenotypic and genotypic changes showing clear relations to aspects of selector demography, such as sex and age. Here we will discuss both the process and ongoing outcomes of this project, as well as its potential utility for both education and outreach.

## Mapping 3D sensitivity of otolith organs of the plainfin midshipman

*Julian Davis, Elijah Berger, Joseph Sisneros, Loranzie Rogers*

Understanding fish hearing is essential for determining how sound source localization operates in aquatic environments. Previous research has indicated that the utricle may play an important role in directional hearing in the plainfin midshipman (Porichthys notatus). Here, we map the three-dimensional (3D) sensitivity of hair cell bundles within the otolithic end organs, aiming to provide deeper insights into the contributions of each end organ in sound source localization by fish.

We digitized planar maps of hair bundle orientations from confocal images to characterize the directional sensitivity of hair bundles across each otolithic end organ. A 100-by-100 square micron grid was overlaid on the orientation maps, and "average" sensitivity orientation vectors were manually selected for each grid area. PhosphoTungstic acid-stained micro-CT scans of adult plainfin midshipman were used to generate 3D epithelial surfaces of the end organs. Sensitivity orientation vectors were projected onto these surfaces to determine their 3D orientation in terms of azimuth and elevation.

Results suggest that while the saccule accounts for a significant portion of sensitivity in 3D-space, the utricle and lagena are essential for covering regions beyond the saccule's reach. However, even with the combined contributions of all three end organs, certain areas in 3D-space remain uncovered, highlighting persistent "blind spots." These areas include rostro-lateral areas at extreme elevation angles and caudal-lateral areas at positive elevations across all end organs.

## Exploring the genetic connectivity of the Eastern oyster (C. virginica) from Northwest Florida

*Maggie Davis, Viktoria Bogantes*

The eastern oyster, Crassostrea virginica, plays a vital role in the Gulf of Mexico marine ecosystem, providing essential environmental assistance such as erosion control and water filtering. However, populations have experienced a dramatic decline over the last few decades, prompting extensive restoration efforts. This study investigates the genetic diversity and connectivity of Crassostrea virginica in Pensacola Bay, Florida. In this study, oysters were collected from three selected sites and one farmed location within Pensacola Bay. Genetic analysis using the mitochondrial marker COI revealed a low level of genetic diversity among the sampled oysters, with most specimens sharing a common haplotype. The findings suggest that the genetic diversity of the studied populations may be limited, but this lack of diversity could be due to a lack of wider variety in sampling. In addition, it is possible that the haplotype seen is simply the most successful haplotype for the area and thus the most dominant. Future research will expand the sampling areas to include a wider set of locations which will be used to better understand the genetic diversity and connectivity of Crassostrea virginica in Northwest Florida.

## Drag reduction and locomotory power in dolphins: Gray's paradox revealed

*Randall Davis, Dara Orbach, Lorenzo Fiori, Bernd Wurzig*

For 88 years, biologists and engineers have sought to understand the hydrodynamics enabling dolphins to swim at speeds seemingly beyond their energetic capabilities, a phenomenon known as Gray's paradox. Hydromechanical models calculating the drag of swimming dolphins estimated power requirements for sustained high-speed swimming that were physiologically impossible. Using an uncrewed aerial vehicle (UAV), we calculated the total power of free-ranging dusky dolphins (Lagenorhynchus obscurus) at speeds from 0.9 to 6.9 m s-1, deriving drag coefficients (Cd) and drag. Our results showed that the Cd decreased exponentially with speed, reducing drag by up to 89% at speeds >2 m s-1, with an additional ~17% reduction during porpoising (>4.0 m s-1). At 6.9 m s-1, drag was 32 N, with a power of 15.8 W kg-1, nearly identical to the allometric prediction for the maximum aerobic capacity of other mammals and physiologically possible. The Cd at speeds >2.5 m s-1 indicated reduced turbulence in the boundary layer around the dolphin's body, thereby reducing drag. The ability of dusky dolphins to swim at sustained high speeds resulted from an exponential decrease in Cd, which was further reduced by porpoising, thereby explaining the low drag and locomotory power that resolved Gray's paradox.

## Bringing inclusive fieldwork practices to malacology

*Elizabeth Davis-Berg, Teresa Rose Osborne, Kevin Kocot, Elizabeth Shea, Jingchun Li, W. A. Nimanthi Abeyrathna, Kelly Martin*

The JEDI (Justice, Equity, Diversity, and Inclusion) committee of the American Malacological Society hosted a panel discussion on inclusive fieldwork at their 2023 meeting to help raise awareness in the society about concerns specific to fieldwork. Fieldwork is not always inclusive to all researchers. We discussed how to plan for inclusive fieldwork, including building comradery within a diverse field team, identifying and mitigating risk factors unique to each fieldwork situation, and drafting day-to-day schedules that accommodate field team members' individual and personal needs. The interest generated by the panel led to a manuscript specifically discussing inclusive fieldwork and belonging of researchers working in the various habitats within invertebrate zoology and malacology. This presentation will address challenges in implementing JEDI work within a scientific society, findings on inclusive fieldwork, and our recommendations for inclusive fieldwork, especially in situations that include individuals who may not be as familiar with potential hazards, those who work in remote locations, and other unfamiliar environments.

## Natural Selection on Testosterone in a Wild Lizard Population

*Myles Davoll, Robert Cox*

In male vertebrates, testosterone is hypothesized to underlie the life-history tradeoff between survival and reproduction. Indeed, testosterone has been correlated with components of male reproduction by way of accentuating courtship behavior, territorial aggression, and the development of primary and secondary sexual characters while simultaneously suppressing components of survival such as somatic maintenance and immune function. Despite the wealth of information surrounding the action of testosterone and its role in the expression of traits correlated with fitness, few studies have simultaneously linked natural variation in testosterone to both survival and reproduction in the wild. To test whether testosterone structures the tradeoff between reproduction and survival, we measured standing variation in circulating testosterone levels of adult males at three points during the reproductive season, then estimated survival (using mark-recapture) and reproductive success (using genetically assigned parentage) in a wild population of brown anole lizards (Anolis sagrei). We predict that variation in testosterone will be positively correlated with reproductive success and negatively correlated with survival.

## Damsels in Distress: How Injury Affects Larval Damselflies

*Alexis Dawes, Emma Mazeika, Sarah Berke, Sierra Libron*

Invertebrates are critically important components of aquatic ecosystems worldwide. Many freshwater invertebrates represent the larval stages of terrestrial insects. Damselflies, for example, lay eggs in ponds and streams that hatch into flightless, fully aquatic larvae. These larvae spend weeks to months feeding and growing underwater before undergoing a terminal molt and emerging as winged adults. Larval damselflies are predators of smaller invertebrates, and are themselves prey for larger insects, fish, and amphibians. Interactions with predators, even when not lethal, can result in injury, such as the loss of a limb or other appendage. Such injuries would potentially influence an individual's growth, ecological function, and future reproductive success. Damselflies have six legs as well as three large posterior gills; these gills are used for both gas exchange and for swimming. Gills are frequently lost to predator encounters; we would expect such loss to influence multiple aspects of the larva's biology including swimming speed, predator avoidance behaviors, and predation risk. We will present data for rates of gill and leg injury for larvae in the genera Enallagma, Ischnura, and Lestes at ponds in the northeastern United States. We will also present comparative data from experiments to quantify swimming velocity following lamellar injury for these genera.

## Epigenetic potential changes over 100 years in five introductions of introduced house sparrow

*Danielle Dawkins, Mark Ravinet, Kevin Kohl, Marty Martin, Aaron Schrey*

Introduced species provide an opportunity to study the impact of epigenetics on rapid adaptation. To cope with the novelty of an introduced location, introduced species can produce variable phenotypes through phenotypic plasticity. Phenotypic plasticity can be modulated through epigenetic mechanisms, which alter gene expression in response to the new environment. Epigenetic potential (EP) estimates the capacity of an individual's gene expression to be epigenetically modified. EP can be quantified via promoter CpG site frequency, with higher frequency representing a higher capacity for epigenetic modification. Higher EP may be particularly advantageous during introduction as it plays a role in colonization success and organism survival. Here, we explored how EP changes over time across five separate introductions of the house sparrow (Passer domesticus). We investigated EP from museum samples collected at 100-year, 50-year, and 30-year ago time intervals. We expected that house sparrows closest to the introduction would have the highest frequency of CpGs in all locations, as they likely experience the most stress associated with initial colonization and require fine-tuning of gene expression as necessary for survival. Our results supported our hypothesis, in showing higher CpG frequencies in house sparrows at the 100-year ago time, closest to initial introduction. We also found that CpG frequency patterns become highly variable and idiosyncratic in the 50-year and 30-year ago samples.

## A comparison of the Mummichog escape responses to different types of predator stimuli

*Alexis Dawson, Noah Bressman*

Mummichogs (Fundulus heteroclitus) are a species of fish that can be found in tidepools within the intertidal zone. When within these tidepools, to be able to still avoid predation is beneficial to their survival. Regarding their leaping behavior, there is not much known on how this movement is incorporated into their predator evasion strategies. This brings into question what their tactics are for avoiding predation when stuck in these small tidepools, and how the type of predator could affect their response. This was tested by recording the mummichog's response to either a prop of a marine predator or to a prop of an aerial predator, then analyzing differences in the frequency of their leaping behavior. By comparing the escape responses of the fish to a marine versus an aerial predator, this study adds to what is known on the behavior of mummichogs. It is relevant to the predator-prey interactions of intertidal fish, including the ecosystems of wetlands, mudflats, creaks, and other shallow water areas.

## Evaluating the relationship between immune function and reproductive success in long-lived reptiles

*Tiffany Dawson, Katherine Mansfield*

Energetic tradeoffs between immune function and reproductive output are common in sexually mature females and can be exacerbated by extended breeding periods and/or multiple reproductive events. For sea turtles, reproductive hormonal shifts months prior to nesting, long migrations from foraging grounds to nesting beaches, and multiple mating and reproductive events in a single nesting season require heavy energy expenditures. Immune suppression is a common tradeoff for producing high quality offspring but is not well documented in large marine reptiles. To evaluate immune function tradeoffs in nesting sea turtles, we examined proxies for immune function relative to reproductive output for loggerhead turtles (Caretta caretta) during the 2020-2021 nesting seasons in Florida, USA. We evaluated n=122 blood samples for packed cell volume, differential white blood counts, and plasma protein fractionation; associated female reproductive output was measured by hatching success and the number of reproductive events were categorized as early-, mid-, or late-season based on sampling day. Generalized linear models showed significant relationships between immune proxies and reproductive success as well as sampling date, indicating physiological changes within the nesting season. Decreases in immune function in reproductive females leave them susceptible to diseases and parasites, which increase with changing habitats during migrations. Understanding the relationships between immune parameters and reproductive output is vital to developing best management practices.

## Foot placement control strategies for stable locomotion across species

*Antoine De Comite, Nidhi Seethapathi*

Legged animals navigate their environment stably despite sensorimotor noise and external perturbations. In humans, stable locomotion is achieved by placing the foot on the ground such that recent errors in the body are corrected. However, stability in many-legged animals is attributed to within-stance as opposed to swing foot placement control. Here, we mined the natural locomotor variability in flies, mice, and humans, developing a data-driven framework to discover foot placement control strategies across species. Using this framework, we found that flies and mice modulate foot placement to correct recent errors in the body state, a strategy previously only attributed to humans. We discovered that the magnitude of foot placement control was shaped by the passive stability of the animal's multi-legged embodiment: flies and mice correct around 15% and 30% of the errors respectively while humans correct 65% of the body state errors in a single step. Similarly, the timescale over which these errors are corrected is longer for flies (3 gait cycles) and mice (2 gait cycles) than for humans (1 gait cycle). Finally, we found that flies and mice use decentralized foot placement control with a gradient along the fore-hind and medio-lateral axes, whereas the control is more centralized in humans. Together, our results reveal foot placement control strategies across species, and provide a comparative framework to understand stabilizing control across neuromechanical embodiment.

## Quantifying the efficacy of clay treatments at removing red tide *Karenia brevis* in mesocosms

*Ivett De La Rosa Montano, John Andres, Michelle R. Gaither, Ashley Reaume, Victoria Devillier, Kris A. Lewis*

Florida is regularly impacted by Harmful Algal Blooms (HABs), known as red tides that have led to the loss of millions of dollars in revenue to the state. A promising method for the mitigation of red tides is the application of clay treatment which reduces cell number by binding cells in the water column, coagulating, and falling to the sea floor. Clay treatments have been employed in Asia but not yet tested in the U.S. Here we report the results of a mesocosm experiment that examined the effects of two different clay mixtures: 1. Modified Clay II with Curcumin (CUR); 2. Geosynthetic Clay with Oxidizer (GCO) at removing K. brevis cells from water. In our replicated experiment, we collected samples before treatment and at 2, 24, 48, and 72 hours after clay application and employed qPCR to quantify K. brevis DNA in water samples. Results showed that both clays were effective at removing Kb cells from the water column, but that CUR performed better. Within 72 hours we found a 70% reduction in Kb DNA for the CUR treatment and a 41.5% reduction for GCO. Interestingly, our cell counts made using microscopy showed a 100% reduction for both treatments. While both qPCR and microscopy showed evidence for a reduction in cells, results also showed that DNA is still detected even when cells were not observed.

## Need for speed: are jaw muscle characteristics different in species varying in singing capacities?

*Jana De Ridder, Dominique Adriaens, Sam Van Wassenbergh*

A bird's beak has several functions, from feeding and drinking to singing, leading to a compromise in morphology. Adaptive evolution in relation to feeding ecology is an important driver in beak shape and size. To crack hard seeds several species evolved a strong beak. Singing on the other hand is an important factor in sexual selection. Females usually prefer more complex songs and high trill rates, reached by fast beak movements. This leads to a trade-off between strong and fast beaks. The biomechanical principles underlying this force-velocity trade-off are, however, still unclear. In a first step to fill this knowledge gap, the anatomy of the jaw muscles was compared for a series of finches varying in beak morphology and singing capacities. Using DiceCT several muscle characteristics were compared. It is expected that closing muscles are well developed in the strong biting species. Opening muscles are smaller in birds, but important during singing. The imbalance between opening and closing muscles in birds creates a delay in activation of opening muscles due to the time needed for relaxation of the closing muscles. This delay prevents fast opening during singing. The hypothesis is that strong biting species have evolved stronger opening muscles to counter the strong closing muscles. For fast singers, a smaller imbalance between opening and closing is expected to facilitate singing.

## Comparing data collection methods for testing web glue adhesion of Argiope spp. [Araneae: Araneidae]

*Sal DeAndrea, Sarah Stellwagen*

Many orb weaving spiders use sticky glue extruded from aggregate glands to trap prey in their webs. Force analysis of extending aggregate glue droplets when pulled from a surface after adhesion has been documented from several spiders in the genus Argiope. However, investigating the glue strength of a sister species from another environment can aid in understanding the evolutionary relationship between habitat and glue properties. Using a force transducer that measures force directly, we tested droplet pull-off forces to obtain the maximum strength values for glues produced by the Australian species, Argiope keyserlingi. This species has never been tested, while a native species, Argiope aurantia, was previously tested using imaging techniques alone. We controlled for environmental conditions and tested droplets at native humidity and temperature, as it is well documented that humidity and temperature can affect capture glue material properties. Understanding if imaging techniques are an effective way to measure the force of spider glues can increase accessibility of these measurement techniques.

## Wear resistance of insect mandibles

*Deegala Deegala, David Labonte*

Many insects use mandibles to mechanically access and manipulate food sources. To keep force demands low, extremely sharp mouthparts evolved in many lineages. However, sharp mouthparts are not without disadvantages: they are more susceptible to wear, which significantly reduces mechanical performance and mouthpart longevity. To understand how wear depends on mouthpart material properties, we conducted extensive nanomechanical characterization of the mandibles of selected insect species: mature and callow leaf-cutter ant (Atta cephalotes) mandibles were compared to elucidate the effect of sclerotization and Zn inclusions; to study the correlation between wear resistance and elastic modulus and hardness, we characterised the mechanical performance of the mandibles of hissing cockroaches (Gromphadorhina portentosa), an omnivore, and leafcutter bees (Megachile ligniseca), which also cut leaves, but, unlike leaf-cutter ants, do not incorporate Zn. Last, nanomechanical assays were performed under different relative humidity to uncover the effect of hydration. Zinc incorporation and sclerotization increased epicutle hardness and modulus by about 100%, but have a negligible effect on wear resistance. Similarly, relative humidity had a significant influence on hardness and modulus, but not on wear resistance. Thus, wear models for engineering materials appear inadequate for insect cuticle; the best material property proxies for wear resistance in biological materials remain remarkably unclear.

## Characterizing the aging transcriptome of Japanese medaka fish

*Megan Deeter, Ethan Shealy, Marilyn Mason, Benjamin Parrott*

Age-related physiological decline is strongly linked to global changes in gene expression; however, our understanding of the specific genetic pathways and their susceptibility to environmental dynamics is limited to only a few taxonomic groups. In this study, we resolve transcriptional patterns associated with age by profiling 84 hepatic transcriptomes from Japanese rice fish (Oryzias latipes) spanning the lifespan. Through multiple modeling approaches, we identify over 280 genes that change continuously across the life course as well as those that change across discrete life stages. Collectively, our findings provide insight into the molecular pathways underlying organismal aging.

## Investigating the threshold of visual acuity in Caribbean Hogfish (*Lachnolaimus maximus*)

*Julie Degnan, Vanessa Moreno, Lorian Schweikert*

Vision is known to serve many ecological functions, including communication via conspecific signaling carried out by dynamic color change of the skin. One animal capable of dynamic color change is the Caribbean hogfish (Lachnolaimus maximus), a territorial reef-dwelling species that undergoes cooperative living in female-dominant harems. For dynamic color change to serve conspecific signaling, the receiver must be able to detect signaling displays, which for hogfish may include contrast patterns of vertical stripes produced by nearby conspecifics. Limited information exists on hogfish visual performance; thus, we set out to estimate hogfish visual acuity to then determine the limits of spatial vision as it relates to the perception of color patterns generated by hogfish. Retinas from the left eyes were whole-mounted, stained with a cresyl violet solution, and imaged through light microscopy to visualize the density and spatial distribution of the retinal ganglion cells. We then combined this information with an estimate of ocular focal length in order to calculate a value of hogfish visual acuity. This allowed us to test the assumption that hogfish have the adequate visual acuity to detect the striped patterns displayed on other hogfish. These findings may provide key insights into the functional significance of dynamic color change and the role their vision plays in detecting these behavioral responses.

## Cost and benefits of autotomy in the grasshopper *Syrbula admirabilis*

*Brendan Dehner, Michael Reichert*

There is variation both within and among species in how readily autotomy, the self-controlled loss of a body part, takes place. This variation is likely due to differences in the costs and benefits of autotomy depending on traits of the organism. Autotomy aids in escaping predators, but it has costs such as reduced movement ability. Many insects will lose an appendage to prevent predation. However, insects cannot regrow their legs, and this is likely to affect movement. We investigated the factors that affect speed of autotomy and the consequences of autotomy on mobility in the grasshopper Syrbula admirabilis. First, we tested if age, sex, and whether a previous limb had been lost affected autotomy speed. It is likely that losing both limbs is more consequential than losing one limb, therefore we hypothesized that grasshoppers would lose their first limb quicker than their second. We also predicted that because adults can fly, they will lose their limbs quicker than juveniles. We did not have a clear prediction for the effects of sex, but factors such as body size and movement vary between the sexes and could affect the benefits of autotomy. Second, we tested the consequences of limb loss on locomotion, by measuring the flight initiation distance, jumping performance, and tendency to fly for intact individuals, individuals missing one hindlimb, and individuals missing two hindlimbs.

## Effects of temperature and age on energetics of starvation-selected *Drosophila melanogaster*

*Elena DeLaTorre, Katrina Pinili, Allen Gibbs*

We reared replicated populations of starvation-selected (SS) D. melanogaster at 18, 25 and 29 oC. SS flies eclosed with 2-3 times higher triglyceride content than their fed control (FC) counterparts. Lipid content did not differ among flies reared at different temperatures. Lipid content was assessed for 3 weeks in adults held at the same temperature as their rearing temperature. Adults maintained constant lipid content as they aged at 18 and 25 oC. At 29 oC, SS flies lost lipid stores as they aged, but FC flies did not. These results suggest that starvation-selected flies are more sensitive to high temperature stress.

## Laser capture microdissection reveals tissue-specific gene expression patterns of a reef-building coral

*Zoe Dellaert, Hollie Putnam*

Reef-building corals are increasingly threatened by rising ocean temperatures and other environmental stressors. Within a coral colony, the diverse cells and tissues of individual polyps perform distinct functions and may respond differently to stress. However, most studies on coral gene expression and DNA methylation rely on bulk approaches that combine all tissues and cell types from multiple polyps, potentially obscuring critical insights. To address this limitation, we developed a novel application of laser capture microdissection (LCM) for precision dissection of ∗Pocillopora acuta∗, a thin-tissued, environmentally sensitive coral. We optimized RNA and DNA extractions from LCM-dissections of cryosectioned, fixed tissue and successfully prepared sequencing libraries from as little as 2 ng of RNA for RNA-seq and 1 ng of DNA for whole-genome bisulfite sequencing. This method enables tissue-specific analysis of gene expression and DNA methylation, which could be used to uncover key stress response pathways masked by bulk sequencing data. Our approach provides a powerful tool for advancing coral biology at the scales relevant to the coral organism's physiological processes and physiochemical microenvironments.

## Proximodistal muscle function and neuromuscular control during steady and nonsteady flight in doves

*Remy Delplanche, Kathryn Greil, Daniel Inman, Bret Tobalske*

The locomotor adaptations exhibited by flying vertebrates have been shaped by the fluid properties of the air through which they navigate. Real-world airflows are complex, and perturbations have likely served as selective pressures upon flying organisms. However, little is known about the neuromuscular control underlying flight in turbulent airflows. To investigate this, we measured the length changes and neuromotor recruitment of proximal and distal wing muscles in Barbary doves (Streptopelia risorii, n=5) using sonomicrometry and electromyography under several flight conditions. Muscles were recorded during gliding and cruising flight in a wind tunnel at an airspeed of 10m/s, as well as in response to simulated upward gusts during gliding flight. Gusts, 1 m/s in magnitude, were generated using 2 airfoils mounted at the front of the flight chamber; by increasing the angle of those airfoils relative to the horizontal, airflow was deflected up into the bird from below. During cruising flight, muscle activation patterns broadly supported a proximo-distal gradient of muscle function: proximal muscles functioned primarily as actuators, while distal muscles were responsible for force transmission and energy storage rather than joint movement. Muscular activity was also observed for gliding flight, consisting mainly of isometric contractions. Consistent strain and activation patterns were not observed in response to simulated gusts, suggesting that passive mechanisms play a larger role in gust rejection in gliding birds.

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## Quantifying structural and sensory olfactory morphology in the Blacktip Shark

*Nicole Demaras, Lauren Simonitis, Aubrey Clark, Marianne Porter, Tricia Meredith*

The elasmobranch olfactory system consists of paired olfactory capsules housing the olfactory rosettes. Sharks detect odorants as water flows into their incurrent nares, through the olfactory rosette, and out the excurrent nares. The olfactory rosettes are composed of lamellae— plates of tissue covered in both sensory and non-sensory epithelium. Lamellar structure varies based on position along the rosette and may correlate with water flow; previous studies have primarily focused on extreme olfactory morphologies such as the elongated rosettes of hammerhead sharks or the spherical rosettes of dogfish. Here, we described the distinct rosette morphology of blacktip sharks (Carcharhinus limbatus). We hypothesized that, similar to other shark species, the lamellar microstructure of blacktip sharks varies depending on its location along the rosette. Using scanning electron microscopy (SEM), we described lamellar morphometrics, including total surface area, degree of secondary folding, and percentage of sensory surface area. We found that lamellar surface areas of the blacktip shark vary along the rosette. Lamellae in the middle region are larger and contain more secondary folding. Differences in sensory and non-sensory lamellar composition could depend on hydrodynamics within the rosette. This project enhances our understanding of olfactory morphology in sharks, which can inspire highly sensitive, non-clogging liquid chemical sensors.

## The effects of salinity on reproduction in the anomuran crab *Petrolisthes cinctipes*

*Asia DeMarre, Brian Tsukimura*

The rocky intertidal zone is an ecosystem subject to a wide range of abiotic stressors, such as temperature, pH, and salinity, which are intensified by climate change. The El Nino-Southern Oscillation (ENSO) influences salinity fluctuations in the rocky intertidal zones through increased freshwater runoff and precipitation. These changes in salinity pose physiological challenges on the reproductive fitness of intertidal species such as the anomuran crab, Petrolisthes cinctipes. This study investigates the effects of climate-induced salinity changes on the reproduction of P. cinctipes. Crabs were exposed to different salinity levels (20, 28, 35 ppt) at a constant temperature of 12°C for seven days. Hemolymph vitellogenin (VG) levels and gonadosomatic index (GSI) were used as the biomarkers to measure reproduction. Results showed a decrease in VG and GSI levels in the crabs incubated at 20 ppt relative to the control at 28 ppt ($p<0.05$). There was no difference between crabs incubated at 35 ppt relative to the control at 28 ppt ($p>0.05$). These findings suggest that under osmotic stress, P. cinctipes may allocate more energy towards maintaining homeostasis at the expense of reproductive investment. This research contributes to the broader understanding of how climate-induced environmental changes may affect marine biodiversity through reproductive and survival strategies in intertidal organisms.

## Androgens regulate acoustic preferences of female *Xenopus*

*Bethel(Betty) Demissu, Erik Zornik, Charlotte Barkan, Juliet Berton*

Male African clawed frogs (Xenopus) vocalize underwater to attract female mates. The Xenopus phylogeny comprises approximately 30 described species, each with a unique advertisement call produced by males. Female X. laevis show a significant preference for conspecific mating calls compared to heterospecific calls during human chorionic gonadotropin (hCG)-induced ovulation. Xenopus ovulation is thought to be androgen-dependent; after treatment with Beta-hCG, the primary circulating hormone produced by Xenopus ovaries is testosterone. To test our hypothesis that androgens also regulate female receptivity behaviors as well as ovulation, we used flutamide, an anti-androgenic drug, to decrease androgen expression in Xenopus experimental subjects. Female X. laevis subjects were exposed to alternating conspecific and heterospecific advertisement calls for 48 hours to assess preference behavior. While hCG-injected control subjects strongly preferred conspecific calls, females injected with hCG and flutamide-treated may have a reduced preference for conspecific mating calls. These results support the hypothesis that androgens may promote female preference behaviors and receptivity toward conspecific advertisement calls.

## Examining the effects of symbiotic state and environmental pollution on wound healing in corals

*Jonathan deMontagnac, Liz Burmester, Justin McAlister*

Understanding coral reef health requires a comprehension of the biological processes that support live coral cover. Corals are frequently exposed to physical abrasion from various sources, thereby necessitating vital resources be directed to wound recovery. This process can affect the overall health of the wounded colony. For corals and other organisms that harbor photosynthetic symbionts, the balance between autotrophic versus heterotrophic energy contributions influences their fitness. Experimentally disentangling the individual effects of environmental stress and symbiotic state on coral health is difficult in most tropical corals due to the obligate nature of their symbiosis. However, determining how nutritional dynamics, environmental stressors, and health interact is crucial to understanding coral resilience. To examine how coral-algal symbiosis and stress tolerance interact, we have been examining wound recovery of a particularly hardy, temperate and facultatively symbiotic coral, Astrangia poculata. Unlike most tropical coral, A. poculata can healthily maintain a spectrum of symbiotic states, from fully symbiotic to fully aposymbiotic. Results from our previous projects using corals of different symbiotic states suggest that there is a difference in the ability of symbiotic states to heal controlled experimental lesions while being exposed to environmental pollutants, such as tire dust leachate. This project expands on our previous work by increasing the sampled population to better discern the impact of symbiotic state on wound recovery.

## Uncovering molecular basis of photoperiod-driven polyphenism in Siberian hamsters

*Irem Denizli, Calum Stewart, Kathyrn Elmer, Annika Herwig, Anna Przybylska-Piech, Tyler Stevenson*

Siberian hamsters demonstrate pronounced seasonal polyphenism, where environmental cues such as photoperiod induce a range of phenotypic changes from a single genotype. These adaptations include alterations in body weight, food intake, energy metabolism, and fur coloration. To elucidate the molecular mechanisms driving these changes, we conducted an integrated study incorporating whole-genome sequencing, transcriptome profiling, and chromatin immunoprecipitation (ChIP) for methylation analysis.A genome-wide association study (GWAS) involving 46 hamsters exposed to varying photoperiods (16L:8D and 8L:16D) identified genetic variants associated with key physiological pathways, particularly those governing circadian rhythms, feeding behavior, and reproductive processes. Transcriptome sequencing using the same samples revealed differential gene expression linked to these pathways, suggesting a robust transcriptional response to photoperiodic changes. Additionally, ChIP analysis uncovered differentially methylated promoter regions, indicating potential epigenetic regulation influencing gene expression patterns.Gene Ontology (GO) analysis highlighted significant enrichment in biological processes related to circadian rhythm regulation, feeding behavior, and reproductive function. These findings collectively offer a comprehensive view of how genetic and epigenetic factors interact with environmental stimuli to mediate the complex physiological adaptations observed in photoperiod-driven polyphenism.This study provides novel insights into the molecular basis of seasonal adaptation, positioning Siberian hamsters as an invaluable model for exploring the dynamic interplay between genetics, environment, and epigenetic modifications.

## Measuring complex 3D curvatures: a mathematical approach to human rib shape

*Randi Depp, Rachel Olson*

Human ribs have complex shapes, with the degree of curvature changing in more than one plane along the rib length. Existing mathematical models approximate rib curvature to mathematical algorithms in a single plane, typically the transverse plane. Additionally, injury biomechanics models and impact studies assume bilateral symmetry of human ribs. Here, a 3D approach for directly measuring rib curvature and testing intraindividual bilateral symmetry is presented. Full-body human CT scans were segmented, and surface meshes of ribs 2-10 were exported via VGStudio Max. Rib centerlines were estimated from the surface meshes utilizing the VMTK extension in 3D Slicer and the curves were resampled to 100 points. The curves were then plotted in MATLAB and smoothed using a cubic smoothing spline (smoothing parameter of 0.01). To isolate curvature in each plane, tangent (pitch), normal (curvature), and binormal (tilt/roll) vectors were calculated for each point on the centerline curve and plotted independently against percentage of rib length. The vector curves for each rib were compared to their contralateral counterparts using the sum of squares (SSQ) methods, and F-tests compared the SSQ residuals to determine differences between right and left ribs. Preliminary findings demonstrate significant deviations from bilateral symmetry in at least one plane for the vast majority of ribs, with the majority of those ribs differing in two or more planes.

## How do you like your eggs? Individual quality of *Harmonia axyridis* in a warming world

*Genavieve Desjardin, Tony Williams*

Climate predictions suggest that many insect species will be at risk of extinction or unsustainable population outbreaks. A closer look at how individual females are reacting to warming temperatures could increase knowledge on the cost of reproduction. This research focuses on the Asian ladybeetle, a globally introduced predatory generalist, which allows us to study a species without post-hatching care. This research aims to understand the costs of reproduction to individuals through various trade offs between egg size and fecundity, lay date and female body size. We predict females will lay an increased quantity of smaller eggs at higher temperatures (i.e., under future climate projections), and that these small eggs will have the same survival rates as eggs under current temperatures. Our findings for individual egg size variability will provide base knowledge that can project population trends under warming temperatures. Further, it will contribute to a better understanding of the trade-offs and the mechanisms behind egg size variation within a species.

## Pollinator thermal preferences in an early-blooming crop

*Nicole DesJardins, James Crall*

Insect-mediated pollination is critical to the human food supply, responsible for roughly one third of the food we eat. However, global pollinator populations are being threatened by a complex mixture of stressors, including extreme weather events and climate change. The production of some fruit crops, particularly those that bloom in the unstable weather conditions of early spring, is currently limited by a lack of pollinators. In this study, we assessed how thermal and climatic preferences varied among the bee taxa involved in apple pollination in the Midwestern US. We hypothesized that, when compared to honey bees, native bees would be active under less favorable weather conditions. To test this hypothesis, we used AutoPollS, a new technology that employs computer vision and deep learning neural networks to automatically monitor pollinator activity in the field. AutoPollS units were placed in four different apple orchards during bloom along with weather-monitoring equipment. The units took photos of insects as they visited flowers, and offline analysis later identified the insects to genus. We will present the results of this analysis, providing critical information about pollinator thermal preferences that will be useful for ensuring food security in a changing climate. Supported by NSF PRFB DBI-2305941.

## Stress produces negative judgment bias in cuttlefish

*Sarah Detmering, Robyn Crook*

Judgment Bias Tasks (JBT) are used to assess emotional state and welfare of animals in zoos, farms, and laboratories, based on interpretation of an ambiguous or intermediate cue. Animals in positive affective states are more likely to interpret the ambiguous cue positively, whereas animals experiencing negative affect are more likely to interpret ambiguous cues pessimistically. Here, we developed a modified JBT assay for the stumpy-spined cuttlefish, Sepia bandensis, to determine whether cuttlefish exhibit negative affective states resulting from external stressors. Positive and neutral visual cues were presented twice daily until animals learned to associate food with the reinforced visual cue. After training, one treatment group was exposed to combined exposure and handling stress produced by six days of impoverished housing and once-daily simulated net capture. Our control group received no stress experience. In test trials performed after the stress experience, stressed animals showed higher latencies to approach ambiguous cues, spent significantly less time in rooms with ambiguous cues once they entered, and were less likely to enter first into the ambiguous cue-paired room compared with controls. These behaviors suggest that stress induces pessimistic judgment bias in cuttlefish, the first indication of this capacity in cephalopods.

## Bilateral forelimb muscle mass, physiological cross-sectional area, and fiber length in primates

*Michael Deutsch, Connor McDowell, Alana DiMartino, Avarie Rembert, Alexandra Abrams, Aleksandra Ratkiewicz, Anand Kanumuru, Ariba Islam, Edwin Dickinson, Michael Granatosky*

Functional morphology in primates tends to study the bony skeleton and dentition while overlooking skeletal muscle. However, muscle architecture is crucial to understanding the form-function relationship of these animals given their wide array of body masses, locomotor modes, and substrate preferences. We present data on forelimb muscle architecture from forty primate species spanning all major locomotor and substrate use categories. We isolated wrist extensors and flexors, digital extensors and flexors, and antebrachial rotators through cadaveric gross dissection and then separated them into fascicles following digestion in 30% nitric acid solution. Based on laterality, phylogeny, substrate preference, and locomotor mode we analyzed gross muscle mass and calculated the length and physiological cross-sectional area (PCSA) of the fascicles. Results indicate positive allometry of muscle mass and PCSA with full body mass, but fiber length scales isometrically. This indicates relatively stronger, but not faster or more flexible forearms in larger primates. Higher taxonomic and different locomotor groups had no significant differences in muscle architecture after adjusting for body size. Arboreal primates had significantly longer fiber lengths than their terrestrial counterparts, suggesting adaptations for greater speed and flexibility. No notable bilateral differences were observed. We thus demonstrate that muscle mass and PCSA depend on scaling rather than ecology, fiber length depends more on substrate use, and all are conserved across taxonomic groups, locomotion, and laterality.

## The regulation of pigmentation and plasticity by corticosterone in tadpoles

*Aaron Devine, Molly Albecker*

Pigmentation plasticity in amphibian larvae is ubiquitous, with pigmentation changes occurring through development from exposure to light, temperature, background color, and perhaps most strikingly, ambush predators. Despite broadly occurring pigmentation plasticity and extensive study of the tadpole-predator system, the ecological and physiological pathways leading to tadpole pigmentation are still poorly understood. However, work suggests corticosterone (cort), a stress hormone, may be responsible for melanin-based pigmentation, and is also involved in the regulation of predator-induced defenses and developmental plasticity in tadpoles. Multiple regulatory functions of cort may suggest pleiotropic expression of pigmentation plasticity and other plastic responses. While many have indicated that exposure to particular stressors like ambush predators is linked to tail pigmentation, we asked whether induction of tail pigmentation is a more general response to stress (e.g., cort) imposed by environments. To test this, we raised Hyla versicolor tadpoles in 9 environmental conditions that could be encountered in nature. Some environments, such as darkened backgrounds, induce tail darkening, whereas tails were clearer in other environments, such as in nonlethal exposure to dragonfly cues. Results from tests of plasma cort levels are expected to indicate that darker pigmentation has an inverse relationship with cort levels. This would support the hypothesis that a relationship exists between cort and pigmentation in plastic responses in developing amphibian larvae.

## Swimming dynamics in fish aggregation: from social groups to shoaling and schooling

*Valentina Di Santo, Camille Morerod, Xuewei Qi, Fidji Berio, Otar Akanyeti*

Fishes exhibit a wide range of collective motions from large-scale migrations to rapidly shifting aggregations. Schooling behavior, where individuals swim in a highly coordinated manner, is considered the pinnacle of fish aggregation. In laboratory settings with controlled flow speed and direction, it can be challenging to determine whether fishes are truly schooling or simply responding to imposed conditions. Even solitary swimmers may display polarized behavior due to rheotaxis and spatial constraints, complicating the distinction between gregarious, shoaling, or schooling behaviors. In this study, we quantified 3D kinematics and group dynamics in 12 social fish species while swimming in a recirculating flow tunnel at speeds ranging from 0.5 to 6 BL/s (five individuals per group and three groups per species). We hypothesized that schooling species might leverage interindividual interactions, particularly at higher speeds, to enhance locomotor efficiency. The analysis of group volume and centroid as well as the distance between the group members show that true schoolers (e.g., smelt) maintained stable formations while gregarious species (e.g., guppy) exhibited continuous positional shifts individually and as a group. The distinction between gregarious and schooler species became more apparent at the highest speeds (>4 BL/s). These results demonstrate that maintaining cohesive group dynamics under increasing flow rates requires enhanced group coordination exhibited only by schooling species.

## Local adaptation of feeding morphology, kinematics and performance in Trinidadian guppies

*Terry Dial, Tess Avery, David Matthews*

Craniofacial morphology of Trinidadian guppies has recently been shown to specialize to the predominant food source of their local environment - high predation (HP) populations that feed primarily on invertebrates have more elongated and rostral-directed mouths while low predation (LP) populations possess steeper, wider heads and more downturned mouths for feeding on detritus and algae. To what extent do these morphological adaptations result in kinematic and performance specializations within such a contemporary divergence? Here we conduct a reciprocal feeding experiment on wild-caught female guppies (n = 22) collected from four populations, representing two distinct drainages (genetic backgrounds) and both HP and LP niches. Individuals were fed two different food types, free swimming brine shrimp or an encrusted algae paste. Each feeding sequence was captured by simultaneous dual high speed (500 fps) video, capturing craniofacial kinematics (f/8) and PIV (f/1.4) from 3 strikes per individual per diet type (n = 264 videos). We use SLEAP AI to track landmarks on the craniofacial apparatus to quantify kinematic determinants of feeding performance such as oral jaw protrusion, jaw rotations, hyoid depression and head elevation. PIVlab (MATLAB) was used to quantify peak suction velocity. Parameters differ between food types and niche background, demonstrating that highly complex and multistructural traits such as feeding kinematics and performance can respond very rapidly to changes in local environments.

## Comparative jumping performance of the critically endangered dusty gopher frog (Lithobates sevosus)

*Kelly Diamond, Catherine Alton, Catherine Hanks, Sinlan Poo*

Captive breeding and reintroduction programs aim to conserve and restore endangered species. Soft releases, where animals are allowed to gradually acclimatize to their new environment, often within an artificial enclosure, can improve reintroduction success by allowing animals to gain necessary experiences while ensuring their protection. The dusty gopher frog is a critically endangered species, with a species recovery plan that includes efforts to restore historical habitats (longleaf pine forests) and annual reintroductions from captive breeding populations. The aim of this study is to quantify if soft-releasing frogs could increase the chances of survival by improving locomotor performance. We predicted that frogs released into artificial ponds would have improved jumping performance (longer and higher jumps and higher endurance) compared to frogs that remained in a laboratory environment. We also predicted that differences between groups would increase as our experimental group spends more time in the outdoor ponds. To test these predictions, we compared the jumping performance of soft-release frogs to lab-reared frogs across a 2-month period. Metrics collected included endurance, jump height, and jump length. While both groups had indistinguishable jumping performance at the start of the experiment, our lab-reared control frogs had higher endurance than their soft-released siblings. Results from this study could inform the current captive breeding programs concerning best practices for future clutches of dusty gopher frogs.

## Glucocorticoids as a mediator of iron-associated changes in body condition and disease

*Amelia Diaz, Vanessa Marshall, Wesley Neely, Samantha Siomko, Shannon Buttimer, Jack Boyette, Carlos Becker, Ryan Earley*

Environmental contaminants like iron are ecologically relevant stressors activating the neuroendocrine stress response. Glucocorticoids (GCs) play a central role in energy balance and immune response. Yet, few studies have linked GC variation to disease dynamics in wild populations, despite chronic high GCs causing immunosuppression and reduced body condition. By incorporating repeated physiological measures into the existing disease ecology framework, we tested the hypothesis that GCs mediate iron-associated changes in body condition and disease in wild Eastern newt (Notophthalmus viridescens) populations. Newts at Ruffner Mountain, Alabama, were surveyed to quantify Batrachochytrium dendrobatidis (Bd) prevalence, iron contamination in two water sources (contaminated and uncontaminated), and GC stress hormone levels in a 7-week mesocosm experiment. Ruffner was an iron-ore mining site until the 1950s, with visible contamination in the man-made iron-ore cleaning ponds ("Red Lakes"). We predicted that 1) newts in "Red Lake" water would have higher CORT levels, higher Bd levels, and lower body condition, and 2) "Wetland" newts transferred to "Red Lake" water would develop higher CORT levels, higher Bd levels, and reduced body condition. Initial results show that poor body condition is associated with higher Bd loads, and body condition, sex, water source, and experimental treatment were key predictors of Bd prevalence and loads. We anticipate our CORT ELISA assays will further elucidate CORT's role in these relationships.

## Reinforcement learning on the fly: modeling how spiders quickly adjust to changing prey availability

*Candido Diaz, John Long, Ashkaan Fahimipour*

Spiders are ecologically important predators found in virtually all terrestrial ecosystems. In response to changing prey availability, spiders quickly alter the geometry of their webs, apparently to enhance prey capture. The mechanisms underlying such fast responses, and their consequences for both predator and prey fitness, remain unclear. To investigate potential mechanisms, we have designed agent-based models of spider predators and prey interacting in a three-dimensional featureless space; spider agents deploy reinforcement learning to progressively update their web geometry based on fitness rewards and silk investments associated with a particular policy (i.e., a combination of web traits). With these computational models, we performed experiments in which the size, speed, and diversity of flying prey were systematically altered to assess the learning trajectories and emergent trait compositions of their spider predators under different ecological scenarios. Further, trained spiders were computationally transplanted to novel conditions, allowing us to assess which traits were universally beneficial and which had a context-dependent utility. This work was supported by the National Science Foundation under Grant No. IOS-2031962 and No. EF-2222478.

## Assessing the impact of rearing strategy on Whooping Crane health through the gut microbiome

*Jessica Diaz, Barry Hartup, Kevin Kohl*

Whooping Cranes (Grus americana) reared using parent (PR) and costume (CR) rearing methods have vastly different early life environmental exposures and differing health outcomes as CR chicks are more likely to develop fatal fungal infections. The reasons for these health disparities between rearing strategies is often unclear, limiting the development and application of remedies.

The gut microbiome is emerging as an important dimension of captive animal health through influences on host metabolism and immunity. We hypothesized that CR chicks lacked microbial exposure from adult cranes in early life, and that the gut microbiome could underlie health disparities. We analyzed the gut and tracheal microbiomes of 21 CR and 8 PR Whooping Crane chicks, as well as five CR chicks given fecal microbiome transplants (CR-FMT) after hatching to simulate microbial exposure from adult cranes.

Initial results show that PR chick microbiomes had distinct composition, increased diversity, and decreased dispersion compared to CR chicks. The fecal transplant did not totally simulate the microbial exposures experienced by PR chicks, as the microbial composition and diversity of CR-FMT chicks still resembled CR chicks. However, CR-FMT microbiome composition did exhibit significantly less dispersion, meaning exposure to adult microbes in early life may constrain microbial variation between chicks. Integration of microbiome data with clinical metadata will help to reveal whether these microbial differences between rearing strategies are associated with chick health.

## Comparative analysis of sstracod crustacean diets; insights into ecology and speciation

*Sofia Diaz, Elizabeth Torres*

Speciation contributes to the diversity and complexity of marine ecosystems, and studying these processes is crucial for understanding how marine ecosystems function and evolve over time. Micro-invertebrates are key contributors to marine ecosystem functioning, as they inhabit every marine niche and maintain many biological communities. These ecological relationships are largely understudied for many marine micro-invertebrates, including cypridinid ostracod crustaceans. Cypridinid ostracods have been the subject of many recent studies because their species-specific bioluminescent mating signals are thought to be the main driver of speciation. However other ecological factors like diet, habitat, and dispersal can contribute to evolutionary processes like speciation. Cypridinids are generally thought to be scavengers with an omnivorous diet. They are demersal during the day and are most active and planktonic at night. Little is known about their diet and the habitats they occupy during the day. This project explores ecology through targeted amplicon sequencing and microscopy to examine and compare the gut contents of six cypridinid species from two different geographic locations: Panama and California. Comparisons are made between co-occurring reef species, bioluminescent and non-bioluminescent species, and species from coral reef and kelp forest habitats. Preliminary results have found gut contents related to fish in the luminous ostracod species native to California. Utilizing diet to study ostracod ecology can provide data on species-specific interactions as well as ecological influence on speciation events.

## Passive vapor harvesting mechanism of the termite mound

*Meron Dibia, Hunter King*

Many termites of the subfamily Macrotermitinae are extremely vulnerable to the elements. Their brood and fungal crops require tightly controlled temperature and high humidity, yet these species are ubiquitous in regions with extreme daily temperature fluctuations and little to no precipitation or surface water for most of the year. Their survival depends on their ability to construct large, abiotic structures (mounds), towering above their inhabited nests, which passively regulate their climatic needs. Previous studies have illuminated the mound's transport mechanisms, which utilize geometry and material to alternatively dampen and harness external thermal oscillations for thermoregulation and convective internal ventilation, respectively. How they simultaneously manage the precarious water budget is not known, but their water needs are at odds with those of respiration, by which metabolic gases exchange across the mound's porous surface. However, simple analysis suggests the necessary features of a sorbent-based, passive atmospheric water generator: use of porous, clay-rich material to enable reversible uptake of vapor at significant quantities; cyclic day-night heating pattern; and previously-described internal flow to bring desorbed water to cooler regions for condensation.

We report preliminary results from sensors positioned within and around a termite mound to record temperature, relative humidity and liquid water content of the mound material. Correlations between those quantities give an early glimpse of the mound's ability harvest water from the air.

## Phylogenetic Scaling Patterns in Primate Muscle Architecture

*Alana DiMartino, Avarie Rembert, Michael Deutsch, Connor McDowell, Pranav Krish, Ariba Islam, Anand Kanumuru, Jonathan Shadan, Laury Arazi, Alexandra Abrams, Ashley Choi, Aleksandra Ratkiewicz, Christine Lee, Gabby Guilhon, Edwin Dickinson, Michael Granatosky, Nicholas Matkiwsky*

As body mass increases, larger species face a unique biomechanical challenge wherein muscle force-generating force capacity does not scale with body volume (i.e., mass), but instead with muscle cross-sectional area (i.e., body mass2/3). Consequently, large-bodied animals would have less force-generating potential than smaller-bodied species. However, this is not always true. To overcome this, it remains unclear whether the muscles of larger animals incorporate a greater number of fibers or increase the cross-sectional area of individual fibers. In this study, we utilize a large phylogenetic sample (∼40 species) of primates, ranging in body size from mouse lemurs (∼30g) to gorillas (∼225kg), to explore how animals maintain relative force-generating potential across a wide body-size range. Four muscles (two forelimb, two hindlimb) were analyzed within each individual. On one side of the body, we used chemical digestion of muscles to calculate fiber length and physiological cross-sectional area. On the opposite side of the body, histological staining was used to visualize fiber density and diameter. Physiological cross-sectional area (an anatomical proxy for force potential) across all muscles scaled with positive allometry with body size, indicating that large-bodied primates were both absolutely and relatively stronger than smaller-bodied species. Such muscle scaling was achieved by increasing the diameter of each individual fiber. These findings highlight the adaptive nature of muscle tissue, emphasizing the importance of soft tissue analyses in comparative biomechanics studies.

## Morphological Adaptations and Energy Allocation in Intertidal and Subtidal Purple Urchins

*Giulia DiRaimo, Stephanie Crofts, Carla Narvaez Diaz*

The purple sea urchin (Strongylocentrotus purpuratus) is capable of burrowing into a range of different rocky substrates by using their spines and Aristotle's Lantern (mouthparts). These urchins can excavate burrows in a variety of substrates, and they are well-adapted to varied environmental conditions and are highly phenotypically plastic. In this study, we compared the Aristotle's Lantern and associated soft tissues (protractor and retractor muscles), as well as the gut and gonad, between urchin populations drawn from an intertidal population, including urchins from burrows and non-burrowed urchins, as well as lab-maintained urchins from the subtidal. We used contrast-stained CT scans of the urchins to visualize and quantify soft tissue anatomy. Our results indicate that Aristotle's Lantern, gut, and gonad volumes significantly vary between urchins from some habitats, but not others. Despite size differences, the shape (aspect ratio) of the Aristotle's Lantern remains consistent, indicating that the Aristotle's Lantern may not be used among these burrowing urchins. Additionally, protractor muscles, used for Aristotle's Lantern protrusion, are significantly larger than retractor muscles across populations, suggesting a greater investment in feeding efficiency. The larger gut and gonad volumes among subtidal/lab populations indicate a higher capacity for food storage and reproductive investment in more stable environments.

## Feeding Performance and Strategies of Durophagous Pufferfish

*Madeline Dissinger, Edward Burress*

The advent of durophagous predators is thought to have caused a shift in the evolutionary strategies of gastropods, particularly in their shell morphologies. While this phenomenon has been well studied in marine ecosystems, there is little to no research on freshwater communities. In this study, we assessed performance of Congo Spotted Puffer, Tetraodon schoutedeni while feeding on live gastropods of variable size and species. The gastropods represented three phenotypes of shell coiling parameters (low, mid, and high spires) that may impose different functional demands on predators. The T. schoutedeni specimens all exhibited species-specific feeding behaviors. The specimens regularly consumed snails significantly larger than the size of the puffers' eyes, which is anecdotally considered the upper limit for pufferfish prey size. We observed notable differences in the performance and approach of the pufferfish in response to shell morphologies. Our preliminary results indicate that T. schoutedeni may have innate, durophagous behaviors that are specific to the size and shape of hard-shelled prey. These findings have considerable implications for the evolution of gastropods in the Congo Basin, as well as the ecological interactions of T. schoutedeni and freshwater snails.

## Symbiotic plasticity in a temperate coral is connected to environment, physiology, and genetics

*Clara DiVincenzo, Stephanie Peak, Sophia Oh, Karl Castillo*

Coral-dinoflagellate symbioses are essential for the survival of coral reefs but highly vulnerable to increasing sea surface temperatures. Temperate corals, unlike tropical corals, form facultative symbioses with dinoflagellates, and naturally exist in both symbiotic and symbiont-free (aposymbiotic) states. Along the sloping reef at Radio Island, NC, colonies of the temperate coral Oculina arbuscula inhabiting shallow (~5m) regions exhibit symbiotic phenotypes, while those inhabiting deep (~10m) regions exhibit aposymbiotic phenotypes. We conducted a reciprocal transplant experiment across depth to investigate phenotypic plasticity in Oculina arbuscula at the molecular, physiological, and environmental level. Symbiotic and aposymbiotic fragments from the shallow and deep sites were collected, transplanted, and sampled at 5 timepoints (0 weeks, 2 weeks, 4 weeks, 8 weeks, 12 weeks). We examine environmental predictors of symbiotic state (phytoplankton, nutrient, light, and temperature), physiological and phenotypic shifts over the transplant (C/N isotope analyses, symbiont counts, and energetic reserve quantification of carbohydrates and lipids), and molecular drivers of symbiosis establishment and breakdown (gene expression). For Oculina arbuscula corals, we found that changes in environment cause shifts in phenotype towards those of corals native to the transplant environment, which are reflected at the physiological and molecular levels. These findings will provide key insights into the molecular, physiological, and environmental basis for symbiotic state in facultatively symbiotic corals.

## The relationship between muscle architecture and in vivo bite force in snakes

*Kyle Dixson, Michael Granatosky, Michael Deutsch, Julia Molnar*

As a consequence of their limbless body plan, snakes have evolved a complex feeding strategy. While numerous studies have explored the mechanics of striking, constriction, and swallowing in snakes, remarkably little is known about their bite force. To explore how bite force generation varies among living snakes, we measured the muscle architecture of the jaw musculature in four snake species using both traditional dissection and diceCT. Additionally, to supplement the existing data on in vivo bite force—measured only in the common kingsnake (Lampropeltis getula)—we measured bite force in a different species, the common boa (Boa imperator), which has a distinct diet, ecological niche, and morphology. Our findings revealed that common boas had a smaller bite force (1.2-2.7 N) than kingsnakes

(2.3-3.7 N) of similar head size. This difference is understandable since kingsnakes rely more on biting than on constriction and use biting during mating. Relative jaw muscle volume, fiber length, and cross-sectional area were similar between the common boa and the rainbow boa, suggesting that bite forces may be consistent across the Boidae family. In contrast, snakes from other families (Pythonidae and Colubridae) exhibited substantial differences in muscle architecture, indicating likely differences in bite force. As the first study to combine muscle architecture and bite force measurements in snakes, this research highlights unexplored variations in the functional morphology of the snake jaw complex.

## A balancing act: gait kinematics and behavior of Cephalotes atratus traversing narrow substrates

*Sammie Dolloff, Alyssa Stark, Stephen Yanoviak*

Animals use diverse morphology, biomechanics, and behavior to move through complex environments. Indeed, there are several forms of locomotion an animal may employ (e.g., walking, swimming, flying). For small animals, energetic costs are minimal, and instead alteration of behavior and gait patterns are often used to reduce exposure time and compensate for any unexpected biomechanical demands. In the tropical rainforest, canopies become highways for ants using vines and stems to navigate within and across treetops. However, these substrates vary in diameter, roughness, compliance, and level of fouling, each of which could significantly impact ant locomotion and prevent falls from the canopy. The purpose of this study is to measure the effect of narrow and rough substrates on the kinematic performance of one large-sized tropical arboreal ant species (Cephalotes atratus) mimicking natural environments in a laboratory setting. Additionally, we characterized locomotor behaviors, specifically, inversion, slipping, and thorax distance (cm) from the substrate during the run to assess if ants made additional shifts to compensate for increased biomechanical demands. We found that C.atratus can maintain their locomotor performance while traversing narrow substrates by altering their gait patterns. However, on extremely narrow substrates, individuals performed inverted locomotion 100% of the time. Our results show that in at least one species, navigation in the tropical forest canopy requires behavioral and kinematic shifts, including unique strategies such as inverted running.

## Seasonal and interspecific variation in VO2 and hematological indices of free-living rodents

*Richard Dolman, Michelle Haynie, Yulianis Pagan, Christopher Goodchild*

We characterized season and interspecific variation in organismal metabolic and hematological indices (hematocrit, hemoglobin concentration, leukocyte counts) in a free-living rodent community in northwest Oklahoma. We measured organismal metabolic rates indirectly via oxygen consumption and collected blood samples to measure hematological indices. We collected data primarily from Peromyscus spp. (leucopus and maniculatus) and Sigmodon hispidus over six trips occurring in January, March, June, and October 2022-2024. Peromyscus exhibited higher hematocrit and hemoglobin compared to S. hispidus, suggesting these species exhibit different energetic demands for oxygen delivery to tissues. Further, Peromyscus sampled in June exhibited higher hemoglobin but lower hematocrit compared to Peromyscus sampled in January and March, which may be caused by water and nutrient scarcity in winter. We are currently analyzing oxygen consumption data to see if these hematological differences are associated with different resting metabolic rates.

## Alternate responses of ectothermic animals to anthropic climate warming

*Saul Dominguez-Guerrero, Brooke Bodensteiner, Sarah Friedman, Guillermo Alfonso Woolrich-Pina, D Mahler, Luke Frishkoff, Martha Muñoz*

Rising environmental temperatures could cause the extinction of 20% of ectothermic animals (such as amphibians, insects, and reptiles) in this century. As ectotherms depends on environmental temperatures to regulate their field body temperature they could die by overheating or thermal stress. As compensatory responses, ectotherms could buffer warmer temperatures by behavioral thermoregulation or by increasing their heat tolerance (critical thermal maximum, CTmax). Yet, it remains unclear whether thermal behavior and heat tolerance shifts are complementary or mutually exclusive responses. From 2022 to 2024 we revisited populations of 16 anole species in the Caribbean islands to estimate thermal behavior and heat tolerance and compare with historical information. We find that thermal behavior does not change across time but CTmax does in some species. Lizards with active thermoregulation maintain a similar heat tolerance across time, likely by behavioral avoidance of thermal selection on their upper thermal limit (Bogert effect). By contrast, thermoconformer species increased their heat tolerance across years because behavioral passivity exposes organisms to selection on the upper thermal limit. Our results indicate that behavioral and physiological adjustments tend to be mutually exclusive responses to warming environmental temperatures. Therefore, anoles can respond to climate warming by thermoregulatory behavior or physiological adjustments but rarely both, a pattern repeated in other squamates (such as alligator lizards, knob-scales lizards, and spiny lizards) and potentially generalizable across ectotherms.

## CORT as a physiological biomarker: decoding the environment-CORT-energy paradigm

*Beverly Domschot, Thomas Riecke, Jessica Malisch, Thomas Hahn, Creagh Breuner*

Corticosterone (CORT) is a crucial avian biomarker yet debates over the most relevant measures often cloud its utility. This study employs structural equation modeling (SEM) to evaluate the Total Hormone, Free Hormone, and Corticosteroid-Binding Globulin (CBG) Profile hypotheses using a 14-year dataset on mountain white-crowned sparrows. The Total Hormone model showed limited power in correlating environmental and energetic variables with CORT levels. In contrast, the Free Hormone model demonstrated strong relationships between free CORT and environmental conditions, suggesting that sparrows modulate hormone availability contextually. The CBG Profile model provided the most nuanced understanding, uncovering sex-specific strategies in hormone regulation, with males and females exhibiting different CORT dynamics in response to environmental stressors. For instance, during wetter years, indicated by higher El Niño-Southern Oscillation (ENSO) values, free baseline CORT levels decreased in both sexes. The CBG Profile model revealed that males achieved this decrease by raising CBG levels, likely as a strategy to bind and store more CORT for future use, while females reduced total CORT secretion instead. These findings highlight the important role that CBG plays in capturing the complexity of environment-CORT-energy dynamics, underscoring the importance of selecting appropriate CORT measures for accurately assessing physiological responses to environmental changes. This research provides a methodological framework for conservation scientists to better interpret CORT data and its ecological implications, thereby enhancing wildlife health monitoring and conservation strategies.

## Accessible Bioinspired Models in Science and Engineering Research

*Cassandra Donatelli, Karly Cohen, Meg Vandenberg, Adam Summers*

Bioinspired modeling is a powerful tool which uses nature to address engineering problems and engineering to answer questions about biology. While we can use tools like PolyJet printers and precision electronics to create realistic models, simple, low-cost alternatives can be just as effective. Biologists have always used simple models to answer complex questions without sacrificing asking and answering important questions. For example, flexible plastic foils laser cut to mimic different tail and body shapes realistically replicate the fluid dynamics of fish and have resulted in countless discoveries about aquatic locomotion. PLA scales 3D printed directly onto fabric accurately mimic different aspects of scales and armor. We can make gelatin-based hydrogels with the same mechanical properties as biological tissues like muscle and fat and use rubber and latex to replicate the elasticity of tendons and ligaments. The accessibility of these types of models allows researchers from all types of universities and colleges to pose and answer real scientific questions, develop new materials and technologies, and share their ideas broadly. The resources required to build these models are widely available, encouraging collaboration, open science, and outreach to primary schools and museums. Accessible models open bioinspired design to more people, encouraging creativity, innovation, and discovery.

## Picture pore-fect: a novel method to map shark electroreceptor pores with photograph-based 3D models

*Natalie Donato, David Edwards, Jessica Schulte, Ethan Personius, Taylor Chapple*

Sharks can detect weak electric fields in their environment via their Ampullae of Lorenzini, which sit at the base of individual gel filled canals terminating in visible pores across the head. The unique pore patterns and quantities vary greatly depending on their phylogeny, biology, and potentially life history stage, providing insights into species-specific behaviors and movements. However, the volume of data needed to uncover broad trends is difficult to achieve due to the constraints of current methods, where the skin is removed from the specimen's head and illuminated from behind to view and map the pores on a flat plane. The dissections provide essential information such as positioning and density of the pores but are tedious, time consuming, and destructive. Photographs can also be used to view the pores, but the 2D images of the round heads result in distorted mapping and density calculations. To bridge the gap between the essential data from traditional methods and non-destructive photographic methods, we developed a novel method using photograph-based 3D modeling (3D photogrammetry) to generate a "digital skin", a flattened 360-degree view of the head. We compared the accuracy of our methods to traditional methods using Salmon shark (Lamna ditropis) heads. Our methods can greatly reduce the time to map the pores and provide a means to map the pores non-destructively.

## Characterizing ecosystem engineering by infauna using acoustics

*Kelly Dorgan, Jennifer Duncan, Kevin Lee, Megan Ballard, Preston Wilson*

The sea floor is inhabited by diverse communities of animals that mix sediments through bioturbation and modify the physical properties of sediments. Infaunal activities such as burrowing, construction of burrows and tubes, and ingestion and compaction of sediments into fecal pellets can compact and dilate sediments and change grain size distribution on small scales. These impacts increase heterogeneity of sediment structure, potentially leading to increased acoustic attenuation, especially at higher frequencies, and increased variability in sound speed. We examined the impacts of infaunal communities from Mobile Bay, AL, and the New England Mud Patch on acoustic properties of sediments both through in situ measurements and complementary measurements on sediment cores collected at each site. We found that infauna increase variability in sound speed and attenuation both in situ and in core measurements, and relate these changes to infaunal community structure. Future linking of high frequency acoustic and small-scale geotechnical properties will provide further insight into the impacts of infaunal organisms on sediment physical properties and heterogeneity.

## Adaptive flight control to increased body mass in foraging hawkmoths

*Benjamin Doshna, G. Steven Chandler, Usama Sikandar, Simon Sponberg*

How do animals maintain motor control following significant mass changes? During a bout of hover feeding, the hawk moth Manduca sexta can increase its mass by 50% in 60 seconds, all while maintaining its performance in tracking the moving flower. Our free flight experiments demonstrated that additional mass leads to an adaptive 70% increase in sensorimotor gain across all frequencies that the moth tracked the robotic flower. This cannot be fully explained by the added mass alone. Here we explore the physiological basis of this "gain knob" in Manduca sexta's motor program by recording electromyograms from all flight relevant muscles while the animal feeds tethered to a 6-axis force torque transducer. We hypothesized that during tethered feeding, an increase in gain would correlate with the actual weight supported by the moth on a force torque transducer, rather than the true mass, due to the lack of mechanical feedback compared to free flight. Alternatively, this gain change could be dependent on satiation levels, potentially regulated by insulin or other physiological signals. We found that change in sensorimotor gain is indeed proportional to the actual weight supported by the moth, suggesting that the moth's nervous system can adapt its motor control strategies in a manner correlated with its ability to produce lift. Finally we test how this adaptation manifests as coordinated shifts in precise muscle activation patterns.

## Uropygial gland size increases isometrically with body size in 35 North American bird species

*Austin Dotta, Caitlin McNamara, Alex Huynh, Mercille Nguyen, Brandon Swayser*

The uropygial gland and the oils it produces have been shown to serve important functions in many bird species including plumage maintenance and chemical communication. Previous species comparisons of uropygial gland size have only been conducted in South American and European birds and have found little to no phylogenetic signal. Here, we document uropygial gland measurements of 34 different passerines, 1 hybrid chickadee population, and 1 Piciformes in eastern Pennsylvania, most of which are reported for the first time. Uropygial gland size is positively related to overall body size, controlling for phylogenetic relatedness. We show a significant phylogenetic signal of relative uropygial gland size and many of the species with the largest gland sizes belong to the Paridae. Overall, females show a nonsignificant but slight trend of larger relative uropygial gland sizes than males. This effect is stronger in some species than others and can also be seasonally dependent. We found no effect of relative total eggshell surface area or nest location on relative uropygial gland size. Together our results provide the first documentation of uropygial gland sizes in many of these North American species and provide interesting insight into factors influencing relative gland size including sex, season, and species.

## Impact of conspecific competition on nesting decisions in arboreal ants

*Marissa Douglas, Matina Donaldson-Matasci, Tito Cuchilla*

Polydomous arboreal ants are dominant throughout tropical ecosystems and are ideal for studying the process and impact of competitive space partitioning within a community. These ants create nest networks interconnected by trails along branches of trees. We were interested in how ants form nest networks on trees where space is limited and other colonies are competing for the same nesting sites. We explored this question using Northern Caribbean Turtle Ants (Cephalotes varians), which is an arboreal ant species that competes with other ant colonies for nesting cavities on single trees. We mimicked a natural nesting environment by allowing ant colonies to explore an artificial tree branch and occupy artificial twig nests. Colonies experienced the branch both without a competing conspecific colony and with a competing colony confined to a section of the branch. We observed the abundance and distribution of colony members per nest, and compared them with and without competition. We found that worker ants did not respond consistently to competition, but colonies may concentrate vulnerable members away from competitors. These results imply nest choice is more affected by spatial constraints and individual colony strategy than by competition in C. varians. Our study contributes to an ongoing body of research suggesting that by spreading their colonies throughout canopies of a tree, arboreal polydomous ants maintain dominance through ongoing, risk-limiting decision making.

## Ungulate body condition as a predictor of immune defenses

*Cynthia Downs*

Understanding the reasons for underlying variation among individuals is important in developing models of population dynamics and management plans based on estimates of vital rates. Immune defenses serve as potential mechanisms because parasites shape population dynamics of wildlife hosts and the immune system is the primary physiological defense by which hosts respond to parasites. Additionally, energy and resources used for costly immune defenses are unavailable for other processes. Consequently, resource-constraint and allocation hypotheses can serve as a framework for linking physiology with population dynamics. However, the results of published studies do not always support the prediction that individuals with less fat and protein reserves have reduced constitutive immune defenses. Dozens of free-ranging, adult female mule deer (Odocoileus hemionus) representing the full range of fat content had remarkable consistent constitutive innate immune defenses (bactericidal capacity, hemolytic complement activity, total antioxidant) regardless of protein or fat reserves. This result contradicts many studies' assumptions of a positive correlation between reserves and defenses and may have arisen because the immune defenses studied were constitutive, highly regulated by negative feedback cycles, and had low energy and resource costs. Integrating published studies with new data from studies of large-bodied ungulates, I will test predictions about how life history strategy, parasites, and environmental correlates shape resource reserve-immune defense relationships in ungulates and the consequence of managing wildlife populations.

## Diversity of dicyemids (Dicyemida:Mesozoa) in Atlantic and Pacific oceans based on 18S marker

*Marie Drabkova, Tijana Cvetkovic, Masoud Nazarizadeh, Jan Stefka*

Dicyemids are rarely studied marine parasites found in cephalopod renal organs. Their morphological structure is very simplified and does not present many features that can be reliably used in systematics. Here we present a novel approach for assessing dicyemid diversity by amplicon analysis of 18S marker coupled with Illumina sequencing. Results show high dicyemid diversity across 24 host species and wide geographic sampling (Pacific, Atlantic, Mediterranean, Australia). Species delimitation analysis revealed 482 ASVs clustered in 95 genetic types, from which only four groups have a representative sequence in databases. Most types were hosts and locality specific, but a few were widely shared between host species worldwide. Genetic analysis points to surprisingly high genetic diversity and variability of life strategies of dicyemids demonstrating benefits of molecular methods for study of parasitic taxa.

## Exploring genetic diversity in green salamanders (*Aneides aeneus*) at Bays Mountain Park

*Brianna Drake, Joe Bidwell, Trevor Chapman*

Amphibians are declining globally due to various site-specific and regional factors including disease, over-collection, climate change, and large-scale habitat loss and degradation. Obtaining complete taxonomic information on threatened species is critical for accurately identifying these organisms and developing effective conservation strategies. Green salamanders (Plethodontidae: Aneides aeneus) are a vulnerable cryptic species in the Southern Appalachian Mountains.

This study aimed to indicate the genetic diversity in A. aeneus at Bays Mountain Park (BMP) in Kingsport, Tennessee to better understand the aeneus complex and promote conservation initiatives. Previous mitochondrial and nuclear phylogenetic analysis determined four distinct lineages within the complex: Northern Apps, Southern Apps, Hickory Nut Gorge (HNG), and Blue-Ridge Escarpment (BRE). However, the limited molecular data on aeneus individuals has inhibited accurate conservation status assessments. To fill this gap, tail tips were collected from individuals found in BMP from April to October 2024. Genetic variation was assessed by targeting and comparing two mitochondrial genes with high mutation rates to address the presence or absence of gene flow. It was hypothesized that individuals in BMP would exhibit genetic similarity to those in the characterized northern lineage but could demonstrate genetic isolation.

## Territorial frogs are aggressive toward other species over a broad acoustic space

*Julia Drennan, James Tumulty*

How do species form and remain distinct from one another? These questions are central to the concept of speciation: the evolution and subsequent maintenance of new species through the divergence of populations. Research on speciation usually concentrates on how female mate choice prevents interspecies matings. Male-male competition also plays an important role in reproduction but is relatively understudied as a mechanism of speciation. This study investigates how sexual selection via male-male competition contributes to speciation in two “sibling” species of frogs: northern and southern cricket frogs. We conducted a field playback experiment to discern to what extent male northern cricket frogs (Acris crepitans) can recognize conspecific male calls versus those of the southern cricket frog (Acris gryllus) and modulate their aggressive responses accordingly. Analyses of the behavioral data show that A. crepitans males respond aggressively to calls ranging from average calls of their own species to average calls of A. gryllus, notably excluding extreme A. gryllus calls. Ergo, recognition space does not equal signal space in A. crepitans males. Overall, anecdotal observations and analyses of results point towards the misinterpretation of some A. gryllus advertisement calls as conspecific aggressive signals or possible character convergence. This research provides insight into the interplay between speciation and competition in two closely related species and demonstrates how signal recognition might evolve with respect to the evolution of the signals themselves.

## Desiccation tolerance among bee species in the Aegean Archipelago

*Anna Dreusicke, Avery Roe, Victor Gonzalez, John Hranitz, John Barthell, Theodora Petanidou, Thomas Tscheulin*

Climate change is expected to not only increase temperatures but also decrease relative humidity, yet our understanding of how bee species tolerate changes in relative humidity and the degree of tolerance among species remains limited. Bees are the most important pollinators of both wild and cultivated plants and understanding these variations in desiccation tolerance is essential for assessing their resilience to climate change and developing effective conservation strategies. To address this, we assessed the desiccation tolerance of 18 bee species across five families (Andrenidae, Colletidae, Apidae, Megachilidae, and Halictidae) from the Greek island of Lesvos by exposing them to a controlled desiccant environment (0% RH). We measured desiccation tolerance by recording the survival time under this simulated desiccation stress event and calculated water loss rate and critical water content. Our findings revealed significant differences in desiccation tolerance among species, with honeybees being the least tolerant and carpenter bees the most. In addition, water loss rate and critical water content varied significantly across species. These results provide valuable insights into the adaptive strategies used by different bee species to cope with desiccation stress, contributing to our understanding of how these pollinators might respond to the changing climate. Other traits not assessed here may additionally impact desiccation tolerance among bees, such as hairiness, sociality, altitude, and crop storage potential.

## Biology instructor efforts to teach sex and gender topics inclusively and accurately

*Emily Driessen, Keenan Walker, Tess Hallman, Aramati Casper, Sarah Eddy, Joel Schneider, Kelly Lane*

Inaccurate sex and gender narratives have saturated the political landscape, resulting in legal restrictions for transgender, nonbinary, and/or gender nonconforming (trans-spectrum) individuals. Biology educators can correct these false narratives by highlighting trans-spectrum and intersex people’s experiences and perspectives in the curriculum. Here, we interviewed four post-secondary biology instructors who reformed their curriculum to include trans-spectrum and intersex inclusive strategies, inquiring about the strategies used, instructor motivations and intentions, and obstacles to implementation. We noticed the instructors’ journeys to include these inclusive strategies in the classroom involved intense personal work and education, both at the beginning and iteratively throughout implementation. We found that instructors focused on changing language, often removing sexed or gendered-language, and used a variety of inclusive activities in their undergraduate biology classroom, ranging from highlighting transgender scientists to assigning students to research trans-spectrum adolescent hormone therapy. Instructors mentioned obstacles to implementing reformed teaching strategies, including fear of potentially isolating trans-spectrum and intersex students and concern about the instructor's own positionality. Removing obstacles and supporting the process of unlearning binary and exclusive ways of teaching sex and gender topics may bolster instructor efforts to provide more accurate and inclusive biology education.

## Does trophic plasticity lead to thermal tolerance? Gorgonian responses to rising temperatures

*Michael Drummond, Alyssa Stark, Asja Radja*

As anthropogenic climate change continues to drive the decline of global ecosystems, coral reefs around the world face increasing threats. Many corals rely on symbiotic dinoflagellates (Symbiodiniaceae), which produce food for the coral through photosynthesis. The health of a coral colony is tied to the homeostasis of its microbiome, a complex system easily destabilized by various abiotic factors, including marine heat waves. While coral cover has reduced by 30-50% since the industrial revolution, the Class Octocorallia, particularly gorgonians, show resistance to climate change. Although the exact mechanisms for this resilience are unknown, field and laboratory studies have determined that gorgonians are resistant to elevated temperatures, increasing in reef cover, and could hold a key to understanding how corals adapt to changing environmental conditions. One hypothesis suggests gorgonians are more successful filter feeders than other coral taxa, allowing them to compensate when the microbiome is unstable. In this study, fragments of the gorgonian Eunicea flexuosa were subjected in lab to a simulated marine heat wave for four weeks, during which their behavior, polyp morphology, Symbiodiniaceae concentration, and metabolic rates were monitored. Preliminary results show that respiration and photosynthesis rates in healthy tissue remain the same, while polyp extension decreases. Corals subjected to the heat wave were also more likely to necrose. These findings suggest that the corals do not rely on prey capture during thermal events, and that trophic plasticity may not play a role in gorgonians' resilience to elevated temperatures.

## Diverse anatomical arrangements underlie elongate body forms in Zoarcoid fishes

*Summer Duba, David Collar*

Extreme morphological changes in evolutionary lineages are linked to novel functional capacities. One such transition is body elongation, observed in various vertebrate groups, particularly multiple lineages of ray-finned fishes. Reconstructing how these transformations occurred is key to understanding the adaptive significance of body elongation. Prior studies determined that elongate fishes evolved combinations of regional addition to vertebral number, elongation of vertebral centra, and head lengthening, suggesting possible roles for diverse selective demands. While earlier work focused on elongation from fusiform ancestors, our study of the suborder Zoarcoidei (eelpouts, pricklebacks, and allies) examines body shape within a radiation with an elongate ancestor, which may have uniquely biased evolution. We analyzed radiographs of 71 species (12/14 families in the suborder) and fit multi-optimum Ornstein-Uhlenbeck models to identify transitions in body shape and skeletal anatomy. Extreme body elongation arose multiple times, and like other lineages of fishes, distinct sets of anatomical transitions were associated with each elongation event. Moreover, we found evidence of cryptic anatomical peak shifts—shifts in anatomical optima that occurred within ancestral lineages that retained the ancestral body shape. These findings reveal that adaptive evolution in skeletal anatomy can occur independently of body shape change, underscoring the anatomical variety associated with elongate fishes. Altogether, our study supports the hypothesis that multiple selective demands—resulting from distinct habitats, feeding modes, and behaviors—underlie body elongation in fishes.

## The genetic origins of hagfish slime gland evolution

*Kaleb Ducharme, David Plachetzki, Douglas Fudge*

When threatened, hagfish release a defensive slime that quickly expands to clog gills and suffocate attackers. The glandular deployment of mucins and threads into the water column takes just a fraction of a second, and upon contact with seawater, will cause the volume of slime to expand 20,000 times or greater. Previous studies have shown that the thread proteins expressed in slime glands have an ancestral epidermal equivalent, but we presently lack a detailed understanding of the genetic composition of hagfish slime and slime glands, or how they evolved. Using RNAseq, we analyzed the transcriptomes of 12 species of hagfish to describe the differences in gene expression patterns across species and genera. We identified the core set of genes across all species, and determined how their expression differs. We also examined codon alignments of the core slime gland genes to pinpoint regions under selection. Finally, we examined slime gland expressed loci in the genome of the inshore hagfish Eptatretus bergeri and identified putative regulatory elements and transposable elements in adjacent regions, suggesting a possible mechanism for diversification of some slime expressed loci by gene duplication and diversification. Our results provide insights into the genomic innovations that underpin slime gland evolution in hagfish, a lineage restricted evolutionary novelty.

## Stiffness of marine sediments measured on the scale of burrowers

*Jennifer Duncan, Semyra Reus, Kelly Dorgan*

Marine infauna extend burrows through sediment by fracture, a process that is strongly affected by the geotechnical properties of sediment, specifically fracture toughness and stiffness. Measuring stiffness that infauna experience can be challenging since they are small and burrow below the surface. A new device was developed to measure stiffness on scales experienced by infauna. A custom-built stiffness probe was created using a force sensor and probe with a 6mm-diameter, spherical tip. This probe aligns with a sediment core with predrilled holes. The probe is slowly inserted into and retracted from the sediment at a rate comparable to pharynx eversion by burrowing worms. From the measured force-displacement curves, stiffness and hysteresis can be calculated. Stiffness is measured over the depth of the core to compare depths where infauna are and are not present. Fracture toughness will be measured at the same depths and orientations, so they be directly compared to one another to understand where infauna are distributed in the sediment. Finally, high frequency acoustical attenuation and sound speed measurements can be taken at the same locations in the core to examine how infaunal activity affect acoustical measurements. These measurements can be compared to fracture toughness and stiffness. Examining all these variables and relating them to infauna community, abundance, and activity can give better insight into the types of environments that infauna prefer to inhabit.

## Unravelling the transcriptional identity of stinging cell types in the sea anemone *Nematostella*

*Jenny Duong, Anna Klompen, Mary McKinney, Lacey Ellington, Matt Gibson*

Stinging cells (cnidocytes) are a unique cell type of the phylum Cnidaria. These cells contain an explosive harpoon-like organelle called the cnidocyst that can be discharged to puncture its predators or prey, injecting them with toxins. Diverse cnidarian species exhibit different types and proportions of stinging cells. According to previous studies, the sea anemone Nematostella vectensis is known to have four morphologically distinct types: small and large isorhizas, mastigophores, and spirocytes. However, recent single-cell transcriptomic data suggest there could be as many as five transcriptionally-distinct stinging cell lineages in polyps: nematocyte 1, nematocyte 2, nep8-like, uncharacterized pharnyx, and spirocyst. The relationship between the established morphological types and these putative transcriptional stinging cell types is unclear. Here, we employ gene expression analysis and knockdown experiments to test the hypothesis that there are five types of cnidocytes within N. vectensis. We first validated multiple selected marker genes that were expressed in each of the five proposed cell types through colorimetric and fluorescence in-situ hybridization. Second, we conducted knockdown experiments on select genes and observed the phenotype, with a focus on the impact of known stinging cell markers. Together, our data suggest that there are likely not to be additional stinging cell types but rather several subtypes of the currently known morphological stinging cells.

## Yolk steroids but not antibodies vary with prior maternal disease exposure and diet

*Sarah DuRant, Erin Sauer, Ashley Love, Ryan Paitz*

Changes in parental physiology or behavior in response to environmental conditions can alter the early life environment of offspring and can sometimes program offspring to better meet the demands of the external environment (i.e., environmental matching). Here, we explored the individual and interactive effects of prior diet and disease exposure on maternal contributions to the egg in canaries (Serinus canaria domestica). Prior to mating and egg-laying mothers were fed a high lipid or high protein diet and inoculated with Frey's media (sham) or the pathogen Mycoplasma gallisepticum (MG). Eggs of first clutches were collected upon laying and measured for total antibody contributions and deposition of 30 steroid hormones. Antibodies were highest in first laid eggs and decreased with lay sequence but were not affected by maternal diet or disease. However, disease-exposed females deposited more testosterone in egg yolks than unexposed females and disease-exposed females on the high lipid diet had higher levels of progesterone and pregnenolone than all other groups. Increasing infection intensity also correlated positively with deposition of some hormones, and this effect was greatest in high lipid moms. Hormones varied with lay sequence, but directionality differed by hormone. Our results suggest that disease-exposed females on high lipid diets have more active steroids and that hormones but not antibodies could shape avian offspring immune traits when moms breed after recently clearing an infection.

## Identification and characterization of miRNAs in three species of stony coral

*Kathleen Durkin, Sam White, Jill Ashey, Ariana Huffmyer, Steven Roberts, Hollie Putnam*

MicroRNA (miRNAs) are a class of non-coding RNA transcripts, ~22 nucleotides long, that dynamically regulate gene expression through RNA interference, both pre- and post-transcription. As epigenetic modulators, miRNAs can influence gene expression without changing the underlying genetic sequence, and may therefore play an important role in stress response and phenotypic plasticity. In Acropora digitifera, for example, an miRNA is differentially regulated under thermal stress, putatively aiding the sequestration of transcripts encoding stress response proteins (Gajigan & Conaco, 2017). However, miRNAs remain understudied in most non-model organisms. In this study, we use RNA sequencing data to identify novel and previously described miRNAs in three evolutionarily and physiologically diverse species of stony coral (Acropora pulchra, Porites evermanni, Pocillopora tuahiniensis) and evaluate patterns of miRNA-mRNA coexpression to explore potential miRNA-mRNA interactions. Approximately 40 miRNAs were identified in each species, with a small subset conserved across species. Conserved miRNAs included several previously described in other species and implicated in biomineralization and growth. Genes shown to have correlated expression with miRNAs belonged to a diverse range of functional classes. Characterizing the repertoire and regulatory functions of miRNAs in corals provides insight into their possible stress response systems and potential for acclimatization, which is becoming increasingly vital as anthropogenic climate change progresses.

## Spatial neophobia is still not correlated with object neophobia in wild-caught house sparrows

*Blake Dusang, Marquise Henry, Melanie Kimball, Christine Lattin*

Neophobia, aversive behavior towards novel objects, foods, and environments, is a trait that affects the ability of animals to adapt to new environments and exploit novel resources. Our previous work demonstrated that individual responses of house sparrows (Passer domesticus) to novel object trials were not correlated with time spent in a novel environment or latency to enter a novel environment. However, because no positive stimulus was present in the novel environment, this study may have compared object neophobia with spatial neophilia (a preference for something novel over something familiar), which may be a distinct trait. In this study, we placed familiar food dishes in the novel environment and assessed whether an individual's willingness to enter and feed was significantly correlated with their willingness to feed from a familiar dish presented with a novel object in the home cage. We exposed house sparrows (n=26) to a novel environment (an adjacent cage with identical perches and branches, but placed in different locations) by creating a small opening in a cage divider on either the left or right side of the home cage. Food was visible through the opening as a positive stimulus. We measured latency to enter and feed, total time spent in the novel environment, and time spent feeding during two novel environment trials. Sparrows were also assessed for object neophobia based on their approach and feed latency in the presence of three different novel objects. Results indicate that there were no correlations between any of the measured behaviors in the novel environment and individual responses to novel object trials. These results suggest that even with food as a motivator, spatial neophobia and object neophobia represent two distinct traits.

## Gene flow, population structure, and color production in an aposematic poison frog

*Ashley Dye, Andrew Rubio, Emma Steigerwald, Jackson Hastings, Rasmus Nielsen, Kyle Summers, Matthew MacManes, Adam Stuckert*

Local variation is expected to increase between populations under different selective pressures. However, high levels of gene flow can erode these population-level differences and drive more spatially-homogeneous genotypes and phenotypes. Transition or clinal zones represent a phenotypic and genotypic gradient between two conspecific populations. These zones are powerful opportunities to study the genomic mechanisms underlying complex phenotypes. The poison frog Ranitomeya imitator exhibits four distinct, allopatric color morphs with three known transition zones of intermediate phenotypes between the striped color morph and each of the other color morphs (spotted, banded, and varadero). We investigated population structure within the striped-banded transition zone and quantified both the extent and directionality of gene flow through the transition zone. Additionally, we asked how differential gene expression between populations contributes to these phenotypes. Using both RAD and RNA sequencing, we investigated population structure, quantified gene flow, and identified differentially expressed color candidate genes throughout a single transition zone. Admixture analyses indicate there are three genetic clusters in the transition zone that are likely driven, in part, by geographic distance. Additionally, our gene flow analysis indicates partial unidirectional gene flow. Finally, preliminary results suggest genes involved in carotenoid metabolism, such as retsat, are differentially expressed between populations, with intermediate expression levels present in intermediate populations. Our analyses suggest both deforestation and geographic distance contribute to driving genetic differentiation between populations.

## A transcriptomic study of the lone star tick's mating behaviors for disease mitigation

*Mitchell Dyen, Robert Fitak*

The lone star tick (Amblyomma americanum) is an expanding public health threat as their population increases, expanding the distribution of various zoonotic diseases such as ehrlichiosis and Lyme borreliosis. Exhaustive amounts of research exists investigating the diagnosis and treatment of these illnesses, but there is a lack of research regarding their prevention. There is a thorough evolutionary and physiological understanding of insects that has led to a variety of biocontrol strategies that exploit their senses. These strategies capitalize on attraction to targets by reflecting or emitting wavelengths of light, or rendering attractants such as crops invisible through UV-shielding films. A similar approach could control tick-borne illnes, yet we do not have a strong enough foundational knowledge of tick systems to implement this yet. Thus, this study compares the genome of male lone-star ticks exposed to one of their mating pheromones, 2,6-dichlorophenol, and identifying changes in expression in order to uncover any relations between mating and sensory systems.

## Seasonality of ectoparasites in a migratory bat colony

*Kristin Dyer, Meagan Allira, Bret Demory, Mackenzie Hightower, Jackson Wingert, Jeremy Ross, Daniel Becker*

Mexican free-tailed bats (Tadarida brasiliensis) migrate annually from Mexico to the southwestern U.S. to reproduce in maternity colonies ranging from hundreds of thousands to millions of bats. Such dense and ephemeral congregations could have important implications for the maintenance and spread of parasites within and between host populations. Blood-feeding ectoparasites can negatively impact host health through resource consumption and pathogen transmission, especially during energetically demanding activities including reproduction and migration. While bats are known to harbor highly bat-specific ectoparasites, the interplay between parasitism, bat health, and migration remains poorly understood. We conducted monthly sampling at a Mexican free-tailed bat maternity roost in western Oklahoma over three years. We evaluated ectoparasite presence by taxa, bat body condition via mass, then marked individuals with a combination of Passive Integrated Transponder (PIT) tags and automated radio-telemetry tags to track fall migration. Using generalized additive models, we tested seasonality in ectoparasite prevalence by taxa and whether ectoparasite presence predicts body condition. Lastly, we tested whether body condition and ectoparasitism affect fall migration timing. We identified several ectoparasite species and observed seasonal shifts in prevalence corresponding to bat life history (e.g., birth of pups). Parasitism, coupled with the physiological demands of reproduction, could adversely affect the bats' ability to survive a long-distance migration. Understanding these interactions is crucial for wildlife conservation and managing the health of wild bat populations.

## Do we know a life stage when we see it?: ctenophore life history and plasticity

*Allison Edgar*

Some ctenophore lineages, exemplified by the classical "model" ctenophore Mnemiopsis leidyi, exhibit morphological plasticity throughout their life cycle. While they attain reproductive competence at a small size and with the ancestral body plan of the ctenophore phylum, as they grow, their morphology changes dramatically. This morphological change is uncorrelated with the onset of sexual maturity, seasonality, or similar common triggers of post-embryonic morphological change. How should we should interpret this change: as a terminally added novel life stage, as a vestigial metamorphosis that uncouples sexual reproduction from adulthood, environmentally responsive plasticity, or something else?

## Exploring the role of *rdh1* in pectoral fin development

*Emery Edgar, Sayoni Chatterjee, Meghana Miryala, Tetsuya Nakamura, Katelyn Mika*

Across the phylogeny, the pectoral fins of fish have incredibly diverse morphologies. The mechanisms of gene and gene pathways in the evolution and development of this variation are still unknown. We can now investigate how gene expression changes in individual cell types can shift across development and influence the variation in morphology by using single cell sequencing. We collected single cell sequencing data from wild-type zebrafish and two known pectoral fin morphological mutants – hoxa13a and hoxa13b knockout zebrafish. By comparing these data, we have identified rdh1 as a gene involved in fin development. Rdh1, also known as retinol dehydrogenase, is a part of the retinoic acid pathway. This pathway is known to help establish hox gene expression boundaries, but little is known about its role downstream of hox genes. In our data, the removal of hoxa13a or hoxa13b directly results in the loss of expression of most copies of rdh1 within the pectoral fins. To investigate this further and the possible connection between these genes, we plan to perform a retinoic acid rescue experiment, as well as generating a knockout of rdh1 itself using CRISPR/CAS9. We hypothesize that the pectoral fin will be lost when rdh1 is not present, indicating rdh1 and the retinoic acid pathway play significant roles in zebrafish pectoral fin development.

## Resilient coral communities on degraded Caribbean reefs

*Peter Edmunds*

After decades of coral death, many tropical coral communities consist of low abundance populations, confirming that future coral reefs will almost certainly differ from those of the past. The large scale of this phenomenon erodes incentive to study the relict communities, yet their study reveals the resource upon which natural reef recovery will have to rely. Here, 32 yrs of annual surveys of benthic communities at six sites on the fringing reefs of St. John, US Virgin Islands, were used to consider the potential ecological end point for low abundance coral communities. The mean cover of macroalgae and CTB (crustose coralline algae, turf, and bare space, combined) increased at 2.8 and 4.0%/decade respectively, together covering 81% of the reefs by 2023 while mean coral cover remained at 2– 4%. The sites differed in coral cover averaged among years (range 1–7%), and in heterogeneity of coral generic abundance measured at the photoquadrat scale; generic richness declined in the third decade of the study in favor of weedy corals. These low abundance coral communities exhibit high ecological resilience even though they are spatially dominated by macroalgae. Communities with $\leq$ 4% coverage of live coral arguably are not coral reefs, but they retain ecological importance by exploiting low abundance populations of weedy corals to avoid the coup de grâs of coral extirpation following decades of degradation.

## The new owners of your trash: characterizing the microbial plastisphere in the deep ocean

*Emma Edwards, S. Ruff, Rut Pedrosa Pamies, Molly Moynihan, Emeline Vidal, Roo Weed, Eleanor Greene, Chase Glatz*

Millions of tons of plastic enter the ocean each year, yet most of this is unaccounted for and is hypothesized to either be ingested by marine fauna, broken down into nano-sized particles settling to the seafloor, or degraded by microbes. We set forth to investigate the latter by studying deep sea microbial plastic colonization and potential degradation. We characterized the microbial community composition of plastics-associated biofilms and their plastic degradation potential via metabarcoding and metagenomics methods. Nine chemically diverse plastic types were incubated in the Sargasso Sea for six months at 750m and 3600m depths using the Oceanic Flux Program (OFP) mooring. We find selective enrichment of hydrocarbon degradation associated taxa on all incubated plastic types and highlight the distribution of certain plastic degradation related genes within the microbial communities. Hydrocarbon-degradation associated microorganisms affiliating with Methyloligellaceae, Oleiphilaceae, PS1 Clade (Parvibaculales), and Colwelliaceae made up the majority of microbial communities on the different plastic types at both depths. Searching the metagenomes using Hidden Markov Model (HMM) profiles revealed metabolic genes involved in plastic degradation, including alkB, pnbA, estA, cut1, cut2, lip1, and lip2 in metagenomic bins affiliating with Pseudomonadales, Alcanivoraceae, Ketobacteraceae, Oleiphilaceae, and Parvibaculaceae. The presence of these lineages and genes suggests the potential for biodegradation of microplastics in the deep ocean water column and a role of plastics as an energy source for deep-sea microbes.

## Expression of apoptotic and autophagic genes in Exaiptasia diaphana upon pathogen exposure

*Katrina Edwards, Angela Poole*

The stability of coral reefs depends on the health of cnidarians and their mutualistic relationship with photosynthetic dinoflagellates. Climate change has led to a rise in both coral bleaching (breakdown of symbiosis) and diseases that harm the entire reef ecosystem. Although coral symbiosis and disease have been studied individually, there is limited research on how these factors intersect. Two pathways that are shown to be active during both processes are apoptosis and autophagy, making these an important topic for future investigation. Therefore, the goal of this study was to measure expression of apoptotic (Bcl-WA and Bax) and autophagic (Beclin and LC3) genes in the model sea anemone Exaiptasia diaphana upon exposure to pathogen Serratia marcescens (ATCC 13880). Since this strain of S. marcescens was not a confirmed coral pathogen, a seven-day infection was conducted to determine the time course of the disease. After 2 days, some infected organisms displayed retraction of both tentacles and body column, however, these attributes were more consistent on day 5. Quantitative PCR (qPCR) indicated no significant differences in the expression of Bcl-WA, Bax, Beclin, and LC3 in either symbiotic or aposymbiotic anemones at 12 and 24 hours post-exposure. These findings suggest that autophagy and apoptosis may not be occurring in early time points after pathogen exposure or regulation of these processes occurs at the protein level rather than gene expression.

## Glucocorticoids across the ovarian cycle in vertebrates: patterns and function

*Phoebe Edwards, Kerry Fanson*

Glucocorticoids (GCs) are steroid hormones that are involved in energy regulation and have numerous functional effects through their actions as transcription factors. While GCs are classically associated with the stress response, they have other functions that are not as well explored. We investigate the role of GCs in female reproduction, in particular, their patterns and functions during the ovarian cycle. To do this, we conducted a comprehensive review of studies that quantified GCs or GC metabolites across the ovarian cycle in vertebrates. The vast majority of suitable studies found were on mammals, followed by ray-finned fishes, with reptiles, birds, and amphibians having fewer representative studies. Overall, the majority of studies indicated that maximum GC concentrations occurred during ovulation/estrus, relative to the follicular phase or post-ovulatory/luteal phase of the cycle. However, approximately 20% of studies indicated no statistically significant effect of ovarian cycle phase on GC concentrations. We discuss how species comparisons can be used to elucidate potential functional roles of GCs during these times.

## Environmental impacts and adaptations on *Uniola paniculata* L, an ecologically important species

*Andrew Egesa, Hector Perez, Kevin Begcy*

Environmental factors control development, reproduction and distribution success in plants. In contrast, plants respond to the environment through physical, biochemical, and physiological adjustments, which promote their distribution and success in new environments. Among these factors, seed morphophysiological and biochemical traits influence critical seed functional traits that control seed viability, longevity, and persistence, which impact the success of ecological conservation, especially in coastline dune restoration. Our research on the environmental factors that regulate physical, biochemical, and physiological traits of Sea oats seeds contributes to knowledge that can potentially revolutionize environmental conservation and restoration of coastline dunes. We analyzed the Trolox Equivalent Antioxidants (TEAC) levels in sea oats seeds and compared them with ten years of climatic data and ecological zoning. We further explored the observed TEAC levels' effect on prevailing seed viability following short-term ex-situ storage alongside germination, viability, and aging stress assays. Our results showed a higher dependence of seed quality on ecological temperature zoning and consequential impacts of seed functional traits on high-temperature aging stress survival. This implies the crucial influence of the environment on seed quality and the importance of considering environmental factors in selecting genetic resources for ecological restoration work.

## Do pollen nutrients released by microbes into nectar affect bumble bee behavior?

*Success Ekemezie, Avery Russell, Leo Carpenter, Marco Russo, Charlotte Davis*

Nectar is commonly contaminated with both pollen and microbes such as bacteria and yeast. These microbes can induce pollen germination, which results in pollen nutrients being made available to foraging pollinators. Yet whether pollen-microbe interactions in nectar impact pollinator behavior remains unknown. We therefore investigated how yeast (Metschnikowia reukaufii) and bacteria (Acinetobacter nectaris), commonly found in nectar, affected pollen germination and whether nectar-microbe-pollen interactions modified bumble bee foraging behavior. We found that both bacteria and yeast induced pollen germination in artificial nectar, with bacteria inducing the most germination. Although microbes can thus potentially facilitate the release of pollen nutrients, neither bacteria nor yeast, alone or in combination with pollen, influenced bee foraging preference. Similarly, we found no effects on how the bees switched between flowers that had sterile nectar versus those with pollen, microbes, or both. Although pollen nutrients are recognized to affect the growth of nectar microbes, which might in turn affect natural floral cues, our work suggests pollen-microbe interactions alone may be insufficient to affect pollinator behavior.

## Earliest record of Carangaria: a new species of moonfishes (*Menidae*) from the Danian of Egypt

*Sanaa El-Sayed, Matt Friedman, Hesham Sallam*

Carangaria are a morphologically diverse clade of primarily marine spiny-rayed fishes, with a fossil record extending to the Paleocene-Eocene boundary. Here, we report on a new species of the carangarian Mene from the Eastern Desert of Egypt from a Danian horizon that is securely dated to 62.2 Ma. Assignment of the new specimens to Mene is supported by numerous synapomorphies (e.g., compressed disc-like body, anteroposteriorly elongated dorsal and anal fins with relatively short rays). These features are strongly conserved in all known fossils Mene from the Eocene and Oligocene. However, the early Paleocene specimens exhibit unique traits compared to other Mene species: separate first and second neural spines, no lateral laminar expansions of the dorsal pterygiophores, rounded dorsal and ventral profiles of the maxilla, and a distinctive pattern of ridges on the frontal-supraoccipital crest. These suggest that the Danian Egyptian Mene represents a new species, with the retention of primitive features indicating it might represent the sister lineage of all other, younger members of the genus. This discovery not only extends Mene's record by over six million years but also introduces a robust new marker for establishing the timeline of diversification within Carangaria. The remarkable similarity of Mene species over 60 million years of evolutionary history represents a striking example of anatomical stasis.This work was supported by NSF grant DEB-2017822 and NG grant NGS-100278R-23.

## Fine Scale Movement of Whale Sharks in the Northwest Atlantic Ocean

*Jaida Elcock, Martin Arostegui, Connor White, Camrin Braun*

Studying fine-scale movement behavior can provide insight into the energetics of organisms. Such information may be especially important for highly migratory species. Whale sharks (Rhincodon typus) make extensive migrations to aggregation sites in warm and tropical waters, including the Gulf Stream in the Northwest Atlantic (NWA). The functional role of these aggregations sites are not known, but may be vital for whale shark feeding and reproduction. Thus, there is a need to determine the role these sites play in the lives of the world's largest fish. Biologging technology allows us to capture fine-scale movement data that reveal different behaviors exhibited by the sharks. In this study, we tagged whale sharks in the NWA in summer months with biologger tags that measure three axes of both acceleration and magnetic field strength, light levels, depth, and temperature. We will analyze these data to investigate overall dynamic body acceleration, swimming path tortuosity, and dive patterns to characterize foraging behavior. These data will confirm the presence of foraging behavior in whale sharks that reside in offshore habitats. Such information will provide a deeper understanding of the functional role of the NWA and its importance as a whale shark aggregation site. It will also allow us the opportunity to project how these sites and resources that are important to whale sharks may be affected in the face of climate change.

## Anatomical mapping of leaf water content

*Ogonna Eli*

Leaf water storage has a significant impact on whole plant susceptibility to functional decline under drought, however, water storage structures have an inherent carbon cost. While several indices exist to quantify stored water in ecological and physiological studies, these indices do not account for the functional implications of water stored in different tissues. This study seeks to improve our understanding of leaf water storage anatomy and its implications for physiological processes. We presented a novel experiment designed to quantitively test outstanding gaps in the literature focusing on three objectives: (1) use tissue-specific anatomical and compositional traits to predict leaf water mass per area (LWMA), (2) determine the relative contributions of each tissue to LWMA across diverse species, and (3) understand the implications of variance in leaf water storage anatomy for drought tolerance. Towards these objectives, we developed a theoretical model; Exhaustive Cross-Sectional Anatomy and Composition of Tissue Water model (EXACTw). When parameterized with empirical data for 17 diverse species, we found high precision in prediction of LWMA from anatomical traits when compared to empirical observations ($R2 = 0.83$, $P < 0 .001$, slope = 0.63). We concluded that although the bulk of water leaf water occurs in the photosynthetic tissues, variance in water storage across non-photosynthetic tissue (i.e., bundle sheath extension, veins, and epidermis) had a stronger impact on leaf drought tolerance indices extracted from leaf pressure-volume curves.

## The green sea urchin and *Desmarestia* sp.: physiological responses to differences in experimental cues

*Francisco Elia-Benfield, Stephanie Crofts, Katie Dobkowski*

The green urchin (Strongylocentrotus droebachiensis) can be highly phenotypically plastic in response to environmental cues, such as climate change. Climate change will not only impact urchins, but will also affect their food sources. The urchins' preferred diet is Bull Kelp (Nereocystis luetkeana), but they will also eat Acid Weed (Desmarestia sp) if given no other choice. Acid weed has an internal pH of ∼#, and releases this acid when stressed. The goal of this study is to understand if/how urchin physiology changes in response to variations in diet under different environmental conditions. To test the effect of environment, we housed half of our urchins in the lab and half in mesh cages, suspended from a floating dock. To test the effect of diet, each environmental treatment was divided into three groups which were fed one of three diets: fresh Nereocystis, fresh Desmarestia, or stressed Desmarestia. Following our experiment, urchins were dissected to measure body mass and gonad mass, we then CTscanned spines and the Aristotle's Lanterns to quantify and compare densities. We found that, when compared with other environmental and diet treatments, the urchins suspended off the dock and fed stressed Desmarestia had the calcified structures with the highest density. Rising ocean temperatures may impact the feeding preferences of the green sea urchin in relation to the deacidifying nature of Desmarestia and bull kelp.

## Magic Angles and Force Transmission in Helically-Wrapped, Pressurized, Cylindrical Worms

*Olaf Ellers, Amy Johnson, Matt McHenry*

Many animal structures and appendages are pressurized, cylindrical and helically wrapped with fibers. Sharks, squid tentacles, elephant trunks, echinoderm tube feet, nematodes, annelids, notochords and arteries are all helically wrapped and their material and structural function depends on the way in which helical wrapping transmits force. Classical understanding of wrapped cylinders in biology is based on Cowey, 1952; Harris and Crofton, 1956; and Clark and Cowey, 1958 working on nemerteans, turbellarians and nematodes. That work recognized the geometric effects of fiber angle on volume and fiber stretch but did not describe forces. Here we incorporate force transmission, allowing an understanding of deformation under some loading regimes and enabling an understanding of mechanical and displacement advantage in biological hydrostats. In a cylinder, hoop stress is twice longitudinal stress, and these stresses can be carried by fiber stresses at the magic angle of 54 degrees. A constant volume cylinder at any other angle will stretch the fibers, store energy, cause shape changes and possibly generate axial, circumferential or radial external forces. Compelling examples can be calculated. For instance, a worm that generates stresses with circumferential muscles will store energy in the helical fibers and cause the fiber angle to decrease. Any change away from the 54 degree angle will cause coelomic pressure to increase. And force transmission efficiency is highest closest to 54 degrees.

## Tail flaring serves as a key signal in male-male hummingbird fighting

*Rosalee Elting, Md Zafar Anwar, Bo Cheng, Haoxiang Luo, Donald Powers, Bret Tobalske*

To obtain food and mates, male hummingbirds often participate in territorial behaviors which are predicted to require greater maneuverability and, in turn, increase metabolic and mechanical power requirements. Seminal work in competition theory predicts that agonistic interactions where competitors assess one another (mutual assessment) should resolve (de-escalate) as soon as a subdominant assesses they cannot win the fight and therefore minimizes risk of body harm. Here we present a novel escalation hypothesis during agonistic encounters between pairs of male Calliope hummingbirds (Selasphorus calliope = 9 birds; 16 dyads; 2 years). Escalation levels increased from initial signaling through several stages to maximum intensity featuring spiral flights and jousting. We observed consistent flaring of the tail by each competitor at all levels of agonism, so we hypothesize this is serving as a key signal during male-male fighting. Our recent work reveals minimal aerodynamic function of the tail during escape maneuvers, and work by others demonstrates that manipulation of tail morphology has minimal effects upon metabolic power during cruising flight. Thus, the evolution of hovering flight, and therefore the dominance of wing aerodynamics in hummingbirds may have relaxed selection pressure on tail morphology. For a given tail length and body size, tail flaring should allow a hummingbird to appear larger and present more of a "looming" threat to their opponent. ONR N00014-24-1-2044.

## Maternal transfer of immunity in reproductive pythons

*Daniel Emanuel, Dale DeNardo, Helen Plylar, Erin Lewis, Kwanho Ki, Susannah French*

Maternal transfer of immunity can protect neonates from infection while their own immune system is developing. While this process is well understood in mammals, there is limited work describing maternal immune transfer in other vertebrate taxa, especially reptiles. This study assessed the effects of an immune challenge on maternal immune transfer in Children's pythons (Antaresia childreni). Twenty-one adult late-vitellogenic (i.e, follicles >20mm) females received an injection of lipopolysaccharide (LPS) or phosphate-buffered saline. Blood samples were obtained from females immediately prior to treatment and again on days two and seven following the immune challenge. Each clutch was divided such that yolk samples were collected 24-hours post-oviposition from half of the eggs and five days post-hatching for the other half of the eggs. To measure the effects of the immune challenge, a bacterial killing ability (BKA) assay and an LPS-specific IgY ELISA were performed on yolk and blood samples. Females that received an LPS injection had significantly lower IgY levels than did controls at day two and day seven post-injection. We detected correlations between dam, yolk, and hatchling antibody titers in the absence of treatment. However, there was no effect of treatment on offspring IgY levels, offspring BKA, or dam BKA. This study demonstrated maternal transfer of immunity against specific antigens and showed that female immune activity later in vitellogenesis may not impact offspring immune function.

## Sexually selected shields: Male-male combat can promote the evolution of damage-reducing structures

*Zachary Emberts, Isaac McEvoy*

Empirical and theoretical evidence suggests that getting injured during combat decreases an individual's chances of winning. Thus, it has been hypothesized that species that engage in injurious fights may evolve armor. However, much remains unknown about the role that male-male combat has in promoting the evolution of such damage-reducing structures. Here, we tested the hypothesis that male-male combat can increase the damage resistance of structures using the giant mesquite bug, Pachylis neocalifornicus. When males in this species fight over access to mates, they use their weaponized hind legs to puncture the dorsal side, but not the ventral side of their rivals. We found that structures on the dorsal side of males could generally withstand the forces of combat, while structures on the dorsal side of females could not. The sexual dimorphism in damage resistance was location dependent because structures on the ventral side of both males and females also could not withstand the forces of combat. Thus, males appear to only increase their defensive capacity in the locations where strikes from rivals normally land. These results provide evidence that male-male combat can promote the evolution of damage-reducing structures (i.e., sexually selected shields).

## Investigating the contribution of autotrophy & heterotrophy to energy storage in *Astrangia poculata*

*Zhoe (Atlas) Emmanuel, Caroline Fleming Ianniello, Julia Band Orange, Drew Bouchie, Ivy Foster, Justin McAlister, Colleen Bove, Randi Rotjan*

Tropical coral-algae symbioses have been studied as an emblematic example of environmental sensitivity in the Anthropocene. In the last 75 years, global bleaching events have led to a loss of nearly 50% of tropical coral cover. During bleaching, corals lose their primary source of energy (transferred photosynthates), which leads to a drawdown of energetic resources and ultimately coral animal mortality. Recent research suggests that heterotrophy can play an essential role in "rescuing" a coral from starvation following dysbiosis, but little is known about the relative contribution of autotrophic and heterotrophic sources to coral functioning, especially at varying levels of symbiosis. In this experiment, we leveraged the facultative symbiosis of the scleractinian coral Astrangia poculata by exposing corals of different symbiotic densities to various light irradiance (100%, 60%, 30%, 0%) and food availability (fed or starved) over 90 days. This allowed us to control the amount of autotrophic and heterotrophic energy available to the system. We regularly imaged corals and quantified red channel value as a proxy for symbiont density. At the end of the experiment, we extracted whole lipid content and measured ash-free dry weight to assess energetic storage. Our results will provide insight into the mechanisms of coral resilience by understanding how and the extent to which autotrophy vs. heterotrophy contribute to a coral's energetic state, and how this is modulated by symbiont density.

## Active tail modulation in snailfishes reduces drag

*Catherine Eno, Hungtang Ko, Charbel El Khoury, Miguel Montalvo, Spencer Truman, Cassandra Donatelli, Brooke Flammang, Jonathan Huie*

Resisting the constant push and pull of ocean currents is a challenge experienced by many marine organisms. Snailfishes (Liparidae) evolved suction discs on their abdomens that facilitate attachment to benthic structures and aid in resisting flow. Many snailfish species have been observed curling their tail around their head to form a dome-like shape and it is hypothesized that curling reduces the directional effect of fluid perturbations across their body. In this study, the behaviors of Liparis florae (n = 1; 8.2 cm SL) and Liparis dennyi (n = 6; 6-6.7 cm SL) were recorded in a high-speed flume in response to increasing flow speeds. Drag forces were then measured at 360 degrees on euthanized specimens (n = 3) and 3D printed idealized models in streamlined and curled orientations to explore the directionality of drag. These data were validated with computational fluid dynamic (CFD) modeling and particle image velocimetry. We found that the live snailfish made behavioral adjustments to reduce the amount of surface area present in the direct line of flow by curling tighter or orienting their streamlined body parallel to flow. This is supported by lower drag force values found at these orientations from the flow tank and CFD testing. Together, our data supports that snailfishes employ behaviors that help them remain attached to substrates in a dynamic environment.

## Zooming in on Bonnetheads: Quantifying sexual dimorphism in denticle morphology

*Hannah Epstein, Madeleine Hagood, Jamie Knaub, Marianne Porter*

The epidermis of shark skin is covered by crowns of dermal denticles, tooth-like scales, whose bases are embedded into the dermis. Denticles provide the shark with functional benefits, including protection during mating and enhanced drag reduction during high-speed swimming. Previous research has shown that denticle shape, length, width, and density varies between sexes of sharks. In lesser-spotted catshark skin, the denticle density, length and width were shown to differ between sexes in body regions where males bite females during mating. However, the denticle morphometrics of bonnethead sharks (Sphyrna tiburo), a species known to exhibit sexual dimorphisms, have not been investigated. We dissected skin from 24 bonnethead sharks (12 male and 12 female) between the first and second dorsal fins and imaged the denticles using scanning electron microscopy (SEM). We calculated denticle morphometrics, including crown width, length, and percent of overlap, using ImageJ. We hypothesized that female bonnethead sharks would have a higher percent overlap and longer denticle crowns, as these may provide greater protection during mating. We found that the denticles of female bonnethead shark skin had longer crowns, but not greater crown percent-overlap or width. Our results suggest that denticle morphology may be another sexual dimorphism of bonnethead sharks, and that denticles could provide specific functional or mechanical benefits, such as tensile strain and ultimate strength, to males and females of this species.

## Mycoplasma gallisepticum suppresses cytokine levels in chicken bone marrow-derived macrophages

*Reihane Eric, Chidambaram Ramanathan, Brandt Pence, James Adelman, Yufeng Zhang*

Mycoplasma gallisepticum (MG) was originally a poultry pathogen but can also infect songbirds in the wild. MG infects respiratory systems and conjunctiva in both poultry and songbirds. Previous research hypothesized that MG has immune-suppressive properties; however, these properties and their underlying mechanisms are not well understood and documented. This study aimed to evaluate the potential immune-suppressive role of MG by using chicken bone marrow-derived macrophages (BMDMs). Here, we established BMDM culture from Leghorn chickens that were infected with the same dose of live and heat-killed MG to test the expression profile of inflammatory cytokines for short and long durations. The expression profiles of pro-inflammatory cytokines (IL-1B, IL-6, IL-8) and anti-inflammatory cytokine (IL-10) levels showed different trends after the infection in heat-killed MG but not live MG treatment. The pro-inflammatory cytokine expression levels peaked after 24 hrs post-infection, but anti-inflammatory cytokine levels were relatively constant across the time in heat-killed MG condition. More importantly, we observed both cytokines' profiles showed reduced expression across the duration of measurement in the live-MG treatment condition, supporting our hypothesis that the live MG shows immune suppressive properties compared to heat-killed MG. Further studies would focus on the underlying mechanisms for the observed immune-suppressive properties of MG.

## The Investigation of Lateral Foraging Patterns and Prey Mobility in Fin and Sei Whales

*Alex Eschmann, Susan Parks, Dana Adcock, Dana Cusano*

Lateralization is often defined as organisms showing preferential body sides to enact basic survival needs including prey capture, predator evasion, and communication signaling. Previous studies have described evidence for lateralization preferences in some large baleen whale populations, during social interactions and foraging behaviors. This study explores the lateral patterns of foraging behaviors in two previously unstudied populations of baleen whales, Western North Atlantic fin whales (Balaenoptera physalus) and sei whales (B. borealis), to test the hypothesis that lateralization in foraging behavior is driven by prey mobility. Fin whales in the study foraged on highly mobile fish prey, while sei whales foraged on slow zooplankton. Data were collected from 10 individuals for each species using suction cup attached biologging tags that contained high resolution movement sensors. The tag data for the pitch, roll, and heading of the animals were used to define left and right rolls for side feeding behaviors. The 10 tag deployments for each species resulted in 90 hours of data for fin whales and 160 hours of data for sei whales. A handedness index is used to quantify lateral preferences and explore the dominance of body side bias. The prediction is that higher mobility prey requires faster and complex foraging maneuvers for capture, that may benefit from enhanced performance through lateralization, which will require quicker reaction times for fin whales.

## "Stance Stance Evolution": How shifts from quadrupedality to bipedality impact skeletal structure

*Lauren Essner, Priscila Rothier, Jamison Thompson, Amy Yang, Andrew Orkney, Brandon Hedrick*

Locomotion has a major influence on the niches available to a species and thus has a massive impact on the macroevolutionary processes, particularly driving the morphological diversity of the appendicular skeleton. Across tetrapod evolution, there have been numerous shifts from quadrupedality to bipedality, freeing the forelimb from locomotor constraints and potentially leading to changes in skeletal structure and inter-bone relationships. For instance, while the majority of mammals are quadrupedal, bipedality has evolved multiple times, notably in small-mammal clades. These small bipedal taxa move via saltation, exhibiting relatively reduced forelimbs and extremely elongated hindlimbs, powering jumping performance. Thus, they provide an ideal model to assess whether postural shifts lead to changes in patterns of integration. We amassed a dataset characterizing fore- and hindlimb bones from 50+ species of small quadrupedal and bipedal mammals. Using geometric morphometrics, we calculated the relative proportions (centroid sizes) of each limb element and evaluated patterns of integration in our datasets. Our results indicate a difference in limb configuration across the two stances. Specifically, quadrupedal mammals show high integration across all limb elements while bipedal mammals evolved strong within-limb integration and lack significant between-limb integration. Additional exploration will provide insight into this stance dichotomy and how different locomotor ecologies (e.g., burrowing) may diverge from the terrestrial generalist limb pattern.

## Exploring the gut microbiome of pricklebacks (Teleostei: Stichaeidae) during an ontogenetic shift

*Nai Estrada, Joseph Heras*

The gastrointestinal (GI) microbial community is crucial for host health and development, with functions including fermentation of substrates and training the immune system. While mammalian gut microbiomes have been extensively studied, the fish gut microbiome remains poorly understood despite the vast diversity in species of fishes. This study investigates the gut microbiota of pricklebacks (family Stichaeidae) to understand the influences of diet, phylogeny, and host development on microbial diversity. Three species, Xiphister mucosusH, X. atropurpureusO, and Anoplarchus purpurescensC (H = Herbivore, O = Omnivore, C = Carnivore) were examined in the present study, with a focus on environment (reared in the lab and wild-caught). Methods included a controlled feeding experiment, gut morphometric analysis, and 16S rRNA amplicon sequences to assess microbial composition and diversity found in the gut of each species. Preliminary results indicate that gut length correlates with diet, with herbivorous X. mucosusH exhibiting longer guts in relation to body length. We are currently generating 16S rRNA amplicon sequences from the gut to investigate microbial diversity and its relationship with the host's diet, environment, phylogeny, and development. Understanding the cause-and-effect relationship between the host and the gut microbiome can provide insights to improve aquaculture, optimize fish growth, and satisfy the growing global demand for animal-derived protein.

## Confirming degradation of polyethylene by Galleria mellonella through fluorescence

*Destiny Etuk, Melissa Plakke*

Plastic has been an integral part of our everyday lives causing not only its exponential increase in production but also its increase in waste within our environment. Plastic in the environment has a known negative impact on all organisms, including ourselves. Although there have been methods (e.g. recycling, phytoremediation) to mitigate the plastic problem, these methods have not been effective in solving the issue. The greater waxworm, Galleria mellonella is capable of degrading polyethylene at considerably higher rates than microorganisms with the same ability, meaning the larva provides potential for a new bioremediation technique. The natural diet of G. mellonella is comprised of honeycomb and beeswax, though whether the larvae are capable of metabolizing polyethylene by similar mechanisms is largely debated. To determine whether G. mellonella can metabolize polyethylene through, we exposed larval G. mellonella to various polymer diets including treatments that incorporated fluorescent polyethylene microspheres. After ingestion of polymer diets, we observed larvae intestines and fat bodies under a fluorescent microscope to establish the rate of uptake, degradation, and absorption into the caterpillar body. We discuss our findings in the context of bioremediation and the natural history of the organism.

## Modularity promotes the evolution of complex biomechanical systems

*Kory Evans*

Biomechanical systems can be inherently complex, comprised of several traits that function and operate together to perform specific tasks. Today these systems are widespread across the tree of life and present across a broad diversity of organisms. How do these complex systems organize and evolve? Modularity-the compartmentalization of traits into semi-autonomous units has been hypothesized to play an important role in the evolution of complexity. Here we examine the role of modularity in the evolution of one of the most complex biomechanical structures on the planet; the fish skull across three different clades of fishes and show that modularity has played a central role in the organization of the fish skull. We also find that evolutionary modularity has strongly impacted the evolutionary trajectories of different regions of the skull. Our results suggest that modularity is critically important for the organization of complex systems by allowing them to evolve and adapt semi-independently.

## : Function Drives the Integration and Modularity of the Fish Skull at Different Evolutionary Scales

*Kory Evans, April Hugi*

Patterns of trait covariation manifest at multiple levels of biological organization and are thought to play crucial roles in how organisms develop, function, interact with their environments and ultimately adapt to selective pressures. While much is known about trait covariation at the evolutionary and developmental levels, less is known about the relationship between these patterns at different scales of biological organization. Here is use wrasses (family Labridae) to study patterns of trait covariation at the population level and the evolutionary to compare differences between patterns of modularity observed in these two different levels of organization. We find that at the evolutionary level, the entire wrasse skull is comprised of two large modules that merge the oral and pharyngeal jaws which evolve in a manner that is distinct from the rest of the skull. However, at the population level, the wrasse skull appears to have a more complex pattern of modularity that comprises 4 modules; two of which separate the oral and pharyngeal jaws. We hypothesize that the population levels of covariation reflect functional relationships among bones while evolutionary patterns of modularity reflect deeper conserved patterns of co-inheritance and functional interactions among traits.

## Bio-Inspired burrowing dynamics in snake-like robots via machine learning

*Sean Even, Yasemin Ozkan-Aydin*

Snakes navigate subterranean environments by employing body undulations that enable effective burrowing through granular media [Yi, Hongyu, 2015]. This study explores these mechanisms by developing a 64 cm, five-segment snake-like robot that mimics snake undulatory motion. Each segment is equipped with two-degree-of-freedom servo motors for pitch and yaw movements, coordinated by a deep learning-based control system utilizing magnetometers. The robot was tested in a tank filled with packing peanuts, where its undulatory amplitude was varied to optimize vertical burrowing depth and speed. The robot started 40 cm above the testing surface and self-burrowed by propagating sinusoidal waves down its body, consistently reaching a depth of $15 \pm 0.5$ cm from the bottom of the testing tank during training. Additionally, the robot exhibited body buckling, allowing it to adjust its trajectory in denser regions of the medium, mirroring the adaptive strategies of biological snakes. The optimal gait pattern involved extreme motor positions, shortening the distance from tip to tail before wriggling back and forth—a behavior similar to that of vipers during vertical self-burrowing [Marketos, 2010]. Integrating these biological principles with advanced machine learning enabled the robot to outperform traditional burrowing methods, highlighting the potential of biologically inspired robotic systems in navigating complex subterranean environments.

## Earthworm-Inspired Soft Robot for Effective Navigation in Obstacle-Rich Environments

*Sean Even, Yasemin Ozkan-Aydin*

Earthworms navigate through subterranean environments using retrograde peristalsis, characterized by sequential radial and longitudinal muscle contractions, which enable efficient movement and obstacle negotiation [Trueman, Edward Arnold, 1975]. Understanding how earthworms precisely coordinate these movements to navigate through complex, obstacle-rich environments remains an ongoing challenge. To explore these mechanisms, we developed a worm-like soft robot (L=36 cm, D=6 cm, 3 segments) that mimics the peristaltic motion of earthworms. Each segment is equipped with pneumatic actuators, allowing for radial, longitudinal extensions and undulation. The robot's control system uses touch sensors at the tip to detect obstacles and modulate movement cycles in real time. We tested the robot's ability to navigate a confined space with cylindrical obstacles (diameter = 7.5 cm) towards a light source using onboard sensors. The robot employed a combination of forward and undulatory turning motions, emulating the earthworm's natural obstacle negotiation techniques, resulting in an average progress of 8.22 $\pm$ 0.16 mm per locomotion cycle when navigating towards a light source through an environment with cylindrical obstacles. In a different obstacle configuration, the robot achieved forward progress of 10.08 $\pm$ 0.27 mm per cycle. These findings suggest that integrating sensory feedback with biologically inspired locomotion strategies allows the robot to adapt its trajectory and enhances its navigation efficiency in complex terrains.

## Comparative Sequence Analysis of Essential Bacterial Membrane Protein Transporters

*Alex Everett, David Bean, Syrus Miner, Jeremy Bakelar, Randy Klabacka*

The $\beta$-barrel assembly machinery (BAM) complex is a crucial protein complex located in the outer membrane of gram-negative bacteria. This complex is responsible for integrating proteins into the bacterial outer membrane. The purpose of this project is to investigate the evolutionary conservation of the essential component of BAM (BamA), and a related homologous protein (TamA). Given the importance of these proteins, we hypothesized that there would be a high amino acid sequence conservation among various gram-negative bacteria of the genus Escherichia and across the bacterial tree of life. Comparing these sequences to all other Escherichia proteins, we found that protein-wide level sequence conservation is not higher in the BAM proteins. However, looking at the conservation of each position within the amino acid sequences we see high levels of conservation at some sites across the bacterial tree of life, suggesting that the conservation of certain positions rather than the protein as a whole is critical for the vital function that these genes play.

## Morphological and Molecular Identification of Smooth Freshwater Stingray (Fontritrygon garouaensis)

*Amaya Everett, Segun Oladipo, Kehinde Adelakun, Lotanna Nneji*

Stingrays of the genus Fontitrygon, particularly those from the African aquatic ecosystems, are now increasingly threatened due to habitat degradation, climate change and bycatch. Native to rivers in Nigeria and Cameroon, the Smooth Freshwater Stingray (Fontritrygon garouaensis) is heavily exploited as food and in traditional medicine and is now critically endangered due to human-induced threats. This study aims to use comparative morphological and molecular approaches to identify F. garouaensis from the African freshwater ecosystems. To do this, we sampled eight individuals from different fish landing sites in Jebba River in Nigeria and measured morphometric and meristic characters for each sample. The morphology and morphometrics of the present specimens compared to previously published prototype and holotype measurements confirmed species identification. Analysis of fragment (~600 bp) of the mitochondrial DNA encoding Cytochrome C Oxidase Subunit (1) gene showed that F. garouaensis samples were 100% genetically similar and distinct species, forming a sister relationship with Fontitrygon margarita and Fontitrygon margaritella from African water bodies. This study was the first to confirm the phylogenetic position of F. garouaensis within the African Fontitrygon group, as well as illustrate the usefulness of DNA barcoding in species-level identification of rays from African aquatic ecosystems.

## Developmental shift in chondrocranial morphogenesis underpins the origin of the avian beak

*Matteo Fabbri*

Birds are characterized by enlarged, edentulous premaxillae, contrary to all other extant non-avian reptiles. Whether the appearance of the avian beak has been a stepwise, evolutionary gradual event or a sudden shift, and how developmental changes might have played a role into its origin remain unclear. To test this, 3D geometric morphometrics was applied on the skull of extant and extinct reptiles, including birds: the lack of intermediate phenotypes suggest that such evolutionary change was abrupt, rather than gradual, suggesting that developmental shifts might have influenced the appearance of the avian beak. Additionally, multiple independent appearances of bird-like premaxillary dominance are recovered across reptiles, namely in pterosaurs, duck-billed dinosaurs and, within Avialae, enantiornithines and ornithuromorphs. While the gene regulatory networks affecting craniofacial development across tetrapods have been intensively studied, the early moments of morphogenesis from the phylotypic stage remain still obscure, especially within an evolutionary framework including non-model organisms. Immunostaining and confocal imaging of developmental series of model and non-model organisms (9 species including avian and non-avian reptiles) cleared with CLARITY show negative and positive allometry of the prenasal condensation among non-avian reptiles and birds, respectively. The prenasal condensation, and the chondrocranium in general, is therefore acting as a scaffold upon which dermatocranial ossification appear, eventually leading to the strikingly skeletal difference between the avian beak and reptilian face.

## Dunk-and-spin: a dragonfly cooling behaviour

*Samuel Fabian, Alexandra Yarger, Huai-Ti Lin*

Dragonflies are well known for their spectacular repertoire of flight behaviours. Their large, independently controlled wings grant them the ability to both hover and glide. To execute demanding flight manoeuvres, muscles must be maintained at a near optimum temperature. Overheating can lead to temporary paralysis or more serious damage if prolonged. Insects typically use thermotaxis and posture adjustments to regulate body temperature and will sometimes use endothermic controls: modifying hemolymph circulation or flight muscle activity. Gliding reduces muscle activity and can also decrease body temperature without interrupting flight. But how do dragonflies quickly drop their temperature when they are at risk of critically overheating? Here, we characterize a "dunk-and-spin" flight behaviour where dragonflies spontaneously impact water before performing multiple aerial somersaults. Dragonflies often drown if they cannot escape the adhesion of water, so dunking is a rare and high-risk behaviour. This behaviour has been observed previously and hypothesized to facilitate thermal regulation, but until recently, was never recorded. To evaluate the thermal regulation hypothesis, we tested the impact of this behaviour on body cooling and found that dunking can quickly reduce muscle temperature. It can also collect water up to 78% of the dragonfly's body weight that must be shed to maintain flight performance. We demonstrate that spinning is a quick and reliable way to remove excess water from a dragonfly's body.

## A transdisciplinary framework for studying climate change impacts on wildlife health

*Anna Fagre*

As the impacts of climate change intensify, wildlife face numerous threats—both biotic and abiotic in nature. These stressors can drive novel interspecies interactions and exposure to emerging or re-emerging pathogens. While observational field studies and longitudinal population monitoring efforts are invaluable for understanding the scope of these impacts, experimental approaches are essential to disentangling the mechanisms by which these drivers alter wildlife health and immunocompetence, infection susceptibility, and ultimately, resilience to anthropogenic changes. Integration of data from both field and lab requires a highly transdisciplinary approach involving quantitative/computational scientists and those with training in biomedical sciences. I will discuss a framework for ecoimmunological research that leverages a dynamic feedback loop between field and experimental disease ecology, where field results shape laboratory hypotheses and experimental design using captive-bred non-model organisms. These empirical studies allow for identification of diagnostic biomarkers, quantification of pathogen shedding and transmission, and characterization of morbidity/mortality associated with a given stressor. They also permit comparative approaches across species to account for taxonomic differences in life history strategies and physiological traits. Integrating these findings into predictive ecological models can inform both conservation priorities and public health surveillance strategies, enhancing our understanding of the synergistic effects of biotic and abiotic stressors on wildlife health.

## Increasing intramuscular fluid volume increases passive tension in mammalian skeletal muscle

*Samantha Falcone, Richard Marsh, Thomas Roberts*

Prior work has found that intramuscular fluid volume is an important determinant of the passive force that develops during lengthening of amphibian skeletal muscles. Increasing passive tension as fluid volume increases has been attributed to the interaction of intramuscular fluid volume with the collagenous extracellular matrix (ECM) that acts as a sleeve encapsulating muscle fibers, fascicles, and whole muscles. If fluid volume plays a similar role in mammalian muscle, this finding could have implications for human performance. Therefore, we explored this mechanism by exposing isolated mouse soleus and extensor digitorum longus (EDL) muscles to hypotonic solutions promoting fluid uptake. When the muscles were lengthened in 50% hypotonic Ringer's solution, passive force was 55% and 190% greater in the soleus and EDL, respectively, than that found in isotonic Ringer's. The increases in force were accompanied by approximately 17% and 44% increases in muscle mass in the soleus and EDL, respectively. This correlation between increasing fluid volume and passive tension suggests that intramuscular fluid plays a mechanical role in mammalian skeletal muscle, and we can further hypothesize that this effect can be attributed to ECM. The greater increase in passive force and mass found for the EDL compared with the soleus may reflect a fiber type difference in water permeability, as previous work has shown that mammalian fast fibers have more water channels than slow fibers.

## The genetics of sex dichromatism: Seeking answers from a female-polymorphic hummingbird

*Jay Falk, Megan Rothstein, Georgy Semenov, Scott Taylor*

The genetic mechanisms underlying conspicuous secondary sexual traits, such as coloration, remain poorly understood. Identifying the genetic basis of sexual dichromatism is particularly challenging because in dichromatic species, coloration is tightly correlated with the entire sexual phenotype, making it difficult to pinpoint genes that specifically regulate color differences. We studied a unique species that offers valuable insights into these questions, the White-necked Jacobin (Florisuga mellivora). In this species, most females exhibit strikingly different coloration from males (heterochromic), while about 20% of females display male-like coloration (androchromic). This rare occurrence of both sex differences and sex similarities within the same species provides a unique opportunity to investigate the genetic factors underlying sexual dichromatism. We sequenced and aligned whole genomes from 10 males, 23 heterochromic females, and 17 androchromic females. Our findings reveal that a small region on a single gene, BNC2, likely controls color differences between the two female morphs. BNC2 is a transcription factor linked to melanin expression in diverse vertebrate lineages. To explore how BNC2 influences plumage dichromatism, we experimentally transfected chicken fibroblasts with BNC2 and sequenced mRNA expression. BNC2 upregulated an enzyme involved in thyroid hormone regulation, suggesting a potential pathway for sexually dichromatic expression. Sexual variation and polymorphism offer a powerful tool for understanding how selection shapes the genome to produce diverse sexual phenotypes.

## Moving away from memorization: Strategies for organismal biology instruction

*Stacy Farina*

Organismal biology coursework typically requires that students learn a large amount of essential terminology, such as species names, clade names, and anatomical terms. However, students often struggle to memorize these terms, and memorization doesn't always lead to long-term learning, even for students who succeed in the course. I will present a strategy for teaching organismal biology courses with minimal rote memorization. Within a module or unit, assignments can be structured to provide repeated opportunities to work with the terminology in increasingly complex contexts. Auto-grading and large question banks implemented through learning management systems allow students to repeat assignments until they earn their target grade, and assignments can be repeated later for review. I will also discuss a system for allowing repeated attempts for in-person laboratory practicals. Practicals are critical for assessing student knowledge, but they are stressful and memorization-heavy. Mini-practicals that can be taken repeatedly with different sets of questions help assess student learning in the short-term while promoting long-term retention. I will give examples of how I have implemented these strategies in classes such as Comparate Anatomy of Vertebrates and Organismal Biomechanics at Howard University.

## Gonad transcriptomes of both sexes are shaped by recent loss of male parental care in stickleback

*Victoria Farrar, Alison Bell*

Sexual selection for, or against, parental care in a population can shape reproductive physiology and investment in both the caring and non-caring sex. While variation in parental behavior has been associated with neurogenomic differences, fewer studies directly examine how gonadal gene regulation differs as parental strategies evolve. To examine the link between parental strategy and gonadal physiology, we capitalized upon the evolutionary loss of parental care in a population of three-spined stickleback fish (Gasterosteus aculetaus). Typical stickleback males care for offspring after mating, while Nova Scotian male "white" stickleback do not, and instead return to courtship post-fertilization. Female whites also invest less in offspring by producing larger clutches of smaller eggs. We thus hypothesized that white stickleback have higher steroidogenic capacity and sensitivity to activational cues in the gonads. To test this, we generated gonadal transcriptomes from both sexes in a caring and a non-caring population during and after the breeding season (n = 23 males, 20 females). We found differential gene expression between ecotypes and reproductive conditions in both sexes. As hypothesized, candidate genes such as luteinizing hormone receptor and steroidogenic acute regulatory protein (star) were significantly higher in the white population in both sexes. These results reveal potential routes by which selection may act on the gonads of both sexes to shape reproductive strategies.

## Natural history and glue properties of the glow worm *Orfelia fultoni* [Diptera: Keroplatidae]

*Hannah Faye, Sarah Stellwagen*

The larvae of some fungus gnat species in the family Keroplatidae have developed a predatory lifestyle and employ sticky traps to capture prey. Furthermore, several species will also bioluminesce, which is thought to draw phototactic prey into their waiting traps. The larvae of Orfelia fultoni build branching silk webs which are equipped with glue droplets that adhere to prey. O. fultoni are found on the banks near stream beds or around waterfalls in the southern Appalachians and surrounding area as they require habitats with high humidity for survival. Despite being North America's only dipteran glow worm species, there is little known about O. fultoni's biology. In addition to establishing stable laboratory colonies and collecting initial life history data, mating habits, and web-building behavior of O. fultoni, we probed and stretched prey-capture glue droplets produced by wild-caught individuals to investigate the forces generated when droplets are extended. O. fultoni prey capture strategies provide an interesting contrast to other species within the same family that produce sticky "fishing lines" that hang from cave ceilings, but also to other arthropods like spiders, and may potentially have more tractable molecular profiles that can be targeted for biomimetics.

## Asymmetry in community assembly and disassembly rules and its impact on the diversity-disease debate

*Inge Feij, Fred de Boer*

The alarming rate of biodiversity loss worldwide can increase zoonotic disease outbreaks by altering host community structure. Highly competent hosts often persist when biodiversity is lost due to a non-random order of species decline, i.e., community disassembly, generating a dilution effect. While dilution effects are frequently reported in both plant and animal studies, the generality of it is debated. Moreover, it is unclear why we often find a dilution effect in human-disturbed environments but not over natural biodiversity gradients, such as over an elevation gradient. This review therefore addresses the diversity-disease controversy by relating community assembly and disassembly rules to species competence. Species traits play a central role in local extinction and colonization of species in communities. In natural biodiversity gradients, community assembly rules often dominate the process of structuring species assemblages, which generally results in weak biodiversity-disease relationships. In contrast, in human-disturbed environments, community disassembly frequently results in a dilution effect due to the persistence of species with traits associated with high reservoir competence, such as fast life history traits. The differing outcomes of the diversity-disease relationship might thus be explained by asymmetry in community assembly and disassembly processes, and the importance of certain species traits therein.

## From armor to action: mechanically constrained stereotypy in Agonid escape responses

*Avalon Feiler, Philip Anderson*

Biological armor, while crucial for defense, often comes with trade-offs with regards to resource expenditure and reduced flexibility and maneuverability. In this study we aim to investigate how the morphology of bony armor plates found on agonids such as the gray starsnout poacher, Bathyagonus alascanus, impose mechanical constraints on the movement of these fish. More specifically, we examine the escape response with high-speed video capture and analyze how the maximum curvature achieved during c-starts may be explained by the physical interaction between their scales, resulting in stereotypic behavior. Using micro-computed tomography ($\mu$CT) scans, as well as scales dissected from poacher specimens, we can visualize the structure between scales and determine if the form of the rigid bony plates constrain defensive movements. This work enchances our understanding of trade-offs between protection and behavioral flexibility, offering insight into how physical features shape escape strategies in the context of evolutionary pressures.

## Sexual Dimorphism in Vertebral Mechanical Properties of Bonnethead Sharks (*Sphyrna tiburo*)

*Genna Felder, Aubrey Clark, Madisan Biordi, Isabella Fernandez, Marianne Porter*

Elasmobranch (sharks, skates, and rays) vertebrae are composed of calcified cartilage that has mechanical properties like mammalian trabecular bone. Some shark species exhibit sexual dimorphism; for example, male bonnethead shark (Sphyrna tiburo) cephalofoil morphology changes significantly after maturity and their skin is tougher than their female counterparts. The elongation of the rostral cartilage and claspers are hypothesized to occur with hormone changes associated with sexual maturity in males that may have implications for other cartilaginous structures, such as vertebrae. Changes in mechanical properties along the vertebral column of sharks have been documented between species and age ranges; here we examined variations between sexes in juvenile and adult bonnethead sharks to understand the impacts of sex and maturity status on skeletal mechanics. We hypothesized that vertebrae mechanical properties from mature male and female bonnethead sharks will be significantly different due to physiological changes at maturity. Using an Instron E1000, we mechanically tested vertebrae in compression from 20 bonnethead sharks of four groups: adult males (N=5), adult females (N=5), juvenile males (N=5), and juvenile females (N=5). Stiffness (MPa; deformation resistance under force) and toughness (MPa; material's ability to absorb energy) were calculated from stress-strain curves and compared across sex and age groups. This study aims to expand our knowledge of the effects of sex on morphology and biomechanics of cartilaginous skeletons.

## Adaptive evolution of the brain shapes other parts of the cranium in birds

*Ryan Felice, Ryan Marek, Jack Oyston, Taylor West, Andrew Knapp*

The acquisition of a large brain and, in particular, a relatively large cerebrum is thought to have been a key innovation in birds, facilitating the evolution of diverse cognitive, sensory and behavioral traits. Whereas the macroevolution of bird brains has been well characterized, it is clear that the brain does not develop or evolve in isolation. It is expected to have experienced correlated evolution with the other cranial traits with which it shares functions, metabolic resources, and developmental programmes. Here, we ask whether changes in brain shape influence the evolution of the jaw muscles, neurocranium, and eyes. We quantified the morphology of these structures using 3D geometric morphometrics in a broad sample of birds (311 extant and 11 extinct species). Phylogenetic two-block partial least squares analysis recovers significant correlation between each pairwise combination of these traits. We also used the mvSLOUCH framework to compare different hypotheses of the adaptive interactions among these traits. Our most strongly supported hypothesis (AIC weight = 90%) proposes that adaptive evolution in brain shape influences the evolution of the eye, skull, and jaw muscles. Brain and skull adaptation are most closely linked, and there is no strong evidence for trade-offs between the neurocranium and eyes or jaw muscles. Together, this supports the brain as the central diver of cranial evolution suggests a compromise between brains and brawn in bird evolution.

## Ferritin and TRPV1 in Burmese python olfactory tissues

*Lucia Felipe Gonzalez, Sophia Prawiradilaga*

The ability to detect magnetic fields is still debated as it is important for understanding how a diversity of organisms navigate the environment. Since the 1990s, Florida has experienced a Burmese python invasion, which may be expanding beyond southern regions. Our goal is to demonstrate that Burmese pythons are capable of navigation using magnetic field cues and cellular machinery located in special sensory tissues, specifically using mechanosensitive TRPV1 and the iron storage protein ferritin. Interactions between the proteins may be capable of detecting magnetic field changes and relaying such information to the brain, as suggested by recent nanoparticle research. Previous analysis of python tissue suggests that TRPV1 and ferritin coexist in the retina, but distribution in olfactory tissues remains unknown. To test the hypothesis that TRPV1 and ferritin exist in the olfactory system of pythons, tissue provided by collaborators was processed and used with immunohistochemistry and fluorescence microscopy to evaluate presence and distribution. In our preliminary assessments, we observed both TRPV1 and ferritin labeling primarily in the olfactory epithelium. Further microscopic analyses are planned to observe more detail regarding colocalization of the proteins. While pythons are not migratory, understanding the mechanisms that contribute to their movement behaviors is critical to understanding their potential for geographic expansion. Importantly, these results also contribute to the understanding of magnetoreception mechanisms in general, in a variety of species.

## Linking seeing with stabbing: visual information encoded in descending neurons of the mantis shrimp

*Kathryn Feller*

Stomatopod (mantis shrimp) strikes occur faster than the speed of action potentials. Since there is no time for neural feedback, control of this ballistic movement must be completely anticipated. It is currently unknown what type of sensory information is required by such a feed-forward circuit to set and release a strike. Stomatopods are known for having one of the most elaborate and complex visual systems, including three regions in each compound eye focused onto one point in space. This trinocular arrangement is hypothesized to generate monocular range-finding, which may provide key information to the strike control circuit. Prior research established that descending neurons in the ventral nerve cord of the species Squilla empusa 1.) encode the time-to-impact of a projected looming object and 2.) are associated with strike muscle recruitment. These results were reproduced using chronically implanted electrodes and then combined with ocular occlusion treatments to test the link between trinocular information and the encoding of time-to-impact descending neural responses. Complete occlusion of one eye largely ablated responses in descending neurons and strike musculature, though responses returned after the occlusion was removed. This rejects the hypothesis that one eye is sufficient information for monocular range-finding. Instead, depth perception for recruiting defensive responses is most strongly associated with binocular information collected from the dorsal hemispheres of each eye. These findings shed light onto a putative co-evolution of stomatopod eye complexity and strike behavior, two traits conserved among almost all 400+ species of stomatopod.

## Tools and concepts for behavioral and neuroendocrinological investigations of mammalian hibernation

*Ni Feng, Sebin Park, Alexandra Porczak*

Diverse vertebrate species utilize hibernation as an energy-management strategy to survive prolonged periods of resource insecurity. Seasonal hibernation is dependent on extreme and reversible changes in major physiological pathways essential for survival. During hibernation, animals enter weeks-long bouts of "torpor", a state of suspended animation characterized by minimal activity, metabolism, and body temperature. Torpor bouts are punctuated by brief returns to an active-like state called "interbout arousals (IBA)". Thus, hibernation is a complex phenotype relying on the coordination of multiple neural and hormonal pathways. Due to this complexity, it has been difficult to comprehensively describe the proximate mechanisms underlying hibernation. Furthermore, the existence of a continuum of heterothermic phenotypes, from daily torpor to seasonal hibernation across a wide range of vertebrate taxa, makes it difficult to reconstruct hibernation's evolutionary history. Here, we discuss applying modern tools and concepts from neuroscience and computational neuroethology to investigate the dramatic behavioral and physiological changes associated with hibernation. We explore specific examples of conserved vertebrate neural and peripheral organ networks that participate in the regulation of rheostasis in mammalian hibernation. Finally, we consider non-invasive and minimally-invasive methods that can be successfully implemented by small labs at predominantly undergraduate and non-R1 institutions. By applying a common toolkit across species with diverse heterothermic phenotypes, the field can move toward an integrative understanding of hibernation at proximate and ultimate levels of analyses.

## Design of an untethered underwater limbless robot for complex aquatic terrain navigation

*Matthew Fernandez, Tianyu Wang, Galen Tunnicliffe, Donoven Dortilus, Daniel Goldman*

Although robotic undulatory swimming in open aquatic environments has been well studied, principles for the navigation of cluttered hydrodynamic environments are largely unknown. We hypothesized that mechanical intelligence principles [Wang et al. 2023] could apply to subsurface aquatic regimes, and developed an untethered limbless robot (BL = 1m) capable of undulatory swimming. The robot features a bilateral actuation mechanism that models musculoskeletal actuation in many anguilliform swimming organisms. In each joint, we have two cables to control the rotation of a single degree-of-freedom pivot, allowing programmable body compliance. The design also features a compact depth control system inspired by the swim bladder and lung structures found in eels and sea snakes. The mechanism includes a syringe driven by a telescoping leadscrew for water intake and expulsion, granting the robot full depth and pitch control with pressure and attitude sensing. Further, the robot is equipped with fins and a tail attachment giving increased stability and propulsion efficiency. Additionally, each module has an affixed set of acrylic rollers resulting in anisotropic ventral friction, allowing forward movement during seabed locomotion. In robophysical experiments, both in open water and in indoor 2D and 3D heterogeneous terrains, the robot effectively controlled heading and compliance resulting in successful complex aquatic navigation, demonstrating principles of mechanical intelligence and improved capabilities under the synergy of mechanical and computational intelligence.

## Evaluating Aging Markers in Blood: Stable Telomeres and Sex-specific Changes in mtDNA Copy Number

*Anet Filipova, Kimberley Glenn, Tonia Schwartz, Robert Cox, Aaron Reedy*

Life history theory of aging predicts that organisms senesce faster when the probability of survival to an old age is reduced. Telomere length is a widely used biomarker of cellular stress and senescence, though its relationship with age varies across species, individuals and sexes. Mitochondria are crucial for cellular energy production and the number of mitochondrial genomes/cell indicates mitochondrial density. While telomere research in mammals and birds is extensive, sex-specific differences in telomeres and mitochondrial DNA (mtDNA) related to aging in reptiles are relatively unexplored. We studied telomere repeat number and mtDNA copy number in blood from lab-born Cuban brown anoles (Anolis sagrei) across six age classes. In the wild, males have increased mortality and shorter lifespan than females. We hypothesized that telomere length and mtDNA copy number decrease with age, with a faster decrease in males. We found no significant difference in telomere length between age classes and sexes. However, there was a significant interaction between age and sex in mtDNA copy number with an increasing slope in males and a decreasing slope in females ($p=0.018$). Males had more mtDNA than females at ages 3 ($p=0.002$) and 4 years ($p=0.007$). Our results suggest male and female brown anoles experience similar cellular aging processes at the telomere level. However, more mitochondrial genomes/cell in older males might reflect greater mitochondrial function and metabolic demand relative to females.

## How slippery is a shark? External mucus on the smooth dogfish

*Melanie Fischer, George Lauder, Dylan Wainwright*

Shark skin is covered in denticles that provide texture important for locomotion. In bony fishes, mucus covers the outermost layer of skin and scales and modifies both texture and skin hydrodynamics. However, very little is known about the occurrence and effect of skin mucus on sharks, despite the potential for mucus to change both skin texture and function. Specifically, it is unclear where mucus is present across the shark body and whether mucus ever covers the surfaces of denticles, which could alter skin hydrodynamics. To address this question, we obtained smooth dogfish (Mustelus canis) and used profilometry to quantify surface texture at eight body regions under (1) a live anesthetized condition with mucus, and (2) a preserved condition without mucus in the same individuals. We discovered that mucus covers denticles on the dorsal fin tip and trailing edge of the tail tip. At these regions, mucus significantly changed five parameters: roughness, skew, kurtosis, developed interfacial area ratio, and exposed area of denticles. No alteration in texture due to mucus was observed at other locations. Both the dorsal and tail fins shed tip vortices during swimming, so perhaps mucus modifies these complex flows. Shark mucus needs further investigation to better understand the changes that can occur in surface texture due to mucus secretion and to understand how and why mucus is secreted onto the skin surface.

## Making a little splash: Porpoising and plunge diving at an acute angle

*Frank Fish, Sunghwan Jung, Tadd Truscott, Megan Leftwich*

Various aquatic animals, including dolphins, sea lions, and penguins, are capable of repeated rhythmic leaping known as porpoising. In porpoising, the animal emerges through the water surface before becoming airborne and plunging back into the water at an acute angle. To study porpoising hydrodynamics, it is necessary to study movement from air into water at an acute angle. However, studies of plunge diving were restricted to drop tests examining vertical water entry. Test launches of 3D model heads of sea lion and bottlenose dolphin through the interface used a catapult device of a modified speargun. The models were launched at an angle of 38o, which corresponds to the water entrance of porpoising sea lions and dolphins. At initial entry, the face is wetted immediately. A forward directed splash was generated at the water surface from the transfer of kinetic energy on impact. The head of the sea lion displayed a larger splash than the dolphin head. For sea lion and dolphin heads, a ventilation bubble was formed and elongated with further penetration into the water. Difference would be due to the extended beak of the dolphin, which has a lower project area than the face of the sea lion. Compared to a competitive human diver, the marine mammals demonstrate a greater degree of streamlining with less splash and ventilation bubbles.

## Delta winged shaped upper jaw acts as a control surface to stabilize whales during lunge-feeding

*Frank Fish, Sophia Sebo, William Gough, Paolo Segre, Jean Potvin, Keith Moored, Jeremy Goldbogen*

Lunge feeding by rorquals occurs by depressing the lower jaw to inflate a throat pouch to engulf prey along with a large mass of water. As the pouch is below the whale's center of mass, its increased drag generates a downward pitch destabilizing the whale. To counteract this instability, the pectoral flippers and upper jaw can rotate upward to provide lift countering the pitching moment. The upper jaw has a triangular delta wing shape, which resists stalling at high angles of attack (>12o). To examine the influence of the upper jaw, 3D scale models of humpback and blue whales were tested with a six-axis force transducer in a water tunnel at Reynolds number of 210,000 with the upper jaw positioned at angles of 0o, 15 o and 30 o. The elevated upper jaws for both species generated upward pitch. Lift generated by the humpback whale's upper jaw angle at 30o fully compensated for the downward pitch from the increased drag of the depressed lower jaw. The depressed lower jaw increased the drag from baseline by 257.1%, whereas at 30 o the drag from the upper jaw only increased drag by 13.6%. Hydrodynamic analysis demonstrated that the delta shaped upper jaw during lunge feeding could act as a control surface to counter downward pitch from drag of the inflated throat pouch.

## Impact energy propagation in diving bird vertebrae inspired segmented structures

*Claire Fisher, Bart Boom, Thijs Masmeijer, Adam Summers, Ed Habtour*

Biological structures by necessity are often optimized for multi-functionality. Northern gannets (Morus bassanus) have developed the ability to plunge into water at speeds of up to 70 mph in pursuit of fish, surviving high impact loads yet maintaining maneuverability. Their long, slender, and segmented necks are the opposite of current engineered structures anticipated to resist compressive forces. The goal of the study is to emulate impact survivability afforded by this unconventional design by establishing the mathematical and engineering principles behind observed diving bird morphology. We take inspiration from the musculoskeletal system of the gannets' necks to examine the effects of muscle connectivity and initial shape on wave propagation in segmented structures. Our study goes beyond previous engineering investigations of water impact that are limited to single segmentation and simple connectivity. We create a mathematical model to systematically evaluate energy distribution with a focus on the initial shape and complex muscle connections. The model is validated with experimental testing under harmonic and impact excitations. Based on open literature, the findings are the first to show how structures can provide passive control of energy propagation to stabilize structures during impact. Understanding these dynamics allows for engineering of novel multifunctional lightweight structures that passively absorb shock or vibration, allowing maneuverability without compromising performance under compression.

## Epigenetics to the rescue? A case study of genetic rescue in Florida panthers

*Robert Fitak*

Genetic variation is lost rapidly in small, isolated populations, thus reducing fitness. This loss of fitness can be restored, or rescued, via gene flow from a closely-related population. Although this process of genetic rescue is well described, the role of non-genetic factors, such as epigenetics, in restoring fitness and evolutionary potential remain poorly understood. Using an iconic genetic rescue event in Florida panthers as a case study, we examined genome-wide epigenetic (i.e., DNA methylation) patterns from Florida panthers, the Texas pumas that reproduced with these panthers, and their admixed F1 and F2 offspring. We repurposed existing population genetic metrics to quantify epigenetic diversity and population structure, and when possible, make direct comparisons with whole-genome data for the same individuals. We also quantified the intergenerational heritability of the epigenomic markers by specifically sampling replicates of parent-offspring trios. We hypothesized that the genetic rescue event would increase epigenetic variation in similar fashion to that observed for genetic variation, and that a subset of the epigenetic markers would be transmitted across generations and associated with genes of functional significance. Our study is the first empirical examination of epigenetic rescue in a small, inbred population and has critical implications for the future of not just genetic rescue programs but the understanding of the epigenetic landscape and its contribution to phenotypic variation and evolutionary buffering in imperiled species.

## Forest management impacts on bat health: insights from northeast Missouri conservation areas

*Katie Fitzgerald, Marcus Jorgensen, Diana Hews, Cory Suski, Joy O'Keefe*

Forest management practices aim to improve natural landscapes and provide critical habitat, but the effects of management practices on wildlife health are not well understood. This study used non-invasive techniques including hair cortisol, a stress hormone, and body mass, to quantify health in four common bat species in northeastern Missouri. We sampled 208 bats in three non-managed forests and three managed forests, where fine-scale treatments such as girdling, thinning, and prescribed burns were applied. Sampling occurred before and after the application of these treatments, which were implemented in 2022 (sampling 2019–2023). Following forest management practices, Indiana bats from managed areas had significantly lower cortisol than those from non-managed forests, while evening bats and Indiana bats from managed forests also had greater body mass. Post-treatment, adult male red bats exhibited higher cortisol levels than pre-treatment, regardless of management. For big brown bats, body mass and cortisol levels were similar across all sample years and forests. Fine-scale Forest management could reduce stress levels and increase body mass, particularly for smaller bat species like Indiana bats and evening bats, by creating favorable foraging conditions that provide greater access to food resources. Overall, our study suggests that hair cortisol and body condition offer a non-invasive method to evaluate the impacts of habitat alterations on wildlife and provide valuable insights into how forest management practices impact bat health.

## Population genomics in the Hawaiian volcano shrimp: cryptic speciation and mitonuclear discordance

*Cecilia Fitzgerald-Cook, Justin Havird*

Halocaridina rubra is an atyd shrimp found exclusively in Hawaiian anchialine habitats, which are coastal pools with underground connections to both salt and freshwater aquifers. Early sequencing of mt-COX1 suggests that H. rubra is composed of at least eight divergent lineages across the Hawaiian islands. However, mitochondrial loci often have different histories than nuclear loci, and mitonuclear discordance is rampant in phylogenetics. We therefore used 2b-RAD sequencing to examine population genomics of H. rubra. Our preliminary results support these general findings as seven distinct lineages were identified. Within certain H. rubra lineages there is increased admixture, but lineages are genetically isolated overall. There are some cases of mitochondrial and nuclear lineage mismatches, with the lineage corresponding to the minor mitochondrial haplotype (∼15% of individuals) sometimes corresponding to the majority nuclear ancestry (∼85% across individuals). We have expanded on these preliminary data by performing extensive genomic and mitogenomic sequencing on 416 modern and historically collected samples from H. rubra across the range. We aim to uncover signatures of mitonuclear coevolution and mitonuclear genetic incompatibilities leading to reproductive isolation. These data will also allow us to evaluate the impacts of volcanism-induced thermal habitat changes on evolution and plasticity in H. rubra. Finally, our findings have conservation implications for the management of this species and Hawaiian anchialine habitats, which are of cultural importance to native peoples.

## Chasing the Red Queen and sex-biased parasitism in a vertebrate killifish system

*Brooke Fitzwater, Laney Woynaroski, Riley Wood, Eoin O'Hearn, Ryan Earley*

Biparental reproduction is an evolutionary conundrum because it has several disadvantages over uniparental reproduction. Despite this, it is the dominant mode of reproduction among animal taxa, and one hypothesis for its prevalence is that biparental reproduction enables production of genetically variable offspring, some of which might be better at keeping pace with co-evolving parasites. Parasites may also differentially affect the sexes, leading one sex to be more parasitized than the other due to differences in behavior and physiology. We used the mangrove rivulus fish (Kryptolebias marmoratus), an androdioecious killifish species with normally few males and high percentages of self-fertilizing hermaphrodites, to explore the Red Queen hypothesis and sex-biased parasitism. We sampled three populations with high male percentages (Belize) and three with low male percentages (Florida Keys) and conducted parasite surveys on each fish to investigate external and internal macroparasites. We found higher percentages of males in Belize versus the Florida Keys, and parasite diversity but not total parasite number was strongly associated with higher percentages of males in a population. Additionally, we found no sex-biased parasitism broadly but there was variation in sex bias across populations, including both male and hermaphrodite-biases. Our results show evidence for the Red Queen Hypothesis and exemplify how sexes may vary in their parasite susceptibility throughout their range, highlighting the importance of spatial gradients in ecological interactions.

## The genetic control of integration across the cichlid pharyngeal skeleton

*Leticja Flamuraj, Hewan Weldai, Emily Tetrault, Riley Kussmaul, Andrew Conith, Craig Albertson*

The evolutionary success of vertebrates has been credited to the diversification of serially homologous elements, including the pharyngeal skeleton. Stem vertebrates were thought to have possessed a series of uniform gill arches, which diversified in fishes to take on distinct functions, including prey capture, filtering, and processing. However, neither the mechanisms through which the pharyngeal skeleton has diversified nor the developmental constraints operating on the system are known. We explore these questions in East African cichlids and document a surprising level of correlation between pharyngeal skeletal elements, suggesting that this trait complex is more integrated than previously thought. We note further differences in the degree of integration between elements, with the strongest correlation between the oral and pharyngeal jaws and the lowest between the oral jaw and the first gill arch. These data suggest that selection for a common function (e.g., "jaws") and common developmental origins (i.e., NCC) may be limiting diversification of pharyngeal skeletal elements. A similar pattern was observed in a hybrid mapping population, allowing us to determine the extent to which phenotypic integration is reflected by the genotype-phenotype map. Using QTL mapping and qPCR, we identify smad7 as a robust candidate gene driving integration between bones, providing important insights into the mechanisms of diversification and constraint acting on the pharyngeal skeleton.

## Staghorn or stingray? High-resolution network analysis of cartilaginous trabeculae

*Benjamin Flaum, Kira Schmitt, Ruien Hu, Ting Fai Kong, Frederik Mollen, Daniel Baum, Melanie Debiais-Thibaud, Mason Dean*

Sharks and rays possess cartilaginous skeletons supported by a cortex of mineralized tiles (tesserae) encasing the unmineralized core, imparting dynamic compressive stiffness to skeletal elements. In certain hard prey-feeding stingrays, an additional reinforcement exists, hollow mineralized trabeculae coursing throughout the unmineralized cartilage like support beams in a building. We combined high-resolution micro-CT imaging and custom quantitative network analyses in a multi-scale characterization of this trabecular network in a series of cownose rays (Rhinoptera). We demonstrate that trabeculae are highly aligned toward the occlusion surface, thickest near their origins, on the non-occlusal side of the jaw, before branching into smaller struts under the teeth. In the labiolingual direction, the trabeculae are considerably more mineralized under the functional teeth, with those under the forming dentition appearing distinctly wispy in microCT. The upright branching morphology of trabeculae gives the network the appearance of colonies of staghorn coral, with the finer branching near the teeth suggesting trabeculae may compartmentalize the unmineralized cartilage in addition to providing compressive reinforcement. Notably, the interaction between trabeculae and the jaw cortex is complex: trabeculae are also formed by individual tesserae but exposed to the external environment via pores in the cortex. The pores suggest a potential growth mechanism for trabeculae through cortical invaginations into unmineralized cartilage, indicating that trabeculae could provide novel models for understanding factors driving cartilage mineralization, growth and mechanics.

## Shifts in salamander body sizes in response to 60 years of climate change

*Morgan Fleming, Kimberly Sheldon*

Climate change impacts species distributions and abundances and can also affect body size, a fundamental trait that influences energetics, competition, and reproductive success. Many endotherms have exhibited body size declines in response to warming, but research on ectotherms, especially amphibians, remains limited. We examined body size shifts in seven species of Plethodontid salamanders in the Balsam Mountains, Southwest Virginia, USA. These species span a range of habitat preferences, from aquatic to terrestrial environments. We used historical data from 1957-1959 as a baseline and resurveyed salamanders in 2021 and 2023. We then examined the role of temperature and precipitation changes in driving body size shifts over time. We hypothesized that warmer and wetter conditions would lead to body size declines in the salamander species. Over the 60-year period, we found a general increase in temperature and precipitation across the resurvey sites. Contrary to our hypothesis, not all species showed body size declines: some species showed significant reductions in body size, others showed significant increases, and some showed no change over time. These differences may be due to variation in the natural history of the salamanders; body sizes of more terrestrial species declined while more aquatic species increased. These varying responses suggest that the influence of climate change on body size is species-specific and may be driven by a combination of factors, including different habitat preferences.

## Do distributions of host susceptibility reflect the evolution of pathogen specialism or generalism?

*Arietta Fleming-Davies, David Paez*

Pathogen life history strategies vary from specialists infecting a single host species to extreme generalists that successfully exploit multiple taxonomically distant host species. Further specialization occurs as pathogens evolve higher infection of a particular host type or population within a species. We propose that the degree of pathogen specialization or local adaptation can be detected by quantifying the continuous distribution of host susceptibilities to that pathogen, a well-described method in disease ecology. We develop a framework that uses these methods to detect specialist vs generalist life history strategies and local adaptation. First, we assume a Gamma distribution of host susceptibilities to pathogen infection and consider this model for three cases: 1) pathogen specialism and local adaptation, 2) non-specialism and local maladaptation, and 3) a pseudo-generalist pathogen. We then present examples from two empirical systems of animal viruses: an NPV infecting the butterfly species Dione vanillae, and

IHNV in salmonid fish. In both empirical systems, we found that pathogen specialism on certain host populations or species resulted in relatively higher values of heterogeneity in susceptibility estimated across the entire host range. Thus, the signature of a generalist strategy resulting in more consistent infections across variable hosts is present in these models. Identifying how parameters in well-established disease ecology models reflect evolutionary change will help us better understand evolutionary impacts on real time ecological host-pathogen interactions.

## Testing the species hypothesis of Fundulus escambiae

*Adania Flemming*

The most recent evaluation of Fundulus nottii, the Bayou Topminnow, reports that it occurs in several river drainages in the panhandle of Florida. However, recent re-identification of the morphology of those specimens, with only one exception, suggests that these represent the similar Russetfin Topminnow, Fundulus escambiae, which is common throughout the panhandle. Though the two species are typically distinguished by color pattern, they are otherwise morphologically similar which makes them difficult to separate through typical morphometric measurements. Because Fundulus notti and Fundulus escambiae are currently recognized as sister species, the objective of this study was to determine whether Fundulus escambiae is a genealogically distinct lineage from Fundulus nottii. Assuming Fundulus notti and Fundulus escambiae are valid species we sampled species across their known range and hypothesized that the genetic data would support two reciprocally monophyletic groups that are in line with the current taxonomy. To test our hypothesis, we utilized phylogenetic analysis of DNA sequence data, created a haplotype network and completed analysis of morphological characteristics. Our data showed that the species hypothesis of Fundulus notti and Fundulus escambiae was not supported by either the morphological or genetic data. Thus, we reject our hypothesis and refute that these are not two reciprocally monophyletic groups. Fundulus escambiae is a monophyletic group nested within the genetic diversity of Fundulus nottii.

## Student-focused, career-driven, exploration in natural history museums via experiential education

*Adania Flemming*

Being immersed in the processes of research can develop undergraduate students' science identities and support their persistence in pursuing science careers. However, it can be difficult for students to find opportunities for engaging in authentic scientific research. The professional staff and scientific objects in natural history museums provide such an opportunity that can create relationships through which both undergraduate students and museums benefit. Students require authentic practical experiences to better understand their academic fields and career trajectories, and museums require assistance curating and managing collections. This can be accomplished through mentorship, training, and research experience in a formal course. At the University of Florida, I developed and taught a course that engaged students in projects in museum collections. Discussion sessions replaced lectures by introducing topics such as the concept of research, distinction between predictions and hypotheses, understanding of the nature of science, and how to conduct literature reviews. In 2019 and 2020, students completed a pre- and post-course survey to gauge their understanding of science and their anticipated career trajectory. My results demonstrate that mentorship and authentic experiential science opportunities using museum collections enable students to realize a passion, sense of purpose, and better understanding of science and careers in science. During this presentation I will share the model of the course and its potential to help broaden representation in STEM.

## Effects of PFUnDA exposure on dopaminergic system and thyroid axis development in Japanese medaka

*Allison Fletcher, Ashlynn Peszko, Dianne Baker*

Per- and poly- fluoroalkyl substances (PFAS) are environmental pollutants, and many short chain variants are known endocrine and nervous system disrupters. However, less is known about the effects of long chain variants, such as perfluoroundecanoic acid (PFUnDA). We hypothesized that PFUnDA disrupts the development of the dopaminergic system and thyroid hormone axis. To test this hypothesis, pools of Japanese medaka embryos were exposed to either control water, 0.01 $\mu$g/mL, or 0.1 $\mu$g/mL PFUnDA. After treatment, RNA was isolated from homogenized pools, and cDNA was synthesized from each sample. Subsequently, qRT-PCR was used to measure RNA transcript levels of genes encoding factors essential in the dopaminergic system (dopamine receptors, dopamine transporter protein, and tyrosine hydroxylase), and thyroid hormone axis (thyroid stimulating hormone subunit $\beta$, deiodinases, sodium-iodide symporter, thyroglobulin, and thyroid hormone receptor). We found that DIO1 transcript levels increased nearly two-fold after embryonic exposure to 0.1 μg/mL PFUnDA, compared to control and low-concentration exposures ($p < 0.01$). Additionally, trends for increased transcript levels of TH, DAT, and DRD2 were found. However, transcript levels of all other genes were not significantly altered ($p > 0.05$). While this study provides some evidence supporting the hypothesis that PFUnDA can disrupt the thyroid system, further testing on the effects of PFAS may reveal more about their potential disruptions to the dopaminergic and thyroid systems.

## Steering multilegged robots by body undulation modulation

*Esteban Flores, Daniel Soto, Dan Tatulescu, Christopher Pierce, Daniel Goldman, Baxi Zhong*

Characterized by their segmented elongate bodies and relatively simple legs, centipedes exhibit great maneuverability in various environments. With similar morphological characteristics, their robotics counterparts also demonstrate effective terrestrial locomotion (Chong, et al.,2023). However, the success of multi-legged robots is largely limited to forward locomotion: turning is substantially less studied partially because of the challenges in modulating their many yet diverse body joints. We used a comparative approach to study turning in elongate locomotors including two model elongate animals, nematodes (Caenorhabditis elegans) and centipedes (S. subspinipes). Our prior work reconstructed nematodes turning as the superposition of two traveling waves in body curvatures (Wang, et al. IROS 2020). We investigated whether a similar approach could be useful in centipede locomotion. In preliminary trials, we recorded the midline trajectories of centipedes turning (2 individuals, 24 trials) using high-speed cameras. Centipede kinematic analysis also identified two active traveling waves during turning. To evaluate the turning strategy, we conducted robophysical (10 legs, body length=1m) experiments. Variation in amplitude (0 to 20 degrees) and spatial frequency modulation (0 to 0.5 waves) result in different types of turns and thus enable control over the angular (0 to 20 degrees) and translational (.28 to .38 body length) displacement. Our two-wave turning template serves as a hypothesis for such behaviors in elongate, multi-legged animals.

## Characterization of data deficient fisheries in Nigeria: The MISS ICONIC approach

*Omolara Fola-Matthews*

Data-deficient fisheries in Nigeria pose significant challenges for the conservation and management of shark populations. This study applied the Integrated Coordinated Open Network Inclusive Conservation (ICONIC) approach to address these challenges. Shark specimens collected along the Nigerian coastline (5°57'N to 6°27'N and 3°23'E to 4°54'E) from both bycatch and targeted catches by artisanal fishermen. The species frequently encountered include Rhizoprionodon acutus (milk shark), Mustelus mustelus (common smooth hound), and Sphyrna lewini (scalloped hammerhead). Biometric data and biological samples were collected using standard protocols. Stable isotope analysis was employed to investigate dietary variation within and among species, providing insights into their diet and trophic ecology. The morphology of the sensory systems on the sharks' head, including the Ampullae of Lorenzini (AOL), was examined using Scanning Electron Microscopy (SEM) to understand physiological adaptations specific to each species. Reproductive information was collected to analyze maternal investment and life history traits to provide insights into its reproductive strategies. DNA barcoding was utilized for precise species identification. Additionally, coastal communities were engaged in outreach activities aimed at raising awareness and educating fishers on sustainable shark fisheries thereby, integrating traditional knowledge with contemporary conservation practices. This integrated approach seeks to address critical data gaps, foster sustainable fishing practices, and enhance the conservation of shark species in Nigeria's coastal waters.

## Improving shark knowledge through conservation education and capacity for fisherfolks in Nigeria

*Omolara Fola-Matthews, Oladimeji Obidairo*

Nigeria lands a significant number of sharks every year through target fishing and as by-catch despite this, there is a dearth of information on the use of educational approaches for shark conservation. This pilot outreach program aimed to engage local fisherfolks in a collaborative effort to protect shark populations by sharing scientific insights and gathering valuable local ecological knowledge (LEK). Seven coastal communities in Lagos and Ondo states, Nigeria were visited between January-June 2024. Semi-structured questionnaires were prepared in local dialect to obtain information from fishers. A minimum of 150 respondents were interviewed per community. From the survey, 27% of the fishers were aware of conservation concerns for some shark species landed, 12.5% had noticed the impact of climate change in the movement and catch trends of sharks in the region and none knew the ecological role of sharks in the ecosystem. Through interactive workshops, we discussed the role of sharks in regulating fish populations, shark identification and the importance of citizen science data to enable data collection across large geographical areas over extended periods. In exchange, we collected LEK from the fisherfolks, tapping into their extensive experience and observations of shark behaviors and populations. This reciprocal exchange of knowledge will not only enrich scientific research but also empower local communities to take an active role in conservation efforts.

## Designing bioinspired robotic flowers that incorporate both attractant and deterrent floral signals

*Joshua Foley, Skylar Mathieson, Melissa Whitaker*

Artificial flowers have long been used in pollinator research to understand and manipulate salient floral features such as nectar rewards and floral display. Recent years have seen many technical developments in robotic flowers, largely due to the increased availability of 3D printing technologies, accessibility of single board computers and microprocessors such as RaspberryPi and Arduino models, and affordable camera and sensor modules. However, despite their flexibility and modularity, the majority of robotic flowers are focused on understanding how pollinators make foraging decisions based on floral reward, with little attention paid to the otherwise rich information landscape that pollinators use to decide which flowers to visit. We have developed robotic flowers that provision artificial nectar and automatically record pollinator feeding times, largely based on pre-existing robo-flower designs, but with the addition of two forms of aversive stimuli that can be implemented together or separately: nociceptive heat and a mock predator. We are currently using these robo-flowers to study pollinator motivation for specific chemical reward compounds by measuring pollinators' willingness to tolerate uncomfortable, painful, or threatening experiences to receive a floral reward. These stimuli were designed to provide more nuanced insight into the information tradeoffs that feature in pollinators' foraging decisions, but the designs could be broadly useful for researchers interested in understanding insect nociception, decision-making, and apparent predation in the context of plant-pollinator interactions.

## Boneyard birds: avian use of cemetery spaces in relation to grave marker style

*Sarah Foltz*

The ubiquity of cemeteries and their common incorporation of lawns and other vegetation in North America creates a common but unusual type of greenspace that may serve as a refuge for urban wildlife. These areas often have relatively little daily human activity and also include unique structural features that set them apart from other urban greenspaces. We investigated how multiple species of songbirds interact with a unique feature of cemeteries, grave markers. Though most cemeteries contain abundant markers, marker size and shape are highly variable both within and between cemeteries. Observations were conducted in July and August 2024 in an urbanized area of southwest Virginia. We compared individual birds' interactions with grave markers across species as well as across types of markers and also measured bird activity in areas with predominantly flat, homogenous markers vs. areas with upright and more heterogeneously-shaped markers. While analyses are on-going, we expect to find that species differ in their use of upright vs. flat markers and the areas that contain them. The results of this study deepen our knowledge of how cemeteries may support urban wildlife, and in particular how grave marker preferences and landscape design can influence local biological communities.

## Exploring the host-microbe interactions that mediate ectotherm fitness under global change

*Samantha Fontaine*

Organisms vary in their responses to global change ranging from precipitous declines to thriving in novel environments as invasive species. Variation in host fitness can be generated by differences in host traits but could also be related to the function of host-associated microbial communities. Here, I present my work studying the role of the microbiome in facilitating host responses to changing environments in ectothermic vertebrates—animals with environmentally-sensitive physiologies that are threatened under global change. First, I will discuss my work on microbially-mediated thermal tolerance in amphibians. I have shown that experimentally manipulating the microbiome of larval amphibians reduces the host's tolerance to both heat and cold and reduces animal fitness under heat stress. Gene expression data suggests these results could be related to nutritional provisioning by microbes during warming. This work demonstrates that interactions between hosts and microbes should be considered when predicting ectotherm responses to changing climates. Next, I will discuss my recent work studying the microbiome's role in facilitating invasion of novel habitats. Specifically, I have created the first germ-free lizard model in an invasive species and have demonstrated microbial colonization-dependent effects on lizard development and morphology. Future work will use this model to test if microbiomes from invasive populations facilitate host phenotypic plasticity and fitness in new environments.

## Hydrodynamics of prey capture in the lobate ctenophore Mnemiopsis leidyi

*Mitchell Ford, Sean Colin, John Costello*

Lobate ctenophores such as Mnemiopsis leidyi are voracious predators of marine zooplankton, forming critical links in costal and oceanic food webs. As the global shipping industry has grown over the past century, Mnemiopsis has invaded costal waterways worldwide, unbalancing ecosystems. Their invasive success is in part due to their stealth as predators. Hydrodynamically inconspicuous feeding currents are generated by beating cilia on the auricles, which draw flow between the lobes and towards the tentillae and mouth. Sessile and slow-moving prey are easily captured on the tentillae but larger, more nutritious prey such as adult copepods often attempt to escape following an initial approach or contact with the oral lobes. However, Mnemiopsis is often able to anticipate these attempts and closes the oral lobes to surround the prey and prevent its escape. In this study, we assess the prey sensing capabilities of Mnemiopsis by measuring the 3D positions and orientations of copepod prey when the ctenophores begin closing of their oral lobes in anticipation of an escape attempt. Additionally, we examine the fluid dynamic wakes of Mnemiopsis using 3D particle tracking velocimetry both with and without the presence of copepod prey in order to determine how the presence of large prey affects swimming behaviors.

## Reduced pore area in zebra finch eggs leads to dark heart coloration regardless of sex

*Ada Forester, Wonil Choi, Haruka Wada*

As climate change runs rampant, wildlife becomes forced to endure the brunt of its effects. Distinctly, ectothermic species suffer extreme consequences from increasing surface temperatures. While adult birds are endotherms, avian embryos exhibit ectothermic phenotypes that make them especially vulnerable to elevated ambient temperature. These embryos grow inside hardshell eggs where the gas exchange takes place exclusively through the pores of the shell, which are fixed at oviposition. Previously, we have shown that limiting availability of the eggshell pores results in edema formation in zebra finch (Taeniopygia guttata castanotis) embryos. Here, we tested the hypotheses that 1) female embryos are more susceptible to edema formation under hypoxic condition, and 2) severity of edema is related to darker heart color, an indicator of low oxygen levels. To test the hypotheses, we covered 30% of the eggshell surface with beeswax and quantified brain mass relative to the body of the embryos, assessed heart coloration, and sexed the embryos. Our results indicate that both sexes were equally susceptible to edema formation when available pores were reduced, and that heart color was correlated with edema formation.

## Beauty in the fish brain: neuroanatomical insights into physiology and behavior

*Paul Forlano*

The outstanding body of work from Dr. Karen Maruska's career exemplifies the power of a highly comparative and integrative approach using fish model systems to uncover fundamental principles in the neurobiology of behavior. Trained as a neuroethologist, Karen's prolific career showed extraordinary mastery in a diverse range of scientific approaches including neuroanatomical, electrophysiological and gene expression tools to study sensory systems and neuroendocrine regulation of social behavior in the context of a changing environment. Karen was both a brilliant scientist and artist and these traits were expressed not only in the rigor of her research, but especially when she studied brain function anatomically. In the spirit of our shared training and scientific philosophies, this talk will focus on neuroanatomical approaches that have revealed novel insights into hormone-driven plasticity of the auditory system and the neurochemical substrates of acoustic-related reproductive behavior in a vocal fish.

## Characterizing ovarian gene expression along steroidogenic pathways in a wild territorial songbird

*Josephina Fornara, Elizabeth Aguilar, Emily Levy, Kimberly Rosvall*

It is common to measure hormone concentrations in blood or other tissues and ask how hormonal variation relates to behavioral variation, as a window into the proximate mechanisms of behavior. It is less common, however, to measure all of the steps along the pathway of hormone production. Sex steroid synthesis, for example, occurs in reproductive tissues and involves interconversion of multiple hormones from an initial cholesterol molecule. Here, we used transcriptomic assays (qPCR) to measure production of steroidogenic enzymes in ovarian tissue, and we asked how these physiological parameters relate to behavior. Specifically, we measured female-female aggression in tree swallows (Tachycineta bicolor) during the early spring when they have just established their territories. We then collected ovaries from a subset of females with consistently high or consistently low aggressiveness. In the lab, we measured the abundance of mRNA transcripts for six steroidogenic enzymes. Preliminary results indicate females with similar aggression scores exhibit substantial variation in ovarian gene expression; this variation is particularly noticeable among highly aggressive females. Forthcoming results will illuminate how variation in gene co-expression may contribute to stable differences in complex social behavior.

## Identifying microplastics in the diets of cavity-nesting songbirds

*Sage Forsythe, Victoria Moreira, Megan Fork, Jennifer Uehling*

Anthropogenic activity has consistently increased the prevalence of plastic within terrestrial and aquatic environments. Over time, plastic degrades and produces microplastics. Wildlife faces an increasing risk of ingesting these small plastic particles, which may be harmful to their health. Yet, little is known about how consumption of different diet items might relate to microplastic exposure. We studied breeding tree swallows (Tachycineta bicolor) and Eastern bluebirds (Sialia sialis) in southeastern Pennsylvania, USA to determine if microplastics are being ingested by these species, and if so, how many and what types. To measure microplastic ingestion, we will extract microplastics from fecal samples collected from nestlings during early and late provisioning. We will use microscopy to identify and quantify any microplastics present. We expect to find microplastics in these fecal samples, considering the widely reported ubiquity of microplastics in the environment. We anticipate tree swallows will have more microplastics in their feces due to their consumption of aquatic insects, as we expect microplastics to bioaccumulate from aquatic ecosystems to the birds. Eastern bluebirds, on the other hand, consume terrestrial arthropods, which may not show similar bioaccumulation patterns. Microplastics may negatively impact animal health and fitness, and quantifying microplastics in the diets of cavity nesters allows us to assess the possible risks these pollutants may pose to songbirds, which are largely declining across North America.

## Comparative intramandibular biomechanics of alligator, majungasurus, and tyrannosaurus

*John Fortner, Kaleb Sellers, Kevin Middleton, Casey Holliday*

In archosaurs and many other tetrapods, the intramandibular joint (IMJ) separates the rostral, dentigerous bones from the caudal, jaw adductor-bearing bones, potentially creating an inherently flexible “weak spot” that constrains mandibular performance. Archosaur IMJ form may reflect its mechanical function in resisting or facilitating excursion, as they modified IMJ articulations to build more robust, or more flexible, mandibles for feeding. We assessed form-function relationships of the archosaurian IMJ by comparing two carnivorous, nonavian theropods – the putatively kinetic Majungasaurus and putatively akinetic Tyrannosaurus – and the extant, akinetic crocodilian Alligator. We built finite element models of their mandibles with IMJs to assess joint surface area, joint excursion, and joint energy density. Majungasaurus possesses lower articular:non-articular surface area ratios, greater dorsoventral and mediolateral joint excursion, and higher joint energy densities than either T. rex or Alligator. Joint excursion and energy density also show greater sensitivity to differential muscle activity – particularly mIM – in Majungasaurus. Our results suggest greater flexibility for Majungasaurus’ IMJ due to its comparatively low intramandibular articular surface area, with mIM maintaining joint coherence by limiting excessive excursion. In contrast, T. rex and Alligator have reduced IMJ flexibility by increasing articular surface areas, with the dorsoventrally taller mandible of T. rex further optimizing it against dorsoventral forces, though its poor performance against mediolaterally-directed forces suggests that Alligator-like thrashing was not possible.

## Neural correlates of increased aggression in an urban songbird: A focus on arginine vasotocin (AVT)

*Taylor Fossett, Samuel Lane, Isaac VanDiest, Sakshi Kaul, Veronica Cole, Elizabeth Gilbert, Kendra Sewall*

Urbanization drastically alters the environment, presenting wildlife with novel challenges to which they must adapt. An animal’s first response to novel environments is to shift behavior, which requires processing environmental cues into neural signals that alter behavior. Urban song sparrows (Melospiza melodia) face greater competition for territories and are therefore more aggressive than their rural counterparts. However, the neural mechanisms underpinning behavioral responses to urbanization are unclear. Arginine vasotocin (AVT) is involved in the regulation of sociality, including aggression. Prior work showed that AVT peptide is more abundant in the paraventricular nucleus of the hypothalamus and bed nucleus of the stria terminalis in urban male songbirds compared to rural. Importantly, social behavior is influenced by both AVT receptor availability and activity, making it critical to compare receptor distribution and expression between urban and rural birds. We localized AVT receptor (R) 3 throughout the brain of urban and rural male song sparrows and compared mRNA expression of AVT, AVT3R, and AVT4R in the hypothalamus following simulated territorial intrusion. Rural males trended towards having more AVT3R transcripts in the lateral septum compared to urban males, but did not differ in other brain regions. Additionally, urban males trended towards higher hypothalamic AVT and AVT3R expression when compared to rural birds. Thus, both AVT peptide abundance, and receptor distribution and expression, are implicated in higher aggression in urban male song sparrows.

## Stepping up a Notch: insight into cell signaling evolution with the ctenophore, *Mnemiopsis leidyi*

*Brent Foster, Fredrik Hugosson, Cezar Borba, Mark Q. Martindale*

Communication between cells was a crucial step in the evolution of multicellular animals. The canonical Notch pathway is a classical juxtacrine signaling cascade best known for its role in maintaining potency in progenitor cells, driving specification and differentiation, and establishing tissue boundaries. Recently it has been proposed that the canonical Notch function emerged through the co-option of existing signaling pathways during the Metazoan lineage, suggesting that the ancestral Notch had an as-of-yet uncharacterized non-canonical function. To clarify this ancestral function, we turned to an early-branching Metazoan, the ctenophore Mnemiopsis leidyi. Despite genomic evidence that M. lediyi has many components of the canonical Notch pathway, no study has considered the cellular context of these components during ctenophore development, nor has any group examined potential non-canonical Notch functions within ctenophores. We address this knowledge gap by characterizing putative MlNotch transcripts via in situ hybridization studies. Our data show that MlNotch and many of its potential regulators are transcribed in highly proliferative zones during ctenophore development, hinting at a possible role in maintaining progenitor cell populations. We are also evaluating intracellular MlNotch functions and attempting to identify potential binding partners and downstream signaling targets. Finally, we have begun troubleshooting knockdown techniques to examine developmental phenotypes resulting from MlNotch perturbations. These characterizations offer insight into how cell-cell signaling in animals may have emerged and evolved.

## The physiological responses of Exaiptasia pallida under different light and feeding conditions

*Ivy Foster, Kate Lloyd, Colleen Bove*

Exaiptasia pallida is a tropical sea anemone that serves as a model organism for many symbiotic cnidarian species because of their shared characteristics, including their symbiotic relationship with algal endosymbionts from the family Symbiodiniaceae. Additionally, like tropical corals, E. pallida are known to reproduce both sexually and asexually in their natural environment. Exaiptasia pallida favor asexual reproduction in laboratory settings and attempts to induce spawning in the lab have yielded limited results. Exaiptasia pallida reproduce asexually through a process known as pedal laceration, where a part of the parent pedal disk breaks off to produce a genetic clone of the parent anemone. Previous work suggests that feeding regimes and symbiont density influence rates of asexual reproduction. However, these factors may have contradictory impacts, including lower rates of pedal laceration when provided increased opportunity for heterotrophy and higher rates of pedal laceration with increased symbiont density. Here, we explore the effects of light availability and heterotrophy on the reproduction, growth, and physiology of Exaiptasia pallida anemones. Based on previous work, we anticipate that anemones with higher symbiont density (high light) with no supplemental feeding will exhibit the highest rates of asexual reproduction. Overall, these results will aid our understanding of how access to nutrients can impact asexual reproduction in symbiotic cnidarians, such as tropical corals.

## Morphogenesis of the ribs and intercostal muscles with implications for turtle body plan origins

*William Foster, Paul Gensbigler, Tyler Lyson, Gabriel Bever*

The shelled-body plan of turtles represents an iconic model system where the evolutionary potential of morphogenetic mechanisms is revealed through the integration of phylogenetic, fossil, and developmental data. A prominent, unresolved question is whether the carapacial ridge—a unique turtle signalling center—is responsible for patterning both the axial arrest of the ribs (ribs remain outside the lateral plate) and the rib widening that constitutes the structural basis of the upper shell. The presence in the earliest stem turtles (Eunotosaurus and Pappochelys) of apomorphically widened ribs that also enter the ventral body wall suggests the carapacial ridge was not originally responsible for both transformations and that other mechanisms must have been involved. Here we begin exploring the hypothesis that the intercostal muscles play an unrecognized and fundamental patterning role. We use multiple imaging modalities to describe the morphogenesis of Trachemys ribs and intercostal muscles with unprecedented temporal and spatial resolution. Results confirm that turtles plesiomorphically develop intercostal muscles, and that these muscles are primary to rib skeletogenesis. The subsequent breakdown and removal of these muscles represents a derived dynamic extremely rare outside indirect developing lineages that reconfigure their body plan at metamorphosis. Experimental testing awaits, but it may be that a removal of intercostal muscles liberated later-stage ribs from their primitive signalling environment, allowing them to develop and evolve along new, turtle-unique trajectories.

## Size of one egg drives that of another: evidence for performance-based feedback in a wild bird

*Nicolas Frasson, Keith Sockman, Emma Reinhardt*

An egg's size should reflect the net benefit of its production, which itself should vary with the environment. Although the environment is often complex, performance-based feedback from the size of an initial egg could signal the cumulative effects of the environment and enable females to optimize size of subsequent eggs, as a recent model and experiment support. However, that experiment could not rule out the role of size-correlates in providing the signal. We conducted an experiment on wild, free-ranging Lincoln's sparrows (Melospiza lincolnii), in which we substituted the first-laid egg—on the day it was laid—with an artificial egg from one of two groups that were identical except in size. The large substitutes drove production of a subsequent egg that was larger than the small substitutes yielded. This study shows that size of an egg is a cue for size-modulation of a subsequent egg and is consistent with predictions from a previous model on performance-based feedback but not with other explanations, such as the minimization of within-clutch egg-size variation. The results here show a facility for the rapid modulation of an egg based on the size of a previous egg, and they further raise hypotheses for how performance-based feedback may play a role in a diversity of organismal processes.

## The escalator to extinction in tropical mountains

*Benjamin Freeman*

Species are on the move as temperatures get warmer and warmer. In this talk, I will present evidence that warming temperatures have set in motion an "escalator to extinction" for tropical montane organisms. I will then describe what we know about the mechanisms that set the "escalator" in motion, arguing that endotherm range shifts are driven more by species interactions than by physiological stresses imposed by climate change. I will conclude by highlighting key unanswered questions and how an integrative approach is necessary to solve these pressing questions.

## Higher temperatures lead to faster development of innate immunity in House Sparrow nestlings

*Hailey Freeman, Emily Regier, Angela Riley, Sarah Brown, Elizabeth Cochrane, Jennifer Grindstaff, Lindsey Willingham, Heather Mathewson*

Altricial young require parental care for survival and are sensitive to environmental fluctuations, especially temperature changes. Incubation and the nestling period are critical time points for physiological and immunological development. During incubation, higher incubation temperatures result in greater innate immunity. However, it is unclear how ambient temperature affects immune function in the nestling period. The objective of this study was to understand how offspring immune development is influenced by temperature during both the incubation and nestling periods in wild House Sparrows (Passer domesticus). Nest box temperature was measured using iButtons placed inside the nest box on the door and parental behavior was recorded during incubation and the nestling period. During the nestling period, we collected morphological measurements on days 2, 6, and 10 post hatching, and blood samples on post hatch days 6 and 10 to measure bacterial killing ability. Individuals that experienced higher average temperatures in the incubation or nestling period exhibited greater bacterial killing ability, a measure of innate immunity. Faster development of innate immunity in higher average temperatures could be caused by parents spending more time incubating and brooding, resulting in faster nestling development. Alternatively, higher ambient temperatures may allow parents to reduce the amount of time spent brooding nestlings and spend more time feeding, resulting in faster nestling development.

## A meta-analysis of the interactive effects of heavy metal exposure and heat stress

*Alanna Frick, Alex Gunderson*

Understanding how organisms respond to multiple stressors is essential for predicting and mitigating the impacts of anthropogenic global change. I conducted a meta-analysis to explore the combined effects of heavy metals and heat on biological function across terrestrial and aquatic organisms. I synthesized data from published studies that included responses in traits such as growth, development, and physiological performance. Common metals included in the analysis were copper, cadmium, lead, and zinc. I found a predominance of synergistic interactions between heavy metals and heat (82%), indicating that their combined impact often exceeds the sum of their individual effects. This finding indicates that predictions based solely on the effects of heat or heavy metals in isolation could underestimate the true impact of global change on biological systems. However, most studies employed simultaneous exposure to metals and heat (67%) without a clear basis in real-world dynamics, which may bias the results towards synergism. Future studies should incorporate more ecologically realistic dynamics between heat and metal pollution to better understand their effects in nature. If multiple stressor interactions are ignored or their dynamics are not carefully considered, we may inaccurately predict the extent of biological disruption caused by global warming and pollution, potentially leading to ineffective or misguided mitigation strategies.

## Neural substrates of aggression and the effect of sex in domesticated and wild-derived mice

*Caitlin Friesen, Sara Guedez Suarez, Geert de Vries, Aras Petrulis*

Aggressive behavior plays a critical role in acquiring and defending resources needed to reproduce and survive. Patterns of aggression can vary across species, individuals, and contexts, but underlying neural mechanisms are often highly conserved across taxa. The vasopressin system regulates aggressive behavior and exhibits sex-dependent effects, largely mediated through its actions on the vasopressin 1a receptor (V1aR) within the social brain. In wild populations, evolutionary pressures can mediate sexually differentiated patterns of aggressive behavior, but decades of inbreeding have largely eliminated female aggression from mouse strains commonly used in laboratory research (e.g., C57BL/6). Consequently, most research has focused on males or females displaying maternal aggression, while the neurobiology of aggression in nulliparous females is poorly understood.

In wild-derived mice, both sexes exhibit robust displays of aggression. To test the effect of sex on aggression and the vasopressin system, we will compare agonistic behavior of male and female inbred (C57BL/6) and wild-derived mice during behavioral assays and examine patterns of vasopressin and V1aR expression, as well as immediate-early gene activity (c-Fos), across multiple brain regions. Given sex-specific evolutionary pressures, we expect that brain circuit activation will differ between sexes in wild-derived mice, and between wild-derived and inbred females. This research will further our understanding of the sexually differentiated patterns involved in aggressive behavior and the underlying neural mechanisms in both sexes.

## Influence of urbanization on developmental instability and endurance in the Common Wall Lizard

*Audrey Friestad, Donald Miles, Eric Gangloff*

There is increasing awareness that urban areas may support a diverse array of animal species. One area of interest is how “urban exploiter species” adapt to novel stressors. Many species inhabit urban green spaces that experienced chemical spills, refuse and other pollutants. Developmental instability (DI) is defined as a random deviation from bilateral symmetry and is a well-known stress indicator in many taxa. In this study, we investigated whether lizards from areas with different levels of human impact exhibit signatures of stress. We captured Common Wall Lizards (Podarcis muralis) from three sites in Cincinnati, Ohio: an area adjacent to a rail yard, an urban college campus, and a forested park. We measured endurance to determine whether lizards from industrial urban sites show a decrease in physiological performance compared to lizards from forested areas. We measured endurance by chasing lizards around a circular racetrack until exhaustion. We assessed DI by measuring the fluctuating asymmetry (FA) of a meristic trait (femoral pores) and the FA in head shape using geometric morphometrics. Preliminary analyses indicate that the lizards from the rail yard had higher endurance than those from the park, but this difference was not statistically significant. By understanding the effects of urban stressors on an introduced species, we hope to translate our knowledge to aid in the conservation of native reptiles facing urbanization.

## Finding Nemo’s colors: the ecology of clownfish color patterns

*Catheline Froehlich, Eleanor Caves, Jolyon Troscianko, Miranda Gibson, Tommaso Chiodo, Aurélien De Jode, Korrie Brown, Nina Luckas, Benjamin Titus*

Convergent evolution is a fascinating rule of life that governs the emergence of many phenotypic traits. However, the function of convergent phenotypes is often inferred without detailed study of the ecological conditions under which these traits evolved. Whether the underlying ecological conditions also converge will greatly improve our inferences regarding the adaptive function of convergent phenotypes. A compelling model for studying the ecology of convergent phenotypes is the color pattern of Amphiprion clownfishes. Three distinct color patterns have converged based on their anemone host use: orange with one bar (Radianthus magnifica specialist), red with one bar (Entacmaea quadricolor specialist), and black with multiple thick bars (host generalist). Yet the adaptive functions of clownfish color patterns are unknown. Here we conduct an integrative study of clownfish color patterns, behavior, diet, and microbiome in relation to their anemone hosts. We find that color pattern phenotypes for specialists align with color matching to their hosts, movement behavior within reach of their hosts, and diet via stable isotopes remaining similar regardless of locality. We suggest that camouflage is the likely function of specialist color patterns. In generalists, which largely do not background match, stay far away from their hosts, and alter their diet based on local sources, we suggest that aposematism or motion dazzle is the likely function of their color patterns.

## Burrowing in Atlantic hagfish (Myxine limosa)

*Douglas Fudge, Charlene McCord, Cassandra Donatelli, Noah Bressman, Kennedy Guillen, Josh Lee, Luke Arnold, Keolani Kahale-Lua, Christian Quinteros, Peter Ly, Larissa Atkins*

Myxine limosa is a burrowing species of hagfish that occurs in muddy areas of the western north Atlantic at depths generally greater than 100 meters. While M. limosa are known to burrow, little is known about the biomechanical mechanisms involved. Here we investigated burrowing in M. limosa by observing individuals as they burrowed through transparent gelatin. A photoelastic setup using crossed polarizers allowed us to visualize stress development in the gelatin as the hagfish moved through it. We found that M. limosa created U-shaped burrows in gelatin using a stereotyped, two-phase burrowing behavior. In the first phase, hagfish drove their head and their anterior body into the substrate using vigorous sinusoidal swimming movements, with their head moving side-to-side. In the second phase, swimming movements ceased, with propulsion coming exclusively from the submerged portion of body. The second phase involved side-to-side head movements and movements of the submerged part of the body that resembled the “internal concertina” strategy used by caecilians and uropeltid snakes. The entire burrowing process took on average 7.6 minutes to complete and typically ended with the hagfish’s head protruding from the substrate and the rest of its body concealed. Our results could lead to improved understanding of sediment turnover in marine benthic habitats, insights into the reproductive behavior of hagfishes, or even inspiration for the design of burrowing robots.

## Long-term sampling provides powerful insight regarding mechanisms of coral resilience

*Lauren Fuess, Erin Shilling, Sofia Diaz de Villegas, Sarah Gignoux-Wolfsohn, Leah Harper*

Tropical coral reefs comprise one of the most biodiverse and ecologically important marine ecosystems on the planet. Nevertheless, the escalating effects of global climate change and other anthropogenic stressors have subjected reef-building corals to an increasing onslaught of mortality-inducing stressors. Reef environments are now characterized by frequent disturbance events, including thermally-induced bleaching (breakdown of coral-algal symbioses) and disease outbreaks. Still, we know little regarding both the intrinsic factors which drive variation in resistance, and the capacity for adaptative evolutionary responses to stressors. Here we detail a comprehensive approach to addressing questions of coral resilience and adaptation using long-term monitoring and sampling data sets. Over the past five years we have monitored and sampled multiple species of coral in Carrie Bow Cay, Belize consistently over the past 5 years, tracking host fate and physiology (gene expression and immune metrics), symbiont communities, and microbiome community structure. This comprehensive dataset spans multiple stressor events including the arrival of a deadly coral disease (SCTLD) and the unprecendented 2023 bleaching event. Specifically, I will discuss insights regarding the roles of phenotypic plasticity in resilience and adaptation to multiple stressors, focusing on host transcriptomic analyses. The insight gained from this ongoing sample set will no doubt provide critical new information regarding both markers of coral resilience and adaptive potential of these vulnerable ecosystem engineers.

## Comparative biomechanics and osteohistology reveal details of small mammal locomotor ecology

*Henry Fulghum*

The diversity of small mammal (< 5kg) life history strategies and locomotor ecologies are disjunct; despite a wide range of life history strategies, their locomotor ecologies are conspicuously simplified. Bone microstructure, a strong quantitative correlate of life history strategy in small mammals, represents a promising avenue with which to assess the diversity of locomotor ecology. To assess this relationship, histological thin sections were generated from the femoral midshaft of 36 small mammals representing a diversity of limb morphologies and locomotor modes. 2nd moment of area was calculated, and the percentage of cortical area that was comprised of woven vs. parallel fibered bone tissue was measured. Compression and three-point bending tests were then conducted on the femoral and humeral midshafts of two scansorial taxa, Didelphis virginiana, and Sciurus carolinensis. Tested bones resisted greater three-point bending stresses when oriented along the greatest 2nd moment of area than an anterior-posterior axis. Further, Didelphis bones resisted higher three-point bending stress and compressive loads relative to bone size than that of Sciurus, despite greater proportions of woven bone. Preliminary results suggest that these limbs are adapted to resist greater stresses along anterolateral axes, which in turn may convey novel insights into the variation of locomotion within traditional categories of locomotor ecology. Additional biomechanical testing is necessary to clarify the relationship between bone microstructure proportions and locomotor ecology in small mammals.

## Sexual selection through a physiological lens

*Matthew Fuxjager*

Sexual selection underlies the evolution of some of the most spectacular traits in the animal world. This includes many forms of “extreme” behavior, in which animals court mates and compete with sexual rivals by producing behavioral routines that can seem highly improbable, if not downright bizarre. My research program explores the physiological basis of these traits, looking at how sexual selection for elaborate reproductive behavior can facilitate the concurrent evolution of supportive mechanisms at the neural, endocrine, and musculoskeletal levels. Here, I discuss some of this work, while highlighting key principles that describe the complex relationship between sexual selection and the physiological basis of the traits it produces.

## From fossil to function: using extant shark denticle morphology to predict fossil denticle function

*Molly Gabler-Smith, Elizabeth Sibert, George Lauder*

Ichthyoliths, (i.e., isolated microfossil teeth, dermal denticles and bone fragments of fishes) are relatively common in marine sediments and have been used to identify changes in functional and taxonomic groups over prehistorical and historical time periods. Fossil dermal denticle fragments can give us insight into the lifestyle and ecology of some of these prehistoric shark species, leveraging the link between denticle morphology and potential function. Many of the fossil denticles have unique morphologies, most of which are absent in modern day sharks. Some of these morphologies include diamond and irregularly shaped crowns and non-parallel, intersecting ridge systems. There are few extant shark species with similar denticle morphology, which gives us a unique opportunity to study how these novel fossil denticles may have functioned by using modern day shark species for comparison. There were two major goals of this study: 1) describe the 3D diversity of modern shark denticles with similar characteristics to fossil denticles and 2) compare these data to the available morphological data for fossil denticles. Modern day shark species included in this study were the cookie cutter shark (Isistius brasiliensis), the frilled shark (Chlamydoselachus anguineus), and the angular roughshark (Oxynotus centrina). The data gained from this study will be used for future investigations using experiments examining flow regimes over various 3D printed models of fossil denticles to predict function.

## Global warming, pesticides and amphibian epidemics: what is all the stress about?

*Caitlin Gabor, Barbora Thumsová, Jaime Bosch, Andrea Aspbury, Manuel Ortiz-Santaliestra*

Global warming is linked to amphibian population declines indirectly via elevated frequency of epidemics that have decimated amphibian populations. Of the two emerging infectious diseases driving amphibian population declines chytridiomycosis is the most well studied and is produced by the amphibian chytrid fungus Batrachochytrium dendrobatidis (Bd). But more recently mass mortalities are being caused by ranavirus (RV). RV are strongly seasonal and are hypothesized to be more frequent and severe at higher temperatures. Pesticide exposure can further decrease frog immunity. One obvious physiological response to infection and pesticide exposure is through the hypothalamus-pituitary-interrenal axis (HPI) stress response as studies have found elevated corticosterone levels in response to RV and Bd. We brought tadpoles to the lab that had either Bd, RV or both. We reared tadpoles at 15 or 20C and exposed them to 2,4-D pesticide at an environmentally relevant concentration for 96h when the tadpoles first developed legs. We measured water-borne corticosterone release rates before and after exposure, plus growth and infection loads. We found that pesticide exposure led to increased Bd loads and elevated corticosterone levels. Moreover, higher temperatures and pesticide exposure interacted to affect development time and infection loads indicating that not only is global warming linked to epidemics but agricultural development near ponds further exacerbates these outcomes.

## Gene Expression Changes Reveal Ground Squirrels Shift Metabolic Fuel Usage Prior to Hibernation

*Mary Gabrielle, Cory Williams, Cole Deal*

Ground squirrels and other hibernators rely predominately on fat stores to survive the winter months when they do not eat. Ground squirrels are hyperphagic and rapidly gain body mass during pre-hibernation fattening, but greatly reduce food intake and begin losing body mass several days before the onset of hibernation (hereafter: post-fattening). We hypothesized that during this transition from hyperphagia to hypophagia, organs of thirteen-lined ground squirrels (Ictidomys tridecemlineatus) are remodeled as animals transition from lipid deposition to use of lipids as their primary metabolic fuel. Using digital droplet PCR, we examined how gene expression changes in key organs coincident with the reduction in food intake during this transition from fattening to post-fattening. In white adipose tissue, expression of PPAR$\gamma$, a central regulator of adipogenesis, was lower in post-fattening versus fattening animals, whereas Pdk4, which is known to block carbohydrate metabolism, was upregulated in post-fattening animals. In the liver, Pck1, a main control point for gluconeogenesis, was significantly overexpressed in post-fattening females relative to all other groups, whereas Acacb, a rate limiting enzyme in fatty acid synthesis, was down-regulated in post-fattening animals. Overall, our results reveal changes in the expression of genes critical to metabolic fuel usage between fattening and post-fattening animals. This suggests ground squirrels begin organ remodeling as they transition to reliance on lipids as their primary metabolic fuel in anticipation of hibernation.

## *B. glabrata* shows differential CNS transcriptomics in parasite-susceptible vs. -resistant strains

*Aparna Gajulapalli, Acacia Ackles, Judith Humphries*

Biomphalaria glabrata is a freshwater snail that is an intermediate host to the parasite Schistosoma mansoni, a parasite which in humans causes the debilitating and neglected tropical disease schistosomiasis. However, not all B. glabrata serve as equal hosts to S. mansoni–some strains are succeptible to the infection, while others are resistant. Previous work has focused extensively on the immune response of both resistant and susceptible B. glabrata after S. mansoni exposure; however, little work focuses on the central nervous system (CNS) despite evidence that parasites can significantly alter CNS activity. Here we present the first analysis of differential gene expression in the CNS of susceptible and resistant strains of B. glabrata. We use RNA sequencing to examine changes in gene expression in NMRI (susceptible strain) and BS-90 (resistant strain) snails in response to S. mansoni at 1, 2, and 4 weeks post-exposure. As expected, we find differential expression of immune-related proteins in infected vs. uninfected B. glabrata; however, we also find significant differential expression between the transcriptomes of each strain regardless of infection status. These results point towards a potential mechanism for S. mansoni susceptibility in B. glabrata and provide direction for future approaches to slowing the spread of schistosomiasis.

## Elevated testosterone advances daily onset of activity in male house sparrows (*Passer domesticus*)

*Holland Galante, Samuel Lane, Emily Elderbrock, Timothy Greives, Geoffrey Brown*

Seasonal changes in sleep/wake cycles often cooccur with seasonal fluctuations in sex hormones. It has been well established through experimental studies that fluctuations in circulating testosterone levels mediate circadian rhythms and daily activity patterns. However, most studies are performed under constant lighting conditions and fail to investigate the effects of testosterone on the phenotypic output of circadian rhythms (i.e. chronotype) under environmentally relevant light:dark cycles. Here we experimentally elevated testosterone in male house sparrows (Passer domesticus) with implants during short non-breeding daylengths to test if observed seasonal changes in chronotype are directly in response to photoperiod or to testosterone. Birds were fitted with accelerometers to track activity across three experimental treatment periods: short day photoperiods prior to manipulation (SD), followed by testosterone implants while on short days (SD+T), then photostimulated on long days (LD) after implants were removed and exogenous testosterone was cleared. Blood samples were collected during the dark phase, which is when testosterone levels peak in house sparrows. Our results indicate that experimentally elevated testosterone under short non-breeding photoperiods significantly advanced daily onset of activity and total daily activity relative to daylength. These findings suggest that testosterone, independent of photoperiod, is responsible for seasonal shifts in chronotypes.

## Effects of vegetation density on noise profiles and signal propagation

*Megan Gall*

Environmental constraints influence the types of signals animals can produce and the sensory systems animals evolve to detect signals. These constraints can come from the physical structure of the environment (e.g. tree leaves influence the spectral properties of propagating light and sounds) or the environmental noise. Here, we were interested in how the physical environment influenced both the propagation of avian acoustic signals and background noise profiles. We addressed this question using a combination of photographic analysis of vegetation density, playback of artificial and natural acoustic signals, and noise monitoring on a 500-acre ecological preserve embedded in a suburban matrix. The artificial acoustic stimuli were tones, trills, and white noise, while the natural stimuli were calls and songs of black-capped chickadees, tufted titmice, and white-breasted nuthatches. Our data suggest that even on a relatively small spatial scale, differences in vegetation structure strongly influence the propagation of artificial stimuli, with the strength of the response increasing with increasing signal frequency (i.e. pitch). Local vegetation density had relatively minimal effects on the noise profiles across sites and a mixed effect on the propagation of songbird vocalizations. These data were collected during the summer, when vegetation density is at its peak. In our ongoing work we are interested in determining whether these patterns hold across the seasons and whether vocalizations propagate optimally during the seasons of primary production.

## A longitudinal behavioral analysis of aquarium whale sharks (*Rhincodon typus*)

*Connor Gallimore, Celeste Walton, Richard Nugent, Maury Fradkin, Laurie Poppell, Christopher Schreiber, Christopher Coco, Mathew Grober, Bruce Carlson, Alistair Dove, Michael Black*

Rhincodon typus, or the whale shark, is the largest extant fish in the world. Due to their enormous size and conservation status, whale sharks are rarely housed in aquaria. Here we present a behavioral analysis recorded by 89 volunteers from 2008–2012 to study four R. typus (ID codes: AL, TA, TR, YU) in an aquarium setting. Behavioral metrics such as swim speed, depth occupation, swimming direction, and lead-follow interactions demonstrated individual variation and responses to habitat changes. All sharks displayed an increased swim speed 30-minutes before regimented feed times when food was distributed to other animals in the same habitat. YU was recorded swimming more at depth, faster, almost exclusively clockwise, and engaged in fewer close proximity interactions with others than expected by chance. In contrast, AL was observed swimming the slowest, at the surface more than others, led other sharks more than she followed, and had strong lead-follow interactions with another shark of the opposite sex. TA and TR did not differ from each other in depth profiles or speed, but did differ in their proclivity to lead or follow. Depth preferences and lead-follow interactions suggest some partitioning of the habitat and the possibility of social hierarchy in this species. These results represent the first longitudinal behavioral analysis of aquarium R. typus, offering meaningful similarities and contrasts to field observations.

## Exploring environmental impacts upon morphology in dam-impacted steelhead trout

*Jacquelyn Galvez, Jack Tseng*

Human actions are impacting biodiversity in real time, rapidly modifying environments and ecological interactions. One of the biggest anthropogenic modifiers of freshwater environments are human-made dams. While dams are a ubiquitous part of infrastructure, they also significantly alter stream ecology, disrupting the physical environment and imposing barriers to upstream breeding habitats for migrating fish. Studying fish populations in watersheds impacted by damming provides a unique opportunity to ascertain the effects of these ecological impacts and their interactions with other environmental factors. We conducted a morphological comparison of anadromous steelhead trout, Oncorhynchus mykiss, along the South Fork Eel River. We used geometric morphometric analyses to quantify shape differences across temporal and spatial scales around a human-made barrier, Benbow Dam. Lateral body shape and morphological disparity both vary temporally and spatially, though shape differences cannot be explained by dam presence alone. While there are overall trends of higher morphological diversity prior to dam presence and larger head regions in above-dam specimens, shape also covaries with locality along the watershed, regardless of dam presence. Future research will leverage 3D morphometrics of high resolution microCT data to further disentangle these various drivers of morphological variation. A focused 3D interrogation of skeletal regions containing the most 2D variation will allow for a rigorous methodological comparison between a non-lethal, field-deployable method and a more data-rich lab method to quantify internal structure.

## Productive PIs at PUIs: Maintaining robust research programs at undergraduate-focused institutions

*Eric Gangloff, Jennifer Houtz, Jerry Husak, Jason Macrander, Jennifer Uehling, Rachelle Belanger, Ariel Kahrl, Veronica Martinez Acosta, Janet Steven, Kari Taylor-Burt*

Faculty at primarily undergraduate institutions (PUIs) face unique challenges balancing teaching responsibilities with maintaining a productive research program. Unlike faculty at large research institutions, there is often little to no training for how to start or maintain a productive, undergraduate-focused research laboratory, while also managing substantial teaching loads and other obligations. This interactive poster, hosted by the SICB PUI Action Group, offers advice for early-career PUI faculty, as well as those interested in pursuing PUI faculty positions. We will discuss topics such as how to set up and structure a research program, manage time effectively, recruit and retain students, and best mentor students in research and writing. We will include insights from experienced PIs, but we will also ask for input from meeting attendees. Questions that are posed by viewers will be answered to the best of our abilities and posted at our conference booth. We will archive all of the advice to be made available on our webpage. The poster will also serve as a space to build community at the meeting during the poster session and while on display at the PUI booth.

## Lessons from Wall Lizards: What We've Learned and What's Next In Urban Morphological Evolution

*Eric Gangloff, Princeton Vaughn, Alyssa Head, Kristin Winchell*

As cities expand around the globe, urban environments offer rich and often repeated opportunities to characterize processes driving trait evolution across compressed spatial and temporal scales. This talk will present a broad framework for studying such evolutionary responses to urban environments, using a case study of common wall lizards (Podarcis muralis), which were introduced to Cincinnati, Ohio, USA from a single European source population over 70 years ago. Over the past five years, our lab's research has identified shifts in body dimensions over the course of the introduction, suggesting that evolutionary processes may be affecting these phenotypes. Limb morphology, in turn, is an important determinant of running performance, albeit dissimilarly for females and males. On the other hand, claw shape has not changed over time but impacts climbing and clinging abilities differentially, demonstrating an important functional trade-off. While our work provides insight into morphology-performance relationships in the context of urban habitats, we still lack important details to holistically understand urban adaptation: habitat differences between historical and present day populations, if these environmental differences exerted novel selective pressures, and the mechanisms producing observed morphological shifts. By demonstrating how these studies fit into a formal framework for understanding urban evolution – both in terms of what has been accomplished and what is lacking – we both provide context to current work and point to fruitful future directions.

## Single-cell sequencing analysis of spotted gar (*Lepisosteus oculatus*) pectoral fin development

*Magnolia Garbarino, Anindita Basu, Neil Shubin, Katelyn Mika*

The appendages of marine animals vary greatly in their form and function in order to suit a wide range of habitats and needs. Analyzing the genes of developing marine organisms can help develop an overarching idea of the cellular differentiation process that has contributed to such fin variation. DROP-seq is a high-throughput single-cell sequencing technique that allows thousands of cells to be sequenced individually and characterized via their mRNA expression, creating a more efficient means of connecting genes to cell types and function. Single-cell sequencing can be applied to the analysis of diseases, the development of organism atlases, and more. My study utilizes samples from spotted gar to investigate pectoral fin development. Using a suite of techniques, cell types and gene expression patterns can be identified and compared with samples from other developmental stages and replicates across spotted gar pectoral limb development. When placed in the broader evolutionary context of other fish species whose genomes have been analyzed using single-cell sequencing (including the zebrafish, little skate, and chained catshark), these findings will help to build an understanding of both the conserved mechanisms driving development of pectoral fins and variation within those pathways leading to the unique specialized appendages seen in marine species.

## Understanding the abiotic impacts of land development on soil micro diversity

*Robert Garcia*

Land development and industrialization cause subsequent abiotic factors which influence microbial diversity and their antibiotic-producing properties. The aim of this research is to investigate the effect land development has on the soil which harbors these microbes and help develop strategies to preserve and protect these essential microorganisms. We are using 16S rRNA gene sequencing to determine microbial diversity while EPA Method 3050B and 1340 will detect any metal and lead contaminations, soil types will also be considered as potential sources of variance. VIDA is 600-acre housing development adjacent to Texas A&M San Antonio University which utilizes Low Impact Development (LID) as an effort to preserve surrounding ecosystems. Soil samples have been collected over the duration of a year during land development in VIDA. LID preservation includes the construction of a greenway and greenway sample sites will be compared to Residential and Undisturbed sample sites. We hypothesize that greenway sites will more closely resemble the microbiome of undisturbed sites given LID practices are effective in preserving surrounding ecosystems and will have less metal contamination. Efficacy of LID ability to preserve microbial ecosystems will be evaluated using microbial diversity and the abundance of microbes producing antimicrobial properties. Analysis of chemical and soil composition will provide an understanding of what abiotic factors are driving diversity across sample sites.

## When the egg wins? application of game theory to the evolution of a complex trait

*Victoria Garcia, Charles Watson, Ashley Teufel*

Vivipary, or giving live birth, is less common than oviparity, or laying eggs, being present in approximately 20% of all vertebrates. It has evolved independently multiple times among squamates, which serves as a convenient model for the evolution of this complex trait. The most common explanation for the adaptive significance of this parity mode is summarized in the cold climate hypothesis (CCH) which posits that colder temperatures selects for vivipary by allowing the mother to thermoregulate and increase the temperature of the developing embryo. Despite the widespread acceptance of the CCH there is evidence that multiple variables, including temperature, oxygen, and water availability all play important roles in the evolution of vivipary. We use these three variables and current distributions of extant squamates, to inform a theoretical game that predicts conditions where viviparity and oviparity are favored. The gradient of scenarios includes temperature, water, and oxygen ranked as high, low, or normal. This provides 18 different "strategies" for each of the parity "players." This research is unique in that it informs our understanding of the evolution of this specific complex trait but also represents a novel application of game theory to an important evolutionary question.

## Do blacktip sharks (*Carcharhinus limbatus*) travel in groups?

*Denise Garcia Salas, Beth Bowers, Stephen Kajiura, Mathew Ogburn*

The blacktip shark (Carcharhinus limbatus) is a coastal, highly migratory species, and its medium size makes it prey to many larger shark species, such as the great hammerhead shark. The blacktip population off the United States East Coast overwinters off the coast of southeastern Florida, forming massive aggregations of about 800 sharks per km2, and uses shallow waters as a refuge from predators. The continental shelf narrows, reducing shallow water habitat where they form these dense aggregations. Many prey species take advantage of safety in numbers, forming aggregations to confuse predators by appearing larger and moving unpredictably. It is unknown whether blacktip sharks aggregate because of the reduced shallow water habitat or to take advantage of a safety in numbers escape strategy from predators. Blacktip sharks were tracked through checkpoints along their migratory route using acoustic telemetry. The proportion of tagged individuals that traveled through each checkpoint per day was calculated. The results indicate that blacktip sharks migrate in groups. The group sizes decreased with northward migration and increased as blacktip sharks migrated southward, approaching the narrow, shallow water habitat in southeastern Florida. Our findings suggest that blacktip sharks migrate in groups as a result of decreased shallow water habitat in southeastern Florida rather than a safety in numbers strategy.

## Cold temperatures and infection with a bacterial pathogen affect avian immune responses

*Jesse Garrett-Larsen, Steven Geary, Edan Tulman, Anna Perez-Umphrey, Kate Langwig, Dana Hawley*

Many wildlife diseases occur seasonally and can be influenced by seasonally fluctuating environmental factors that affect host physiology. Cold ambient temperatures often reveal tradeoffs between thermoregulation and immunity. These tradeoffs may differentially affect the immune responses of individuals, amplifying population-level heterogeneity in immunity and disease responses. However, this has not yet been directly tested. Here, we ask how cold temperatures affect mean host responses to infection, as well as the degree of inter-individual variation, using experimental infections of house finches (Haemorhous mexicanus) with the bacterial pathogen Mycoplasma gallisepticum (MG). In two complementary studies, wild-caught house finches were held in temperature-controlled rooms at sub-thermoneutral (4-9oC night-day) or thermoneutral (22-27oC night-day) ambient temperatures and inoculated with either MG or sterile media (control) to ask how cold temperatures interact with infection status to modulate population-level variability in immunity and disease responses. Host responses were monitored over the course of infection using a series of immune assays, disease metrics, and ocular pathogen loads. In the first study, cold temperatures did not influence mean disease responses, but cold temperatures and infection augmented population-level variability in several host responses. In the second study, we examined the transcriptomic responses of two tissues to examine how infection and cold temperatures alter variability in host gene expression. Overall, increased heterogeneity in host responses may have key downstream consequences for outbreak severity.

## Form and function relationship within ligaments, focusing on a cranial ligament in birds

*Samantha Gartner, Thomas Roberts*

Functional adaptation has been the backbone in studies with bones and muscles with few studies focusing on soft tissues, specifically ligaments. The postorbital ligament (POL) in birds is a robust, prominent ligament in the skull that is hypothesized to decrease cranial kinesis dorsoventrally and mediolaterally. The POL is present in some bird species and not others, leading to questions of morphometric differences between species with or without the ligament. In this study, we investigated the cranial and ligamentous morphometrics of 356 species of birds in about 60% of families. We determined the presence or absence of the POL in all the species and there seems to be no phylogenetic pattern across birds. It is present in most bird species, but is absent broadly in paleognaths, parrots and cockatoos, and toucans. There seem to be no general cranial morphometric patterns that differentiate species with the POL from those without. In species with the POL, there is a positive relationship between the length of the postorbital process and the length of the ligament standardized by mandible length. Comparatively, Passeriformes have smaller and thinner ligaments compared to Non-Passeriformes. Future studies will focus on the mechanistic differences between the POLs and identify traits that differentiate species where the cranial ligament is present or absent.

## A bioinformatic examination of the crustacean ecdysone receptor complex throughout the molt cycle

*Olivia Garvin, Jorge Perez-Moreno, Vanessa Bentley, David Durica, Donald Mykles*

Molting is an essential process for crustaceans to grow and develop and is initiated by the increase of ecdysteroids in the hemolymph. 20-hydroxyecdysone (20E), the most active form of ecdysteroid, is produced by the pair of Y-organs (YO) or molting glands. The crustacean molt cycle is regulated upon 20E binding to the ecdysteroid receptor as it causes a downstream signaling cascade to occur that results in ecdysis. The ecdysteroid receptor is a heterodimer composed of two different proteins – ecdysone receptor (EcR) and retinoid X receptor (RXR). While it is known that EcR is expressed during the molt cycle, it is uncertain to what extent EcR is expressed across different molt stages. EcR and RXR transcripts, including the isoforms, were identified and characterized in the blackback land crab (Gecarcinus lateralis) YO transcriptome using phylogenetic and bioinformatic tools. Additionally, RNA-seq data of the YO was analyzed to examine differential gene expression across the different molt stages. Findings from this study will unveil the gene expression levels of various isoforms of EcR and RXR proteins across molt stages including the corresponding ecdysteroid levels. A better understanding of the ecdysteroid receptor can have significant impacts in the aquaculture and fisheries industries. Supported by NSF grants to DM (IOS-1922701) and DD (IOS-1922755).

## Shark community responses to the onset of industrial fishing in the Indian Ocean

*Emma Gee, Francesco Ferretti*

Apex predators such as sharks are a critical component of ocean ecosystems. Yet the ecosystem consequences of shark declines remain poorly understood, primarily because of a lack of population and community baselines. The Indian Ocean is especially data-poor in ecological data, and even moreso in historical data. We utilized a longline survey dataset from 1966 through 1989 that spanned the majority of the Indian Ocean and recorded 19 shark species. This time period corresponds to the start of large-scale industrial fishing in the region. Trends across the species were highly variable; life history and fishing pressure metrics were not able to explain differences in responses between species, suggesting that changes in ecological interactions such as competition and predation had a prevalent role historically. To further explore ecological interactions between the species, we conducted a literature review of the study species' diets with a focus on intra-guild predation. We constructed an interaction web to identify keystone species. Several species were neither predator nor prey of other sharks, suggesting that competition may be the more salient relationship to other sharks. Overall, species with broader habitat preferences and smaller individuals are now a larger part of the pelagic shark community, whereas open-ocean species have declined. These results suggest that industrial fishing restructured shark communities and diminished the top-down control of sharks in pelagic ecosystems.

## Variable host susceptibility to the multi-host sea star wasting pathogen

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Sea star wasting disease (SSWD) infects up to 20 species of sea star, and little work has been done to evaluate the consequences of multi-species susceptibility to SSWD. We address this gap by quantifying variability in response to disease in controlled lab experiments, and by evaluating population response to the outbreak of SSWD by species in the field. In lab exposure experiments, we used a focal disease agent to expose Dermasterias imbricata, Pisaster ochraceus and Pycnopodia helianthoides to SSWD. As a control, we co-housed all three species with a focal control agent. In the field, we quantified the abundance of 35 sea star species from 2013-2024 with subtidal 30-m belt transects. In the lab susceptibility varied by species, with P. helianthoides being the most susceptible. D. imbricata appeared resistant in all trials. Disease progression was faster for P. helianthoides than P. ochraceus. Field patterns showed the highest declines following the SSWD outbreak in P. helianthoides, then P. ochraceus and no change, or even an increase, in D. imbricata populations. We observed wasting signs in 17 sea star species, with SSWD outbreaks following the initial pandemic showing intriguing species-level patterns, often with a single species dominating infection prevalence within a site. Field observations suggest that there could be more resistant species than currently documented, and that species variability in susceptibility could be driving disease dynamics.

## The survivability onion: tradeoffs in armored fishes, and the cranial pit of *Bothragonus swanii*

*Daniel Geldof*

Armor is among the most ubiquitous, diverse, and successful defensive traits in the tree of life—including among fishes. However, its protection is not without costs. Beyond the expense of its growth and maintenance, the penalties of armor frequently make it more difficult to detect, avoid, and respond to danger. To understand the defensive strategies of fishes, I have adapted a concept from the profession of arms: a Survivability Onion. The Onion consists of many layers to mitigate danger before relying on physical armor. Armored fishes have specialized morphology and behaviors to counteract the drawbacks of their protection. The Rockhead Poacher (Bothragonus swanii) is a small, armored fish noteworthy for a large dorsal cavity in its head—the cranial pit. Its function is undetermined. I will explore the morphology of the cranial pit, expand on its function, and explain it in context of life as an armored fish.

## Optimized workflow for serial histological sectioning of whole embryos

*Paul Gensbigler, William Foster, Ryan Carter, Cooper Kosinski-Buckhorn, Lott Steffey, Max Blecher, Gabriel Bever*

The emerging emphasis of comparative spatial transcriptomics and machine learning techniques for the study of developmental evolution reveals the value of histological techniques as a critical source of primary data. If these approaches are to revolutionize our ability to cross reference molecular data with in-situ tissues and to accurately reconstruct 3D models from 2D sections, we must ensure that our histological protocols are optimized for these uses. Relative to standardized techniques for the study of adult organ microanatomy, which we have found to be destructive to embryonic tissues, our specialized methods maximize both quantity and quality of histological data. We detail our workflow for high throughput production of whole embryo serial sections from egg incubation through differential staining. Specifically, we present modified dehydration, embedding, and serial sectioning techniques better suited for whole-embryo imaging and the preservation of delicate neurological tissues and epithelia. Our contributions highlight the need for gradual dehydration during the embedding process and for the careful control of humidity and temperature during serial sectioning. Many of these variables need to be adjusted depending on developmental stage and species of interest, which we have broadly tested amongst reptiles. Whilst advancements in transcriptomic analysis and computation have been rapid, our ability to bridge molecular and phenotypic data emphasizes the continued relevance of traditional histological techniques at the frontier of evolutionary developmental biology.

## Using diceCT to characterize the 3D architecture of the ceratohyoideus muscle in A. carolinensis: unraveling the functional anatomy of dewlap extension

*Jacob George, Christopher Zobek, Casey Holliday, Haley O'Brien, Susan Williams*

The architecture of muscles is tightly coupled with musculoskeletal system function and performance. New methods of digital imaging and muscle visualization have revealed unprecendented levels of detail in muscle architecture, particularly for small or complex muscles. In some lizard species, small difficult-to-dissect muscles of the hyoid apparatus are responsible for extension of the dewlap, an external cervical flap used during intra- and interspecific interactions. In these species, the dewlap is extended by protruding the second ceratobranchial elements of the hyoid apparatus into an elastic tissue fold. The M. ceratohyoideus is a small, intrinsic muscle to the hyoid apparatus. In Anolis, this muscle is hypothesized to be the primary driver of the dewlap extension mechanism. Therefore, the architectural properties of this muscle may play a key role in the performance of signaling behaviors and thus life history. However, because of the small size of these muscles, quantification of their architecture to understand function and performance is difficult. In this study, we used a combination of Diffusible Iodine-Based Contrast-Enhanced Computed Tomography (diceCT) and the Avizo XFiber extension to characterize the ceratohyoid of Anolis carolinensis. Fascicle lengths, fascicle orientations, and muscle volumes of the M. ceratohyoideus were successfully quantified from 3D reconstructions of 7 individuals. This study demonstrates how 3D visualization of the small hyolingual musculature in anoles can be informative for understanding the mechanics of dewlap extension.

## GasTRICK: genes, biochemistry, & morphology show gastric dietary specialization in prickleback fish

*Donovan German, Michelle Herrera, Jordan Buckner, Joseph Heras, Nefertiti Smith, Matthew Hileman*

Dietary specialization in fishes is not well understood on the molecular level. Hence, we used genomics, as well as comparative transcriptomics of stomach tissues to observe how prickleback fishes (Stichaeidae) achieve dietary-driven differences in stomach size and function. Xiphister mucosus (herbivore), X. atropurpureus (omnivore), Phytichthys chirus (omnivore) and the carnivorous Anoplarchus purpurescens were harvested from the wild, and fed omnivore and/or carnivore diets in the laboratory. All four fish species strongly expressed pepsinogen and chitinase genes in their stomachs, yet biochemical activity levels of these two digestive enzymes matched natural diet, with the species consuming the most protein (A. purpurescens) and chitin (P. chirus) having the highest pepsin and chitinase activities, respectively. These enzymatic activities were the same (chitinase) or enhanced (pepsin) by the laboratory diets in these two species. Stomach size was largest and least plastic in the herbivorous X. mucosus, coinciding with high intake in this species, and with strong selection on genes for tight junction formation (occludins and plectins). More genomic and transcriptomic comparisons are in progress. Pancreatic and intestinal function have received more attention, and thus, this may be one of the first studies to show gastric size, enzymatic activities, gene expression, and genomic changes also vary predictably with diet in fishes. Thus, beyond being an important vertebrate innovation, the stomach may show dietary adaptation.

## Geographic variation in physiological traits: are there macrophysiological patterns?

*Cameron Ghalambor, Alex Mauro, Alfredo Escanciano Gomez, Aksel Fosse, Hanna Kissener*

Geographic variation in climatic conditions is often assumed to drive divergence in physiological traits, such as thermal tolerance and desiccation resistance. However, tests across latitudinal or altitudinal gradients in climate are often based on literature reviews of data sets using diverse methodologies which are known to influence the results. To date, relatively few studies have used standardized methods to test macrophysiological patterns. We present preliminary results on the thermal sensitivity of metabolic rate, critical thermal maximum, and desiccation rates from a subset of insects across a latitudinal gradient from northern Norway to central Spain. We find evidence for divergence in these physiological traits across latitude, but also variation within sites that suggests phylogenetic and microclimatic differences also play a role in explaining physiological diversity. Such results also have important implications for responses to climate change, as different geographic regions may be more or less sensitive to similar climatic stress like heatwaves and droughts.

## DspikeIn quantifies absolute abundance across domains and addresses spike-in biases in herpetofauna

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Relative abundance (RA) metrics are constrained by a fixed sum, where an increase in one taxon reduces the apparent abundance of others. This limitation complicates the interpretation of host-associated microbiomes across life history stages, particularly in health/stability versus disease/dysbiosis studies. Although spike-in methods have improved absolute abundance (AA) quantification, a consolidated approach for calculating scaling factors and correcting biases remains undeveloped. Additionally, wildlife gut microbiome studies, including those of endangered species, still largely rely on RA assessments. To bridge these gaps, we introduce the DspikeIn package, designed for AA quantification, data preprocessing, scaling factor assessment, bias correction, differential abundance, and visualization, using herptile gut microbiomes as a model. Built on the phyloseq framework, DspikeIn supports both ASV/OTU approaches, quantifying AA and filtering taxa using Random Forest and prevalence for assessment and visualization. The package is designed to accommodate and facilitate the quantification of specific species or synthetic communities using variable/equal spike-in volumes. Converting RA to AA in the core microbiome data of Plethodon salamanders reshaped microbial community structures, unveiling intricate patterns among dominant families such as Lachnospiraceae, Tannerellaceae, and Ruminococcaceae. RA identified Peptococcaceae as a network hub, but this was absent with AA. AA also revealed a more structurally stable network with negative microbial associations across domains. DspikeIn permits a shift from relative to absolute abundance quantification, enhancing biological interpretations of microbiomes.

## Variation in the gut microbiota among urban and rural populations of wild house mice

*Samantha Giancarli, Renè Clark, Adrienne Kasprowicz, Stephen Kupchella, Logan Lacy, Megan Phifer-Rixey*

House mice (Mus musculus domesticus) have evolved alongside humans for thousands of years and now have a near cosmopolitan distribution. Urbanization over the past century and a half in the United States has introduced many changes, including temperature, the built environment, and notably, diet. The gut microbiome may play a role in mediating response to dietary shifts associated with urban living. To investigate this possibility, we sampled the cecal contents of 110 wild mice from urban and rural settings in three metropolitan areas with surrounding rural counties (New York City, NY, Philadelphia, PA, and Richmond, VA). The V3 and V4 regions of the bacterial 16S rRNA gene were sequenced. We then assessed patterns of community composition and diversity associated with urban and rural habitats. We also conducted stable isotope analysis to characterize potential dietary or trophic differences between the urban and rural mice. Together, these approaches will provide insight into differences in diet among habitats and their potential impacts.

## Discontinuous gas-exchange cycles in the blacklegged tick, Ixodes scapularis

*Allen Gibbs, Emily Marinko, Matthew Meiselman*

Ixodid ticks can survive months of inactivity between blood meals. During these quiescent periods, they breathe in a discontinuous manner, with CO2 being released in short bursts separated by minutes to hours. We characterized discontinuous gas-exchange (DGE) cycles in blacklegged ticks under differing light conditions. Under a 12:12 LD cycle, ticks breathed discontinuously during the photophase, then switched to irregular CO2 release for ~2 hours after the scotophase began. Total CO2 release during this period accounted for >90% of overall metabolism over a 24-hour period. Ticks then resumed DGE for the rest of the scotophase. CO2 burst volumes were smaller during the scotophase, but ticks breathed more frequently, resulting in higher total hourly CO2 release than in photophase. Similar patterns were seen in ticks held under constant light or dark conditions. In the dark, ticks released smaller volumes of CO2 more frequently, although overall metabolic rates did not differ. Larger ticks released CO2 in larger, less frequent bursts, resulting in similar mass-specific metabolic rates across body sizes. As a result of these changes, allometric relationships between body size and burst volume, breath frequency and metabolic rate were dependent upon circadian patterns.

## On the relevance of biomechanical and kinematic variation in mammals for clinical jaw joint studies

*Nicholas Gidmark, Saxon Alvarez, Naeun Kim, Sonia Lopez, Emily McParland, Rosalie Ross, Amira Siddique, Alyssa Stringer*

Mammals consume diverse foods; the motions and morphology of their jaw joints (TMJ, temporomandibular joint) reflect this diversity. Several mammal species are used as model organisms for studying the etiology and progression of jaw joint pathologies, termed TMD (temporomandibular disorders). Commonly used species in this biomedical and pre-clinical context are mice, rats, rabbits, monkeys, sheep, and pigs. The diversity of jaw joint form, biomechanics, and chewing kinematics across this selection of species is immense. The implications of this diversity have historically been difficult to compare objectively because of technological and logistical limitations. Here, we leverage XROMM data and comparative functional morphology tools to examine kinematic, anatomical, and biomechanical variation in rats, monkeys, and pigs through a clinical lens. We measured 6DOF kinematics of healthy chewing via five disparate, clinically-relevant anatomical alignment methods, and though some had tenuous comparative utility, all methods of alignment showed that rats had the greatest anterior translation. Additionally, We measured variation in the size & shape of TMJ space, articulation topology, muscle length & mechanics, and ligament length dynamics across the chew stroke for all three of our study species. In each of these areas, we observed greater variation across species (∼80%) than across the chew stroke (∼20%). These data suggest that, while chewing kinematics are no doubt important, inter-species variation is perhaps more relevant for translating clinically-relevant findings to human TMJ health.

## Characterization of Nereid Epitoke Swimming

*Alyssa Giedd, Emily Carrington*

Nereid worms utilize an oscillatory motion to achieve locomotion in their native habitat. This oscillatory motion is efficient, requiring little caloric expenditure to achieve. However, this motion currently lacks a mathematical model to describe its relation to flow speed. In this study we aim to correlate a change in the frequency of parapodia oscillation of Alitta virens during swimming locomotion to a change in flow speed. This will be done by utilizing video analysis to track horizontal parapodia oscillation over a set of known speeds in a flume. We expect to see a near-linear relationship between the frequency of Alitta virens parapodia and flow speed. The development of this mathematical model will allow for improved control of robots of similar morphology to Alitta virens. It is additionally proposed that by combining several actuators used for traditional winged locomotion in insect robotics, it may be possible to achieve a similar type of locomotion to what is observed in worms such as Alitta virens at a smaller scale.

## Using Experimental Invasions to Measure Natural Selection During Island Colonization in a Lizard

*Anthony Gilbert, Amélie Fargevielle, David Delaney, Andrew Durso, Joshua Hall, Ariel Kahrl, Tim Mitchell, Philip Pearson, Aaron Reedy, Robert Cox, Daniel Warner*

Colonization of new habitats exposes populations to novel selective pressures, and the evolutionary dynamics of invasive species, including their success or failure, are determined by how the founding environment interacts with the phenotypes of invaders. Measuring these processes depends on measuring natural selection immediately upon colonization, which has been a logistical hurdle for understanding how selection operates in newly established populations. We experimentally introduced brown anole (Anolis sagrei) populations to six unoccupied spoil islands in Florida and manipulated initial sex ratios to describe how natural selection operates during the incipient generations following colonization, and to understand how natural selection varies based on the composition of founding populations. We found unpredictable spatial and temporal variation in natural selection, and selection increased in strength over time and with increasing adult density. Age-specific and sex-specific selection was predicted more strongly by adult lizard density and was strong immediately following introduction, conflicting with theoretical expectations of invasive populations experiencing a relaxation of selective pressures. The relationship between phenotypes and fitness in newly established populations may not be consistent over time. As a result, each colonization event by an invasive population provides the opportunity for a novel evolutionary trajectory towards either establishment or extirpation.

## The evolutionary developmental biology of holobionts

*Scott Gilbert*

One of the most remarkable discoveries of twenty-first century biology (perhaps its distinguishing autapomorphy) is that organisms are holobionts. Holobionts are organisms consisting of both the host (the larger symbiont) and its persistent symbionts. Holobionts are, thus, multilineage consortia that are characterized by mutualistic symbioses. Even "single-celled protists" are multicellular holobionts. Importantly, symbionts are also needed for the development of organisms, and symbionts are seen providing important cues for the development of body axes, digestive systems, immunocompetent cells, and neurons. If symbionts are required for development, and if evolution involves changes in development, then alterations of the symbiont-host relationship should be able to generate new selectable variations. This has been found to be the case. For instance, the rumen, which is critical for nutritional symbiosis in cattle, is generated by chemical signals from the bacterial symbionts that expanded through the calf's gut after birth. Moreover, the microbial symbionts and "hosts" are the environments for each other, and changes in symbiont-scaffolded development may also be responsible for some major evolutionary transitions such as meiosis, multicellularity, and herbivory. This notion of developmental symbiosis ("sympoiesis") provides a new framework for envisioning life and how it has evolved in a microbial world.

## Under Pressure: transcriptomic response to embryonic development under applied hydrostatic pressure

*Kinlie Gililland, Katelyn Mika, Katie Smith*

The processes responsible for teleost adaptation to deep sea hydrostatic pressure are not well understood. Hydrostatic pressure is defined as the pressure exerted by a static liquid, here water, on an object. Little is known about the mechanisms which allowed shallow water fish migrating deeper into the ocean in search of food, mates, or shelter to adapt to increasing pressure. To explore the effects of hydrostatic pressures outside the range typically experienced during the embryonic development of shallow water teleosts, we are exposing developing embryos to additional hydrostatic pressure and measuring the transcriptomic response. Using zebrafish as our model organism due to its rich history and fully sequenced genome, we will perform bulk RNA sequencing on zebrafish embryos which have been subjected to increased hydrostatic pressure in modified pressure chambers. These increases in pressure range from zero to four additional atmospheres (atm). Samples will be taken at major developmental timepoints to determine the timeline of the response, if any is observed. This is one of the first publications exploring the embryonic development of shallow water teleosts under constantly applied pressures using RNA sequencing. The findings may have implications for the fields of deep sea and evolutionary biology, as further understanding of the developmental response to increased pressure may elucidate more of the momentarily murky mechanisms responsible for deep sea fish development and survival.

## Distributed sensing and its robustness in a bioinspired model of a navigating leech

*Jeffrey Gill, Cindy Harley, Brian Taylor*

Water waves can help aquatic animals to distinguish between predators and prey. Previous studies suggest that leech sensory receptors have evolved to respond to relevant wave frequencies. While these studies examined how sensory information affects animal behavior, the underlying neural processing remains unclear. In this study, we present a model that mimics leech goal seeking behavior using an agent-based simulation. Our model uses neural fields, a computational neuroscience Winner-Take-All framework, to process sensory data. A simulated leech was placed in a simulated environment containing artificial water waves. A distributed sensor array around the agent detected the wave motion, which was then processed via neural fields. This processed sensory information was used to compute motion directions. Modeled behavioral data aligned with data from previous animal experiments. Additionally, we performed ablation experiments by systematically altering the accuracy and noise of individual sensors and sensor groups, allowing us to determine how the model responds when different sensors are damaged or unreliable. Our model can complement animal experiments by allowing us to pose questions that would be challenging to address directly in an animal. Also, our results may provide insights into novel and robust processing approaches that can be leveraged by man-made sensory systems to process data from multiple sensors.

## Patterns of morphological regionalization within vertebral centra: a case study of mouse vertebrae

*Celina Gilmore, Jack Tseng*

The mammalian vertebral column consists of distinct regions differentiated by their external morphology. This vertebral regionalization has previously been studied for their role in enabling the diversity of locomotor adaptations exhibited in mammals. In contrast, it is unknown whether characteristics of trabecular bone within vertebral bodies also reflect this well-documented external regionalization. In this study, we use high-resolution micro-computed tomography (micro-CT) of vertebrae from the cervical, thoracic, and lumbar regions of Mus caroli to assess regional variations in trabecular microarchitecture. We developed datasets of bone volume fraction of total volume (BV/TV), trabecular thickness (Tb.Th), and trabecular separation (Tb.Sp) and used them to test whether vertebral regionalization exists internally in addition to external differentiation. Results indicate that the lumbar region exhibits higher bone volume fraction and lower trabecular thickness compared to the cervical and thoracic regions, but the latter two regions cannot be distinguished on the basis of trabecular features alone. This pattern of trabecular architecture differentiation across cervical, thoracic and lumbar regions contradicts the external classification of vertebral regionalization. Rather, region-specific vertebral microarchitecture of the cervical, thoracic, and lumbar regions may reflect local biomechanical environment whereas external morphological regionalization likely correlates more closely with overall ranges of motion. Such a hierarchical framework for trabecular and vertebral biomechanics may be informative for teasing apart selective factors in macroevolutionary patterns of vertebral mechanical performance and functional adaptation.

## Examining relationships between pre- and postcopulatory selective traits in male green frogs

*Maxwell Girard, Charlotte Clark, Ariel Kahrl*

Sexual selection is thought to be a primary driver of trait evolution. The expression of traits that improve mate acquisition or fertilization success may be linked in organisms that experience intense sexual selection as they must invest sufficient energy into many different sexual traits to reproduce. Two prevailing models - the phenotype-linked fertility hypothesis and the trade-off hypothesis describe potential positive or negative correlations, respectively, between pre- and postcopulatory traits. We examined the interaction between precopulatory traits (belly coloration, forearm size, calling traits) and postcopulatory traits (sperm morphology, sperm velocity, and sperm count) in male Green Frogs (Lithobates clamitans). We found multiple positive and negative correlations between pre- and postcopulatory sexual traits. Interestingly, many of precopulatory traits were negatively correlated with postcopulatory traits suggesting that the expression of these traits is constrained by energetic resources, fitting the trade-off hypothesis. However, male forearm size was positively correlated with both sperm count and sperm velocity and aspects of throat color were positively correlated with sperm head and total length. These results suggest that males must make complex investments in suites of sexual traits in order to maximize fitness in the face of energetic trade-offs.

## The effects of flapping on longitudinal stability in flight

*Ronan Gissler, Santiago Romo, Kenneth Breuer*

Passive stability has important implications for animal flight, particularly in unsteady flight conditions, such as highly turbulent air streams. We characterize the static longitudinal (pitch) stability of two robotic flapping systems operating in different parameter spaces as a model for bird and bat flight. One small model (wingspan 20 cm) flaps at high frequencies ($\sim$10 Hz) with light flexible wings ($\sim$0.5 grams) while a larger model (wingspan 60 cm) flaps at moderate frequencies ($\sim$5 Hz) with heavier rigid wings ($\sim$10 grams). We conducted wind tunnel experiments and recorded triaxial forces and moments over a range of wind speeds, flapping frequencies, and pitch angles. Phase- and cycle-averaged data are used to determine static longitudinal stability as a function of flight kinematics, body and wing geometry. Through this lens of stability, we can interpret flight behavior when active flight control is strained such as in turbulent air or when sensory systems are compromised.

## Lateralization of righting response in arboreal chameleons

*Gene Glover, Michael Curran, Christopher Anderson*

Morphological and behavioral lateralization is an adaptation seen across vertebrates. Initial focus on mammals and birds found that many species showed biases in use towards individual limbs at the individual and sometimes population level. Lateralization of limb function was believed to be an adaptation limited to species which use their limbs to manipulate objects and produced through convergent evolution. Recent work on fish predator escape, amphibian pawedness, and reptile aggressive responses, however, provides evidence for an earlier origin of brain lateralization in vertebrates. Chameleons are an intriguing group to further research into the origins of brain lateralization and the effect of ecology on the magnitude of asymmetry. Chameleons span a spectrum of arboreality, and lateralization of their limb strengths and behavior may be key to navigating environments of differing complexity. We examined chameleon behavioral lateralization by looking for biases in their righting response among three species. Individuals were suspended on a horizontal dowel by their tail to observe their righting response with specific attention to righting time and direction. While no pattern could be discerned at a species-wide level, certain individuals were found to have a bias in the direction of their righting response. These results provide important insight into locomotor control in complex environments and baseline data for future work to determine the effect of differing degrees of arboreality on lateralization in chameleons.

## The macroecology of fitness and physiological challenges to upslope shifts in birds

*Pranav Gokhale, Benjamin Freeman*

Understanding why species live where they do is a fundamental question in organismal biology. In my talk, I will present data investigating the macroecology of fitness along an elevational gradient in the Western Himalaya. Specifically, I will test predictions of the Abundant-Center and Biotic Interactions Hypotheses. The Abundant-Center Hypothesis predicts species have high reproductive success at the centre of species' ranges but lower reproductive success towards their range edges. In contrast, the Biotic Interactions Hypothesis predicts that species should have lower reproductive success at low elevations where biotic interactions such as nest predation are predicted to be strongest, with increasing success at higher elevations. Taken together, I will present hard-won field data describing how abiotic factors (e.g. temperature) and biotic factors (e.g. predation) interact to affect fitness and form range limits along an elevational gradient. Additionally, I will present data on the physiological challenges posed by climate change-induced upslope shifts, examining how these shifts impact breeding success using data on nest incubation temperatures and nest characteristics. Overall, my talk will provide fundamental insights into how spatial variation in fitness sets elevational range limits and how climate change is posing physiological challenges to species undergoing upslope shifts.

## Alveolus spacing trends in convergent long-snouted reptiles reveal divergent ontogenetic patterns

*Erika Goldsmith, Michelle Stocker*

Elongate snouts have repeatedly evolved in every major vertebrate clade through evolutionary history; however, few studies have compared the extent of convergence and effects of ontogenetic constraints on convergent morphologies between extinct and extant organisms. To assess the extent of convergence and compare ontogenetic trajectories of convergent morphologies, we quantify the rostral and alveolar trends between superficially convergent long-snouted reptiles (extinct phytosaurs and extant crocodylians) that are inferred to have occupied the same ecological niche due to their convergent body plans. We created linear models to quantify the relationship between preorbital alveolus dimensions (i.e., mesiodistal distances [AD] between and lengths [AL] of alveoli), rostral shape (i.e., longirostrine, intermediate, and brevirostrine), and skull length as a proxy for ontogenetic age. In phytosaur and crocodylian specimens in this study ($n = 63$), AD:AL is correlated with rostral shape such that brevirostrine taxa possess the smallest AD:AL values, suggesting rostral broadening adds complexity to alveolar dynamics. However, divergent patterns are also recovered; in phytosaurs AD:AL values decrease through ontogeny, yet in crocodylians, there is no correlation between skull size and AD:AL. Although these convergent clades are hypothesized to have experienced similar selective pressures related to feeding ecology, phytosaurs and crocodylians undergo different alveolar ontogenetic processes during rostral elongation, and illuminating these nuanced differences may reveal how ontogeny and functional ecology contribute to the development of convergent morphologies.

## Bat (pelvic) signal: sexual dimorphism is a major factor in bat pelvic shape at a clade-wide scale

*Caroline Goldstein, Andrew Orkney, David Boerma, Brandon Hedrick*

Sexual dimorphism is prevalent across animals, and primarily present in traits linked to reproductive success. Long gestation and live birth in mammals can necessitate female structural compensation, resulting in different ideal pelvic shapes between sexes, giving males the opportunity to structure their pelvis in closer association to ecological demands. To examine how male and female forms diverge and evolve, we examined pelvic structure of over 60 species of bats using geometric morphometrics. Bats are a highly diverse order, evolving under extreme anatomical constraints due to their volant lifestyle and unique roosting habits. Additionally, bats are commonly born at 66% of female body mass. Despite their ecologically driven constraints, we expect male and female pelves to exhibit substantial dimorphism. By plotting shapes in morphospace, we visualized male and female morphologies and observed clear patterns of sexual dimorphism. Although there was strong phylogenetic signal, sexual shape dimorphism was a dominant factor structuring morphospace occupation. One of the leading shape characteristics dividing male and female bat pelves was the extent to which the pubic tubercle extends medially. While most genera adhere to a consistent pattern of dimorphism, some follow a different system (e.g., Mesophylla). Bats occasionally exhibit novel sex chromosome systems (e.g., Mesophylla), and future work will examine whether novel chromosome systems impact the manifestation of sexual dimorphism in bats.

## Antlers and horns likely communicate different attributes of quality in long-lived species

*Monet Gomes, Wendy Hood, Geoffrey Hill, Haruka Wada, Stephen Ditchkoff*

Ungulate antlers or horns can serve as indicators of condition and researchers often discuss them interchangeably when assessing their influence on sexual selection. While cranial appendages, like antlers, horns, pronghorns, and ossicones, share many similarities, we suggest that their varied degree of condition dependence cannot be ignored when evaluating their role in sexual selection. Our research focused on two of the most directly compared cranial appendages: antlers and horns. We examined the evolution of such structures, the physiological constraints associated with their development, and evaluated the degrees of condition-dependence of these traits. Although both traits indicate condition, they may communicate vastly different messages in long-lived species. Cervid antlers are grown and shed annually and are the fastest growing tissue in the animal kingdom. While antlers increase in size with age, size is also highly dependent on an individual's ability to cope with illness, injury, and nutritional demands during the growing period of the current year. By contrast, bovid horns are maintained throughout life, with incremental annual growth. While healthier males experience greater horn growth rates, horns might provide better insight into an individual's ability to cope with stressors across their entire lifetime. Given these differences in developmental timing and condition dependence, we call for greater distinction between these two traits and suggest that antlers and horns may play fundamentally different roles in sexual signaling.

## TBI-Induced Behavioral Change in Mangrove Rivulus Fish: Prevention and Rescue with Gardenin A

*Marisol Gomez, Kathryn Leu, Elizabeth Wiese, Jamie Brown, Ann Parker Baldwin, Lukasz Ciesla, Ryan Earley*

Tramatic brain injury (TBI) promotes brain inflammation and free radical production, which can drive significant changes in neuronal function and behavior. Mangrove rivulus are an interesting model in which to explore TBI-related behavior changes because they jettison from water, move about on land by tail-flip jumping, often land on their heads, and take more risks post-TBI. We tested the hypothesis that behavioral changes can either be prevented or rescued by administration of the flavonoid Gardenin A, which has anti-inflammatory properties and can scavenge reactive oxygen species (ROS). The experiment quantified baseline behavior before dosing with Gardenin A either prior to (prevention) or after (rescue) TBIs were delivered through a custom apparatus with a 0.3 g weight. Dose-response relationships between Gardenin A and risk-taking behavior are unknown so, we administered one of four doses with increasing concentration, including a vehicle control (N=20 fish per dose). Fish were immersed in Gardenin A solution at a pre-assigned dose for seven days (solution refreshed daily) to ensure consistent exposure and uptake of Gardenin A. We predicted that Gardenin A would diminish TBI-related behavioral deficits in a dose-dependent, non-monotonic fashion. Our results have the potential to identify radical-scavenging compounds as promising preventatives or treatments for debilitating behavioral changes and long-term cognitive impairments associated with TBIs sustained during high impact activities.

## Evolution of migratory drop-offs and flight feather modifications in Tyrant Flycatchers

*Valentina Gómez-Bahamón, Juan Gómez, Alex Jahn, Elkin Tenorio, Diego Tuero, Bobby Lauer, Carlos Cadena, Juan Areta*

When a population colonizes a new environment, it needs to accommodate to new selective regimes to persist. If the traits involved are also under sexual selection, this can lead to correlated evolution of communication signals, accelerating divergence from the parental population through pre-mating isolation. Migratory behavior in birds often involves long sustained flight of up to thousands of kilometers in a short amount of time. This behavioral strategy exerts strong selection pressures on flight morphology favoring phenotypes that enhance efficient flight. Migratory drop-offs occur when a population of migratory birds stops migrating and switches to a non-migratory lifestyle. Instances of migratory drop-offs have been common across the evolution of Tyrant flycatchers (Tyrannidae). Males of some species produce non-vocal acoustic signals during displays, using modified flight feathers. Here, we studied whether feather modifications evolve in correlation with migratory behavior across Tyrant flycatchers. Next, we explore the aerodynamic consequences of wing feather modifications in a species that has gone through a migratory drop-off. We find that the evolution of feather modifications has a strong phylogenetic signal and has not evolved in correlation with migratory behavior. However, within a species, a drop-off has led to less efficient flight morphology and changes in a feather-produced communication signal, likely because of relaxed selection after losing migration. We hypothesize that there are tradeoffs between aerodynamic efficiency and communication pressures.

## Three-dimensional kinematics of tail twisting during vertical maneuvering in largemouth bass

*Ming Gong, Yordano Jimenez, Eric Tytell*

Fish use their tails to generate forward thrust, but they can also use them for maneuvering to generate forces in other directions. Based on the previous work that indicated that the body and tail twist during maneuvering, we hypothesized that fish might twist their tails to produce vertical forces for changing body angles and maneuvering up and down. Thus, to understand how fish use their tails for vertical maneuvers, we recorded high-speed video of largemouth bass (Micropterus nigricans) swimming in three directions, upward, downward, and horizontally forward. We conducted a three-dimensional analysis of the motion of the peduncle, the caudal fin, and the body to investigate the relationships among the body angle of fish, the speed of swimming, the amplitude of caudal fin twisting, and the phase difference between the dorsal and ventral lobes when reaching the peak amplitudes. We found that fish tend to twist their tails differently with distinct differences in the motion of the dorsal and ventral lobes depending on whether the fish was swimming up or down.

## Machine Learning for Estimating In Vivo Muscle Force in Rat Plantarflexors

*Shu Gong, Amro Alshareef, Gregory Sawicki*

Building muscle models has been studied for decades, ranging from simple mechanical models to complex molecular models. Recent developments in computational power and algorithms have brought attention to data-driven machine learning methods. However, the proper strategies for effectively building a machine learning muscle model remain to be discussed. Here, we compared three fundamental machine learning models (i.e., FCNN, LSTM, and TCN) to impedance models using data collected from the medial gastrocnemius of rats. We found that while impedance models can predict general trends in muscle force responses, they often fail to accurately predict the magnitude of force. Machine learning models, whether or not they can capture temporal dependencies, significantly outperformed impedance models in terms of $R^2$ and RMSE, in both rat-dependent and rat-independent scenarios. Additionally, we observed that statistical features extracted from muscle length and velocity can further improve model performance. These results preliminarily verify the feasibility of building machine learning models for muscles, paving the way for future research on detailed machine learning muscle models across different species and muscles.

## Finders Keepers: DNA uptake facilitated by T6SS competition among Vibrio fischeri symbionts

*Perla Gonzalez Moreno, Michele Nishiguchi, Salma Arechiga-Mendoza*

The Type VI Secretion System (T6SS) is a syringe-like structure that delivers toxic proteins to a target cell which induces cell lysis. Upon lysing, DNA from the target cell is released into the environment (eDNA) and can be taken up by other cells via natural transformation (NT). In the Euprymna-Vibrio symbiosis, some strains of bioluminescent Vibrio fischeri encode for a T6SS that can be deployed to eliminate competing strains – thereby generating a pool of eDNA within the squid light organ (LO). We used an in-vitro approach to determine whether T6SS competition could promote NT among the population of V. fischeri symbionts housed in the LO of Euprymna. Lethal V. fischeri strains and a target T6SS-deficient strain were coincubated under host-like conditions to allow for T6SS-mediated killing of the target strain and subsequent uptake of eDNA by the lethal strain. Coincubated strains were plated onto selective and non-selective media to determine the number of lethal V. fischeri transformants that recombined with eDNA. Our results demonstrated that lethal V. fischeri successfully kill target strains, leading to the subsequent uptake and recombination of a chloramphenicol resistance cassette (CamR) from the target strain. These findings suggest that T6SS competition may promote genomic diversification among V. fischeri symbionts in the squid LO by facilitating the uptake and integration of beneficial genes.

## Effect of dopamine manipulation on social behavior and neural gene expression in a juvenile fish

*Jessica Gonzalez Rodriguez, Veronica Britton, Andrew Yuan, Kiren Kanazawa, Lauren Anderson, Ailinh Nguyen, Tessa Solomon-Lane*

Social animals are constantly exposed to different social environments that lead them to produce context-dependent behavioral responses, affecting their survival and reproduction. However, the neural mechanisms that mediate social behavior in early life are less understood. Using juvenile Astatotilapia burtoni, a highly social cichlid fish, we investigate the effect of central (intracerebroventricular) Dopamine-2-Receptor (D2R) manipulation on whole brain gene expression and aggressive, territorial, and affiliative social behaviors within a complex social context. This manipulation in adults mediates context-dependent behavior. We activated (agonist) and blocked (antagonist) D2R in focal fish and placed them back in a complex social environment, with fish of different levels of familiarity. This allowed them to have different options for social interactions. We measured the changes in behavior and compared expression levels of ten candidate genes across treatments, related to dopamine, serotonin, nonapeptide, and glucocorticoid signaling. We show that D2R manipulation can affect the pattern of interactions across social networks. Additionally, we found that expression levels of some genes were correlated, for example, serotonin receptor 1A and D1R. We also tested for associations between gene expression and behavior, for example, D1R expression was not correlated with behavior. Our results will reveal roles for D2R signaling on social behavior and gene expression, providing insight into the neuromolecular mechanisms behind social decision-making and its development.

## Behavioral tolerance and physiological responses to human proximity in the rufous-collared sparrow

*César González-Lagos, Pablo Sabat, Natalia Ricote, Maite Arriagada, Benjamin Corvalan, Karin Maldonado*

Increases in human-wildlife interactions due to urbanization have led many wild animals to reduce their fearfulness and increase their tolerance towards humans. As cities expand, it is vital to understand behavioral tolerance to human proximity. Prior studies have underscored the role of intrinsic factors, such as body size and metabolic rates, in determining animals' risk-taking behaviors, such as flight initiation distance. Previous findings align with the pace of life syndrome hypothesis, which suggests that behavioral and physiological traits are integrated within life-history strategies, defining 'fast' and 'slow' coping styles that influence fitness across environmental contexts. In this presentation, we extend these concepts to Zonotrichia capensis in an urban setting. Our study investigates how these sparrows adapt their coping styles in response to human proximity and novel objects, with laboratory experiments measuring behavioral tolerance and physiological traits such as corticosterone levels and oxidative status. These adjustments may represent an evolutionary response to human proximity, reflecting a novel coping style characterized by reduced aggression, lower physiological stress responses, and increased behavioral flexibility. This integrative approach not only explores the emergence of novel phenotypes but also illustrates the broader implications of coping styles for urban wildlife management and conservation strategies.

## Complex song in Bachman's sparrows: examining relationships between vocal performance and quality

*Hans Gonzembach, Rindy Anderson*

Animals exhibit exaggerated phenotypes to signal individual qualities that predict fitness. In some species, males exhibit multiple phenotypes where the information about an individual's quality is intended for the same or different receivers. Songbirds use both behavioral and visual phenotypes, such as broadcast song and wing epaulet coloration, to signal their fitness to receivers. Further, in some species of songbirds, the signaling system is complex with multiple categories of song produced in different social contexts. In addition to broadcast song, Bachman's sparrows (Peucaea aestivalis) produce "complex song" during aggressive interactions with conspecifics. The acoustic structure and social function of complex songs have not been thoroughly investigated in many species, with only a handful of published studies. Males of this species also exhibit yellow feathers on their wings and variation is present among individuals. We hypothesized that males produce complex song to showcase their vocal performance. We predicted that larger, stronger males produce complex songs that are more physically challenging to produce. We also hypothesized that larger, stronger males exhibit more pronounced epaulets. Our results show a significant relationship between body condition and vocal performance ($p = 0.006$). Further, our results showed that males who produce complex songs with high vocal performance also exhibited more pronounced epaulets ($p = 0.036$).

## Critical thermal limits and VO2 of Mediterranean geckos at the northern most extent of their range

*Christopher Goodchild, Jade Langoc, Allyson Fenwick*

Mediterranean geckos (Hemidactylus turcicus) are native to the Middle East but spread worldwide, including regions that should be too cold for survival. Critical thermal limits have only been measured for U.S. populations along the Gulf Coast and south Texas. At the University of Central Oklahoma geckos are found outside in temperatures far below published critical thermal minima suggesting that Oklahoma geckos are more cold-tolerant than those previously measured. We take advantage of a well-known, dense population to measure critical thermal maxima, to compare geckos sampled across seasons, and to compare individuals at different life stages. Critical thermal minima and maxima from winter-sampled individuals averaged lower than most published values. Sampling continues through next fall, which will result in better understanding of metabolic responses, differences across seasons, and differences across life stages.

## More to gain, more to lose: interspecific differences in muscle contractile properties in lizards

*Colin Goodman, Stephen Deban*

Thermal effects on locomotor performance are ubiquitous; yet there exists a high degree of heterogeneity among species. One potential source of this heterogeneity is the underlying muscle contractile physiology. We hypothesized that the thermal effects on muscle contractile properties will be larger in species with greater maximal locomotor performance. To test this, we used an in vitro muscle preparation to examine the contractile properties of the m. iliofibularis in three lizard species that differ in their maximal locomotor performance: the veiled chameleon (Chamaeleo calyptratus; lowest performance), brown basilisk (Basiliscus vittatus, moderate performance), and black spiny-tailed iguana (Ctenosaura similis; highest performance). We tested muscles from each species at 20, 25, and 33°C. In spite of large differences in whole-organism performance, we failed to detect any significant differences in thermal effects among species in peak relative shortening velocity. However, we found significant differences in thermal effects among species in peak power, with C. similis exhibiting the greatest thermal sensitivity ($Q_{10,20-25°C} = 4.2$; $Q_{10,25-33°C} = 2.1$) and C. calyptratus exhibiting the lowest thermal sensitivity ($Q_{10,20-25°C} = 3.2$; $Q_{10,25-33°C} = 1.6$). Further, we found significant differences in the shortening velocity at which power was maximized among species, with peak power occurring at greater relative shortening velocities at all temperatures for C. similis. These results suggest that species relying on high performance may suffer greater losses at lower temperatures.

## Are opsins an alarm clock for dormant zooplankton?

*Alexander Goodrich, Joseph Covi, Amalie Mattison*

Encysted brine shrimp embryos undergo a period of reduced metabolic activity and arrested development called diapause. In Artemia franciscana, diapause occurs in the gastrula stage. Environmental cues break diapause and cause further development. One of these well characterized cues is light, but it is unclear what sensors detect light in gastrula stage embryos. One possibility is light sensing proteins called opsins. Opsins detect specific wavelengths of light, and published data indicates that the response of diapause A. franciscana is wavelength dependent. This suggests that specific wavelengths of light detected by opsins are responsible for breaking diapause in A. franciscana. In support of this hypothesis, opsins are differentially expressed during early development according to RNAseq data. Additional data from quantitative real-time PCR measuring the levels of opsin expression during early development of post-diapause A. franciscana will be presented.

## The neural basis of parent-offspring communication in poison frogs

*Billie Goolsby, Tony Chen, Ashlyn Callan, Loranzie Rogers, EmJ Rennich, Mark Cutkosky, Lauren O'Connell*

Parenting quality has far-reaching impacts on many aspects of offspring survival. Signals of need by offspring require accurate and precise interpretation by their caregivers to provide care. However, little is known about the neural basis of communication between parents and offspring, and even less is known in biparental species about how synchrony between parents influences offspring care. Filling this knowledge gap in parental behavior circuit architecture is essential for understanding the brain mechanisms underlying high quality parenting, and how this variation influences offspring development. Poison frog tadpoles are altricial and rely entirely on parental investment for healthy development. In the biparental Mimic poison frog (Ranitomeya imitator), mothers provide more food to tadpoles that beg (vibrate) more intensely, suggesting somatosensation is an important component of offspring signaling. We found that parents, depending on sex, may use different offspring signals to make care decisions. In parallel, we explored how parental brains respond to the begging behavior of their offspring. We found that offspring touch coincides with activation of opioid pathways and suppression of nociceptive pathways. When opioid signaling is perturbed, we found that only high care fathers modify their contact with offspring. Currently, we are delineating what neural pathways are recruited during parental care, and what individual variations drive increased or decreased attentiveness to offspring. Overall, we aim to better understand how endogenous opioids regulate social bonding.

## Desert tails: caudal regeneration trades off with lizard performance in the wild

*Akhila Gopal, Guillermo Garcia Costoya, Noa Ratia, Karla Alujevic, Madison Glenwinkel, Shea McKendree, Kaitlyn Napier, Ethan Carmona Hockstedler, Cody Chapman, Allison Dorny, Michael Logan*

Phenotypic traits often covary in ways that optimize evolutionary trade-offs. For example, when resources are limited, ectothermic organisms may sacrifice time and energy spent engaging in behaviors such as thermoregulation in favor of somatic growth. One form of somatic growth that is important for many lizard species is the regrowth of tail tissue that occurs after caudal autotomy. Caudal autotomy is the voluntarily or involuntarily loss of a lizard's tail, usually in response to a predation or competition event. Regrowth of the tail requires energetic resources that could otherwise be allocated towards thermoregulation, foraging, and mating. Here, we estimate frequency of caudal autotomy and rates of caudal regeneration in wild western fence lizards (Sceloporus occidentalis) from multiple years of intensive mark-recapture at two sites across an elevational gradient in the Great Basin Desert. We combine field and lab measures of population dynamics, life history, thermal physiology, metabolism, and immunology, to understand the contexts in which tail regeneration generates trade-offs with other traits. We discuss how our findings contribute to understanding the evolution of integrated phenotypes and their potential impact on adaptation to environmental change.

## Trashy birds: a comparison of the use of anthropogenic materials in nests across species

*Amber Gordon, Sarah Foltz*

Anthropogenic materials (e.g. plastic bags, food wrappers, paper napkins, etc.) are a form of macropollution that animals commonly encounter and sometimes preferentially seek out, especially in urban environments. Multiple avian species have been documented incorporating various forms of anthropogenic materials into their nests, which alters nest composition and may affect nestling success. Some bird species are less selective than others about the materials used to build their nests, which may relate to their propensity to incorporate anthropogenic materials. There have been few studies comparing species' usage of manmade materials in nest building, or the impacts that these materials may have on reproductive success. In this study, we compared the nesting materials used by 3 different cavity-nesting bird species: eastern bluebirds (Sialia sialis), tree swallows (Tachycineta bicolor), and house sparrows (Passer domesticus). These species bred concurrently in nest boxes at 3 different locations of varying urbanization in southwest Virginia. Nests were collected after breeding was complete and examined for anthropogenic materials. Data analysis is ongoing, but our preliminary results suggest that species differ in their use of anthropogenic materials in nest construction. A better understanding of how, when, and which specific types of anthropogenic materials birds use in nest building will help us to better predict impacts of anthropogenic materials pollution on avian populations that commonly co-exist with humans.

## Arthropod phylogenomics refute the monophyly of Panarthropoda

*Jacob Gorneau, Sarah Crews, Edward Myers, Michelle Trautwein, Lauren Esposito*

Despite focused phylogenetic investigations of many classes within Arthropoda, the evolutionary history of this diverse group remains unclear. Not only are arthropods the most diverse animal group, the group also contains many species of agricultural, commercial, conservation, cultural, medical, and veterinary importance. Past efforts to infer the arthropod phylogeny have been hindered by the amount of missing data due to undersampling of extant and extinct taxa, and the lack of clarity surrounding the closest sister taxon to the Arthropoda. In this study, 1013 single-copy BUSCO loci are used to infer the phylogenetic relationships of all of the major classes of Arthropoda with 142 ingroup representatives, and 13 non-arthropod ecdysozoan outgroups. We infer a topology that is partially reflective of current phylogenetic consensus, but that also reflects some historically proposed relationships that are no longer considered valid. These results call into question our current understanding of arthropod evolution, but also bring to light some older ideas about arthropod relationships that are rooted in morphology. We also employ a range of phylogenetic inference methods to interrogate these relationships, and investigate whether they change in the face of additional missing sequence or terminal data. Additionally, we time-calibrated this phylogeny using node constraints from previous work to infer dates for the origin and diversification of major extant arthropod groups.

## The consequences of life history for mammal cranial evolution

*Anjali Goswami, Julien Clavel, Eve Noirault, Robin Beck, Russell Engelman, Nicole Barber, James Mulqueeney, Lucy Roberts, Roberto Portela-Miguez, Anne-Claire Fabre*

Life history is a significant influence on morphological evolution in numerous clades, and mammals are no exception. The three mammalian orders are distinguished by their developmental strategies, ranging from highly altricial monotremes and marsupials to moderately altricial to precocial placentals. The highly altricial strategy has long been suggested as a significant factor suppressing the morphological and taxonomic diversification of marsupials and limiting their exploration of ecological niches. Previous work has tested this hypothesis with analyses of disparity across crania, jaws, and postcrania and demonstrated that marsupials display less variation in early ossifying elements, specifically the masticatory apparatus and forelimbs. We extend these analyses with high-dimensional analysis of evolutionary rates in cranial bones, demonstrating that precocial placentals have significantly higher rates of evolution in the facial region, including the premaxilla, maxilla, and nasals, relative to both highly altricial and altricial mammals. Smaller differences in rate are observed between these groups in most other cranial elements, though these are near equivalent in the cranial vault. Unexpectedly, altricial placentals show slower rates of evolution relative to highly altricial marsupials and monotremes in most cranial elements except for the vault and basicranium, in which they are comparable in evolutionary rate. These results suggest that the impact of life history on morphological diversification is not limited to extreme differences between subclasses, but rather is broadly observed across mammals.

## Neural expression of the CPEB2 RNA-binding protein is a common feature of ctenophores and bilaterian

*Urvashi Goswami, Yuriy Bobkov, Valeria Dountcheva, Joseph Ryan, Labib Rouhana*

The phylogenetic position of ctenophores as the sister lineage to the rest of animals, establishes that ctenophore neurons either arose independently from cnidarians and bilaterians or were present in the last common animal ancestor (LCA). Studies on the evolution of neurotransmitters, ion channels, and neurogenic factors have not been able to resolve the evolutionary relationship between ctenophore and bilaterian neurons. Cytoplasmic Polyadenylation Element-Binding Proteins (CPEBs) are post-transcriptional regulators that interact with specific target mRNAs to drive timely and localized translation. Two major CPEB families were established in the stem ancestor of animals: CPEB1, which is expressed primarily in oocytes and during early development, and CPEB2, which is expressed during spermatogenesis as well as in neurons, where it drives localized translation in response to synaptic activity. Our single-cell RNA-Seq analyses show that CPEB2 is expressed in developing neurons and in most adult Mnemiopsis neural cell types. Our HCR in situ hybridization data on early stages of Mnemiopsis development show that CPEB2 expression is localized to cells in the developing tentacle bulbs and tentacles. Moving forward, we aim to understand the role of CPEB2 in Mnemiopsis neurons, compare it to CPEB2 activity in bilaterians, and reconstruct the ancestral function of CPEB2 in the LCA of animals. Our work provides a novel perspective from which to investigate the evolutionary history of neural cell types in animals.

## Multilevel perspective reveals heterogeneous acoustic adaptation in the strawberry poison frog

*Max Gotts, Stephen Pacala*

Acoustic traits are sensitive to natural selection due to habitat type and background noise, and simultaneously experience sexual selection. Acoustic divergence may play an important role in facilitating speciation in many species. Acoustic traits are therefore likely to be a crucial component of the evolutionary ecology of many systems. Despite this, acoustic adaptation to heterogeneous environments has remained understudied. This is the first study to investigate likely heterogeneous acoustic adaptation in a frog species, and few, if any, models exist to describe how this process occurs. Acoustic traits may be variable both within and between individuals, which makes heterogeneous acoustic adaptation especially dynamic. This article uses a Bayesian hierarchical (multilevel) analysis of acoustic calls recorded in Islas Bastimentos and Solarte in the Bocas del Toro Archipelago to investigate potential heterogeneous acoustic adaptation in the strawberry poison-dart frog (Oophaga pumilio). We find that both the mean and standard deviation of peak frequency (average call frequency), and the mean and standard deviation of repertoire width (intraindividual variability) shift or increase in Bastimentos. In silico experiments indicate that simulated females were able to distinguish Bastimentos and Solarte males with approximately 82.5% accuracy based on only 4 calls; the eco-evolutionary implications of this are discussed. By describing a model of heterogeneous acoustic adaptation for simple calls, we propose an interpretation of population-level distributions of acoustic phenotypes that provides information not only about the average direction and variability of selection, but also about the average patch size (or periodicity in the case of temporal heterogeneity) and variability in patch size (or temporal unpredictability), and contextualize this model in terms of its application to Bastimentos. The results found here differ from a previous analysis of the archipelago, underscoring the importance of multilevel models.

## Competition between native and introduced snail species in the mid-Atlantic region of North America

*Joseph Goudy, Mitch Williams, Isaac Ligocki*

Globally, invasive species pose a risk to wildlife in many ways, including as potential competitors with native species for access to resources. In the present study, we investigated competition between Mesodon thyroidus and Anguispira alternata, two species native to the mid-Atlantic region in North America, and Cepaea nemoralis, a species introduced to the region. Each of these species shares a similar niche and co-occur in the region, and our aim was to evaluate whether they may compete with one another. One snail of each species was placed together in an arena with two pieces of zucchini and two pieces of squash placed in opposite corners with two pieces of cuttlebone in the center for one week. Trials were filmed continuously, and the time spent eating, sleeping, moving, burrowing and interacting with heterospecifics was recorded. Each species did not differ in the amount of time spent foraging or moving, but A. alternata did spend significantly more time buried in the substrate than either other species. We continue to evaluate whether snails differ in their growth rate, and to what extent social interactions between heterospecifics influence access to food resources.

## What, if anything, is a rhythmic oral process? EMG variation in rodent cyclic oral behaviors

*Francois Gould, Ireneusz Wojtas, Zachary Cohen*

Rodent feeding is characterized by repetitive oral behaviors such as chewing, licking, gnawing, and oral transport. These behaviors are executed by the same hard tissue and muscular structures. Central pattern generators (CPGs) in the brainstem are involved in the initiation and maintenance of these rhythmic behaviors. However, sensory feedback from food materials in the oral cavity also plays a role. Sensory feedback changes depending on what is being ingested, and how the ingested substance changes through oral processing. In this study we tested how variation in repetitive cyclical feeding behaviors differs between solid food eating and liquid drinking. We recorded simultaneous high speed (200 fps) videofluoroscopy and electromyography (EMG) in awake, freely feeding rats. Rats consumed both solid food and water mixed with barium in a single feeding session. Beginning of chewing and licking cycles were identified in the videofluoroscopy to identify cycles in the EMG recordings. Signals from the digastric and mylohyoid muscle were rectified, integrated, and baseline corrected and the area under the curve for each muscle burst calculated for each cycle. The coefficient of variation in both muscles was lower in drinking (digastric: 0.3, mylohyoid: 0.16) than in chewing (digastric: 0.61, mylohyoid: 0.69). The relative importance of CPGs versus cortical motor control may vary in rhythmic feeding behaviors, possibly reflecting changing oral sensory feedback.

## Sensory feedback in a single joint: implications for agility and internal regulation

*Thendral Govindaraj, Gregory Sawicki, T. Richard Nichols*

Houk1 proposed the hypothesis that the stiffness of a muscle was proportional to the ratio of excitatory length feedback from muscle spindles to inhibitory force feedback from Golgi tendon organs. Therefore, impedance and internal regulation against fatigue and environmental heat could be controlled separately. To test the hypothesis in dynamic, locomotion-like conditions, we applied a sinusoidal torque at 2.5 Hz in a novel computational model with one segment and one joint with muscle-tendon unit properties. The model included parameters from the cat hindlimb literature and kept inertias and intrinsic (passive + pre-set active) viscoelastic parameters constant. Our study characterized the apparent impedance for a range of excitatory muscle spindle gains and both inhibitory and excitatory Golgi tendon organ gains. As we predicted, different combinations of spindle and tendon organ gains could achieve the same impedance, even with 20% lower intrinsic impedance. Our results supported the stiffness regulation hypothesis because they showed that changing the ratio of excitatory length to force feedback, both inhibitory and excitatory, could be used to alter joint impedance while leaving internal regulation unaltered. In addition, high excitatory force feedback and low excitatory spindle feedback could lead to high agility and maneuverability, while compromising stability. Therefore, this feedback combination could be beneficial for a small animal, such as a field mouse, being chased by a predator.

[1] Houk 1972, Biocybernetics of motor control

## How are North American breeding birds responding to climate change?

*Lily Gowens, Benjamin Freeman*

p[tClimate change is widely predicted to alter where species live. One prominent hypothesis is that species will track their preferred climates via geographic shifts. One way to test this hypothesis is by combining contemporary and historical survey data to assess range changes and population declines associated with climate warming. In this talk I will examine how North American birds responded to increasing summer temperatures by analyzing 57 years of North American Breeding Bird Survey data. Specifically, I will calculate the community temperature index of each location—this metric represents the average temperature preference of the species in a community. By examining how this metric changes over time I will reveal the degree to which a community is tracking climate warming as the composition of the community changes. In summary my study will test whether avian communities in the United States are tracking increasing summer temperatures, uncovering whether climate warming is driving observed changes in species abundance and community composition.

## A repeatable method of leveraging crustose coralline algae to increase coral larval settlement

*Isha Goyal, Nadege Aoki, Nathan Formel, Chris Keller, Amy Apprill, T. Aran Mooney*

Coral reefs are hubs of ocean diversity, and larval settlement is critical to maintaining populations of reef-building coral. Crustose coralline algae (CCA) are a biochemically diverse, vital component of this diverse reef ecosystem, playing a key role in cueing settlement of coral larvae. Thus, CCA can be used to study and improve this key settlement process under stress, but current experimental methods leveraging CCA are poorly standardized, isolate only certain chemicals, and/or are risky, because experimental success depends on time-sensitive CCA biofilm development. There is a need for integrating CCA and its experimental cues in a predictable, standardizable, repeatable manner that is easily accessible for labs. In an experiment using Pocillipora damicornis coral larvae, we demonstrated the feasibility of using crushed CCA, in powder form, to induce greater settlement rates. Introducing mass-specific quantities of powdered CCA to incubations with coral larvae significantly increased settlement rates above controls [mean = 35% ($p = 0.016$)]. Increasing the quantity of CCA powder (208 – 2500 ppm) beyond the minimum concentration tested, 208 ppm, did not have a clear positive or negative impact on settlement. Rather, settlement plateaued with higher concentrations, after an initial jump upon CCA powder introduction. These findings introduce promising new methods for supporting research and restoration on coral larvae and their recruitment to reefs.

## Sometimes the boat is worth rocking: addressing root causes of inequities in science

*Jasmin Graham*

This keynote address will explore some of the root causes of inequities in science through historical and contemporary real-life examples, storytelling and social science research. It will also demonstrate the importance of equity in science and the value that is added to the field when marginalized communities are welcomed into the field. It will discuss best practices, lessons learned and impacts of existing programs and projects addressing the root causes of inequities in science. The keynote address will close with a Q & A from the audience.

## Collective behavior improves foraging in *Procellariiform* seabirds

*Jesse Granger, Sonke Johnsen, Gabrielle Nevitt*

Procellariiform seabird species use smell to locate food in the open ocean, but how collective behavior / social strategies might improve success rates for olfactory foragers is unknown. Here, we use agent-based models to explore the impact of three social strategies on olfactory foraging: Flock Foraging (foraging in a dispersed flock), Local Enhancement (movement towards individuals that have detected an odorant), and Network Foraging (flock foraging that prioritizes movement towards individuals that have detected an odorant). We found that regardless of the bird's olfactory sensitivity, all social foraging strategies improved success, with network foraging being the most successful. In some scenarios, the use of social strategies resulted in birds with low olfactory sensitivity exceeding the success rates of those with high olfactory sensitivity. We found that social foraging success rates are highly dependent on the range at which birds can perceive one another, which supports reported trade-offs in visual acuity relative to olfactory behavioral sensitivity. Furthermore, we show that by using social strategies, there is high group-success rates even under conditions where $< 10\%$ of foragers are olfactory. Finally, we show that success rates decrease at low population densities. These findings underscore the benefits of social foraging for olfactory-foraging procellariiform seabirds in addition to other species, and the threat that diminishing populations may have on their survival.

## Comparative Analysis of Ovarian Biomaterials in Juvenile and Adult Shiner Perch (C.aggregata)

*Jordan Graves, Janine Ziermann-Canabarro, Jaquan Horton, Stacy Farina, Paola Correa-Alfonzo*

The shiner perch, Cymatogaster aggregata, is a viviparous species known for its capability of superfetation. Shiner perch engage in mating and parturition during the summer months, with offspring born sexually mature. However, females do not undergo their first reproductive event until they reach one year of age. The reproductive system consists of a single cystovarian ovary, and gestation is intrafollicular. Previous research has demonstrated the presence of biomaterials, specifically elastin and collagen, throughout the ovarian cavity. These biomaterials are crucial for the expansion and cushioning of the ovary as embryos develop and play a key role in accommodating cyclic changes in the epithelium of the ovigerous folds during copulation, sperm storage, and embryogenesis. The objective of this study is to investigate and compare the content of elastin and collagen between juvenile and adult shiner perch. This comparison will provide valuable insights into how these biomaterials are organized in the species prior to their first reproductive events.

## The Field and Function of the Historically Black Colleges and Universities in STEM, 2024

*Joseph Graves*

In 1933, W.E.B. Du Bois penetrating essay opposed the "trade school" education model of Booker T. Washington. He argued that historically Black Colleges and Universities (HBCUs) were obliged to prepare their students in the scholarly disciplines. The failure to achieve this would result in Negroes becoming a "doomed and inferior caste" for incalculable time.

In the remainder of the 20th century HBCUs due to chronic underfunding and external societal changes were prevented from doing making significant inroads into the persistent structural racism engrained in American society, particularly in STEM. In addition, affirmative action programs at Historically White Institutions (HWIs), consistently underperformed. This due to their own internal struggles related to the legitimacy of affirmative action as strategy to achieve social justice, and an absence of sufficient numbers of STEM faculty with both a commitment and adequate knowledge to mentor non-White students. In 2023, the Supreme Court of the United States struck down Affirmative Action in higher education.

We are now left with the question of how to respond to this action. Here I will argue for the seminal role of the modern HBCU is addressing underrepresentation in STEM. I will also outline what must be done to allow HBCUs to fill the gap left by the dismantling of affirmative action at HWIs.

## Turn yourself around: analysis of a swimming snake's turn

*Elizabeth Gregorio, Ramiro Godoy-Diana, Anthony Herrel*

Snakes are highly maneuverable when swimming, in part due to their limbless elongated bodies and anguilliform swimming style. They often change direction or stabilize in the water column by coiling, tying and turning their bodies. These techniques allow them to solve a mathematically difficult problem of maximizing torque while minimizing the moment of inertia. In this talk we will consider how Natrix maura accomplishes this goal. To do so we analyze the vortex force and shift in moment of inertia during one turn. These results will enhance our understanding of how animals change directions while swimming and are applicable to the development of bioinspired swimming robots.

## Manipulating individual state during migration: carry-over effects of cumulative stress on survival

*Ilona Grentzmann, Gilles Gauthier, Frédéric Angelier, Bêty Joël, Frédéric Letourneux, Pierre Legagneux*

Cumulative stress can affect fitness by reducing reproduction and survival. However, the effects of multiple stressors on stress physiology and their consequences on demography have received little attention in wild populations and such studies are mostly observational. Here, we investigate the consequences of experimentally imposed stress on greater snow geese (Anser caerulescens atlantica) during spring (pre-breeding) migration. In 2009, female snow geese were captured at a spring staging site and kept in captivity for up to 4 days with or without access to food. Blood samples were taken at capture, banding and release to measure corticosterone (CORT) levels, a stress-response hormone, during the experiment. CORT response peaked within the first hours after capture and decreased during the following days in captivity. We observed a stress-induced CORT response, negatively related to pre- and post-experiment body condition, but unrelated to subsequent reproductive success (presence of offspring in autumn). However, we detected carry-over effects of food deprivation on survival, and marginal effects of pre-experiment spring body condition and stress-induced CORT levels on survival. We showed that the carry-over effects of multiple unpredictable stressors are modulated by individual energy state and the intensity of the hormonal response and can ultimately affect survival and the intensity of the hormonal response and can ultimately affect survival.

## Damage control: does telomere length explain individual variations in survival?

*Ilona Grentzmann, Gilles Gauthier, Cristoforo Silvestri, Frédéric Angelier, Pierre Legagneux*

While chronological age is the number of years since birth, biological age may be defined as the level of deterioration of an organism due to cumulative stress and damage occurring during life. Telomere length (TL) has been increasingly suggested as a marker of biological age in the recent literature. Telomeres are repetitive, non-coding DNA sequences, protecting the coding sequences. At each cellular division, telomeres are mechanically shortened and enzymatically repaired. Individual stress level, metabolic activity and physiological condition may affect the shortening rate by damaging the sequences or modulating telomerase activity, which makes TL a good indicator of cumulated damage and individual quality. We used TL to investigate individual variability in survival in greater snow geese, a long-lived migratory bird species. We found a significant relationship between TL values and chronological age in 180 individuals marked as goslings and recaptured up to 24 years of age despite large individual variability. We also measured TL in 561 individuals marked on the migratory staging area and reobserved for up to 13 years. These TL values are currently integrated into capture-mark-recapture analyses to determine if they can explain variability in survival rate of individuals. Previous results already showed a link between survival, stress and body condition. TL will add information about the cumulative damage over the individuals' lifespan, testing for a possible link between survival and biological age.

## Using transfer entropy to discover how wild gray bats use sound for sensing in groups

*Megan Grey, Eighdi Aung, Nicole Abaid*

Gray bats are a social species that use echolocation to locate objects while flying, but how their sociality impacts their use of sound for sensing has not been rigorously studied. In fact, we expect that calls from neighboring bats may overlap and cause jamming, which suggests that bats may change their calls based on nearby conspecifics. Here, we collect and analyze data from a wild colony to explore whether the number of gray bats emerging from a roost at a given time influences their echolocation calls. Specifically, we explore whether the number of calls and their acoustic properties are influenced by the number of bats present using a time-series analysis tool called transfer entropy. Transfer entropy (TE) was developed using information theory to determine whether information flows from a source time series to a destination time series, given what we know about the past states of the destination. We use TE to explore this data when bats are flying in an unobstructed natural environment and when we introduce an obstacle course to their flight path. We find significant information flow from the number of bats to some salient call properties, including the number of calls per bat and the acoustic power of their calls. These results can be used to define calling behaviors for a motion model of flying bats which actively use echolocation.

## The developmental mechanisms underlying the evolution of the avian pelvis

*Christopher Griffin, Zachary Morris, Bhart-Anjan Bhullar*

The evolution of the avian pelvis is documented by an excellent fossil record. This transition is paralleled during the avian ontogeny, with embryonic pelves initially possessing ancestral anatomies which transform into derived conditions across two days of development. The transient presence of these ancestral features reveals that stem-group forms are not lost to time, enabling investigation of the developmental mechanisms underlying a major anatomical transition. Previous developmental studies have shown that genes (e.g., PAX1) that regulate bone development are expressed in the hip during this critical window. To investigate the role these genes may have played in generating the apomorphic avian pelvis, we captured three-dimensional gene expression patterns in embryos made optically transparent. Lightsheet microscopy allows us to not only quantitatively compare the shape of gene expression patterns to the embryonic pelvic morphology of birds and crocodylians, but also reconstruct gene expression patterns in stem birds. Our next steps will be to mis-express these key genes and cellular processes. We hypothesize that the retention of these states is the result of overall covariation among disparate portions of the archosaurian pelvis. This hypothesis can be tested via these targeted embryonic experiments: inducing these developmental processes early in ontogeny should produce a bird with a hyper-elongated ilium and extremely retroverted pubis, whereas arresting these developmental processes should result in the retention of ancestral states into late ontogeny.

## Micro-environmental correlates of species distributions within an island lizard community

*Katie Griffin, James Stroud*

Species distribution within communities is influenced by habitat charecteristics. We examine the distribution of five Anolis lizard species representing four ecomorph classes across a small island in relation to leaf litter depth and tree canopy cover. Species spatial distribution will be visualized using maps overlaid with habitat characteristics; local density hotspots will be identified using kernel density estimates. We will explicitly test for associations between species presence and density in relation to these habitat features. This study contributes to understanding the ecological factors driving species coexistence in island lizard communities at very geographic scales.

## Skin color development and CRISPR genome editing in the brown anole lizard (*Anolis sagrei*)

*Zoe Griffin, Bonnie Kircher, Richard Behringer*

Animal communication is variable across species. Anolis (anoles) is a large genus of lizards that rely almost exclusively on visual communication cues. The dewlap, a colorful neck skin flap, is heavily used during Anolis communication between potential mates and conspecifics. Though dewlap coloration across the genus is variable, many dewlaps have large patches of red, orange, and yellow pigment, and the developmental basis of this coloration is not well understood. Scarb1 is a receptor associated with yellow pigment development in other visual communicators, and plays a role in digestive and reproductive function across numerous vertebrates. Although the role of scarb1 is well-studied in many vertebrates, its function in reptiles remain unexplored. Here, we investigate the role of scarb1 in the brown anole, Anolis sagrei. We find that this gene is well conserved in Anolis, and is highly expressed in A. sagrei skin, intestines, and reproductive tract. We have also successfully targeted scarb1 with CRISPR guide RNAs in vitro. The goal of this project is to utilize CRISPR/Cas9 to generate mutants to study the functional role of scarb1 in reptiles. We hypothesize scarb1 mutants will lack yellow skin pigment and may have impaired digestive and reproductive function. These data will further our understanding of whether scarb1 plays a conserved role in tetrapod development, strengthening our understanding of color-based signaling and cholesterol transport in an understudied phylum.

## Assessing the Likelihood of Convergent Evolution of Dichromatic Coloration in Dabbling Ducks

*Emily Griffith, Jason Weckstein*

Evidence of repeated gains and losses of a trait across a phylogeny can spark interesting questions about how and why that trait evolves. In the dabbling duck clade (Anseriformes; Anatidae), dichromatic plumage coloration is an iconic example of sex-linked phenotypic variation with a varied and poorly understood evolutionary history. Although most research on sexual dimorphism focuses on repeated gains of male ornamentation, biological evidence suggests that dichromatism in dabbling ducks may be the result of repeated losses of bright coloration in both sexes. Currently, it is unknown what regions of the genome are responsible for controlling bright plumage color in dabbling ducks, or if the trait's genomic underpinnings are consistent across the clade. This study assesses whether the repeated gains and losses of dichromatism the result of either convergence (homoplasy) or incomplete lineage sorting/introgression (hemiplasy) by 1) Comparing the genomes of monochromatic and dichromatic species in three genera of dabbling ducks (Anas, Spatula, and Mareca) through whole genome comparisons of sister monochromatic/dichromatic species, and 2) Utilizing a hybrid phylogenomic/GWAS approach (PhyloGWAS) to map changes in dichromatism to genomic changes across the entire phylogeny. Together, these two approaches allow us to evaluate changes in both coding and non-coding regions of the genome and assess whether or not the repeated gains of dichromatic plumage we see across the phylogeny are an example of true convergence.

## Dietary specialization impacts feeding behavior in arthropod-eating snakes

*Noah Gripshover, Patrick Hennessey, Lance McBrayer, Jesse Meik, Daniel Nicholson, Charles Watson, Christian Cox*

Understanding feeding can be a powerful approach for understanding constraint and integration of morphology and behavior. For example, gape-limited predators cannot process food items using limbs, and therefore must use specialized behavior and morphology to consume prey. However, much remains to be discovered about how gape-limited predators process and consume prey, particularly for dangerous or otherwise difficult prey. In this study, we compared the feeding behavior of two generalist predators, ground snakes and flat-headed snakes, to a specialist predator, the crowned snake which is a centipede-eating specialist. We recorded the prey preference and feeding behavior of each species based on a variety of prey offered ranging from harmless (mealworms) to dangerous (scorpions, spiders, and centipedes). Flat-headed snakes and crowned snakes consumed only centipedes. We found that the generalist flat-headed snakes used generalized feeding behaviors, while specialist crowned snakes stereotypically coiled around, envenomated, and swallowed centipedes headfirst. In contrast, generalist ground snakes consumed all three prey types using different behaviors. Ground Snakes grasped and envenomated scorpions in all trials, and this behavior lasted significantly longer for scorpions than for spiders. Rather than using body restraint, ground snakes often held and dragged spiders across the substrate. Our study reveals unexpected diversity in prey preference and feeding behavior based upon prey defenses, highlighting yet unappreciated diversity of feeding behavior in snakes that allows them to exploit dangerous prey.

## Comparative Immune and Stress Responses in Red-Eared Sliders and Western Painted Turtles

*Santi Groat, Lori Neuman-Lee, Mike LeMaster, Gareth Hopkins, Antonette Tilgner*

Invasive species pose a significant threat to many native species, although the mechanisms that allow invasive species to outcompete native species are still unclear. In this study, we compared the physiology of invasive Red-Eared Sliders (Trachemys scripta elegans) and native Western Painted Turtles (Chrysemys picta bellii), with a focus on understanding species-specific differences in key physiological processes: immune function and the stress response. While Red-Eared Sliders have been extensively studied for their robust immune responses, there are prevalent gaps in our understanding of the physiology of the threatened Western Painted Turtles. We used established methods such as lymphocyte and heterophil counts, bacterial killing ability (BKA), and corticosterone (CORT) measurements to compare the ecophysiology of these species in a semi-urban habitat in the mid-Willamette Valley of Oregon. Our research highlights possible differences in immune function and stress physiology between these species, offering insights into how invasive and native turtle species may differentially cope with environmental challenges while filling in data gaps for Western Painted Turtles. These ecoimmunological findings contribute to broader conservation efforts by improving our understanding of the biological factors that influence species' success in changing habitats.

## From pond to proteome: comparing sperm and egg jelly proteomes of anurans

*Lorin Groll, Amy Shanahan, Miranda Gregory, Ariel Kahrl, Antonio Gomez, Scott Pitnick, Stephen Dorus*

Sperm-female interactions (SFIs) are complex and ubiquitous, but poorly understood. Resolving SFIs may advance our understanding of critical mechanisms of sperm and female reproductive tract diversification, sexual selection, reproductive isolation and idiopathic infertility (including those relevant to conservation efforts). Post-ejaculatory modifications to sperm (PEMS; e.g., capacitation of mammalian sperm) is an important class of SFI, for which externally-fertilizing frogs offer an especially tractable experimental system. Here, we characterized the proteomes of egg jelly and sperm from three anuran species—Bullfrogs, American Toads, and Green Frogs that vary in their egg jelly and sperm structure. We compared the proteomic composition of egg jelly layers and sperm proteomes in light of orthology relationships to determine the nature and degree of divergence among species. This research contributes to our understanding of SFIs and the potential role of proteins in the fertilization process in a clade of closely related vertebrate species with external fertilization.

## The integration of sensory organs and skeletal formation: neuromasts and bones of the facial complex

*Joshua B Gross, Brooke Blackburn, Amanda Powers, Alyssa Hamm*

The development of the facial complex requires coordinated changes between physiological systems. In vertebrates, peripheral sensory organs transmit information from the environment, but must do so in coordination with the cranial architecture. A number of classic studies hypothesized that the organs of the lateral line system - neuromasts - directly induce formation of bone. Here, we compare the development of a freshwater fish, Astyanax mexicanus, which includes both surface- and cave-dwelling morphs. Surface morphs demonstrate highly stereotypical positions for neuromasts and the bones to which they are associated. However, cave-dwelling morphs showed substantial variation - included common fusions between bones. These morphological aberrations are only evident in adulthood. Here, we examined the earliest steps the development of facial bones associated with neuromasts. We sought to determine potential sources of osteoinduction, inclusive of the sensory organ itself, the cranial mesenchyme and nerve fibers. We show that a putative mediator of bone induction, BMP signaling, is evident prior to the first appearance of mineralized bone. This expression implies a clear integration between nerve fiber positions and the eventual positions of the primary ossification centers of canal neuromasts. Using a combination of chemical and manual tissue ablations, we show that removal of the neuromast does not necessarily impede the formation of bone. Taken together, this work sheds on the fundamental origins of facial bones in cavefish, and provides insight to fundamental tissue and molecular interactions that mediate sensory-skeletal integration.

## Ethanol exposure impacts: cardiac development and function in zebrafish

*Lauren Gross, Marosh Furimsky*

Ethanol is commonly used for sterilization and disinfection in the clinical setting and is present in alcoholic beverages when diluted. Chronic ethanol consumption has detrimental effects on organ systems such as the cardiovascular system, nervous system, and digestive system. Researchers have sought to investigate the developmental and physiological effects of prenatal exposure to ethanol, sparking interest in Fetal Alcohol Spectrum Disorder (FASD). Research into FASD has focused on concentration-dependent deficits but not time-dependent deficits. This study focused on both the timing and concentration of exposure to experimental ethanol groups. We hypothesized that when compared to a control, higher ethanol exposure groups will show more extreme changes in cardiovascular morphology and have compromised cardiac function. Furthermore, we hypothesized that when zebrafish are exposed to ethanol early in their life cycle, they will be unable to overcome developmental and physiological deficits when compared to those exposed later in their life cycle. Zebrafish (Danio rerio) were placed at random into ethanol concentration groups (0.0%, 1.0%, 1.5%, 2.0%, and 2.5%) and timing groups (6-24 hpf, 12-24 hpf, 24-48 hpf, and 48-72 hpf). Development, morphology, and physiology of the cardiovascular system were assessed.

## Progestin receptor regulates fertility and spawning in female cichlid *Astatotilapia burtoni*

*Karen Gu, Scott Juntti*

Knowing when to mate and how to behave is important for maximizing reproductive fitness. In the cyclical female reproductive system, reproductive state and behaviors are synchronized through hormones. However, the mechanisms underlying this synchronization are not well understood. We utilize gene editing in the cichlid fish Astatotilapia burtoni to understand the effects of hormones on its well-documented spawning routine. In female cichlids, prostaglandin F2a (PGF2a) drives spawning behaviors. Sensitivity to PGF2a and expression of its receptor, Ptgfr, varies across the reproductive cycle. We look to progestin as a potential regulator of PGF2a sensitivity. Increasing progestin levels (important in final egg maturation) precede PGF2a levels which rise during spawning. Additionally, progestin upregulates ptgfr mRNA in a socially relevant part of the brain. To test whether progestin regulates prostaglandin sensitivity and reproductive behaviors, we developed a CRISPR/Cas9 progestin receptor (PR) mutant. PR-/- mutant females are infertile with large ovaries and reduced spawning behaviors. We utilized in situ hybridization in the brain, behavioral assays, and hormone injections to parse out the effects of PR on the ovary and brain. We demonstrate successful rescue of spawning behavior in the absence of a functional progestin receptor. These surprising results suggest that the PGF2a-sexual behavior circuit is intact in the absence of PR signaling despite PR being necessary for progestin-induced ptgfr mRNA upregulation.

## The role of the vertical septum and neural-haemal spines in swimming mechanics of burrowing wrasses

*Olivia Guerra, Linnea Lungstrom, Mark Westneat*

Evading predators is vital to many fishes' ability to survive in the wild. Sand diving, a burrowing behavior in which an individual conceals itself under substrate, is employed by many wrasses (family Labridae) to avoid predation. Previous investigations show that these wrasses differ from non-burrowing wrasses in morphological traits such as body shape and depth, head shape, vertebral prezygapophyses, and neural spine overlap. Here, we investigate vertebral force transmission in wrasses by examining the diversity in the vertical septum of both burrowing and non-burrowing taxa through the analysis of morphometrics in the neural and haemal spines of the caudal region. We performed 2D geometric morphometrics on vertebral images of burrowing and non-burrowing taxa using the R packages StereoMorph and geomorph to quantify caudal spine shape variation. To demonstrate tension undergone by spines during backbone bending, we developed models by visualizing the collagen fiber system in the vertical septum using polarized light. To improve models, we performed three-point bending flexural tests of caudal vertebra with intact and cut vertical septa using a Mark-10 universal testing tensometer. Results show that sand divers and non-sand divers occupy different regions of vertebral morphospace, and that spines undergo tension within the collagenous fiber system upon backbone bending. Flexural tests also show that the backbone is stiffer with an intact vertical septum, advancing our understanding of its role in swimming mechanics.

## High temperature limits swimming performance in the Death Valley pupfish *Cyprinodon nevadensis*

*Teresa Guerre, Sean Lema, Kristin Hardy*

Maximum temperatures and extreme rainfall events are predicted to increase in some regions under climate change. In fishes, metabolic demands increase under warmer conditions, despite lower dissolved oxygen. This paradox may limit fishes' ability to endure flooding events when they occur during periods of anomalously warm temperatures. Pupfishes in the Death Valley region of California and Nevada, USA, occupy habitats with extremely high summer temperatures. Major flood events in this region typically occur during winter, but more frequent summer floods are predicted with climate change. Here, we investigated how temperature impacted metabolic and swimming performance of adult Cyprinodon nevadensis amargosae pupfish, an endemic species of the Death Valley region. Pupfish were acclimated to 16°C, 27°C, or 35°C for 49 to 101 days, and then tested for metabolic performance (standard metabolic rate, SMR; maximal metabolic rate, MMR; and absolute aerobic scope) and swimming performance (critical swimming speed, Ucrit) using an intermittent respirometry swim-tunnel. Aerobic scope decreased at warmer temperatures, diminishing the ability of pupfish to meet the aerobic energetic demands of swimming under high water velocities. The 35°C pupfish also had decreased Ucrit values compared to 16°C and 27°C. These observations support our hypothesis that aerobic swimming performance in pupfish declines under higher temperatures, which may compromise the ability for pupfishes to endure high-flow flooding events when they co-occur with periods of elevated temperatures.

## What kind of claws do you need to survive? An opossum perspective

*Gabby Guilhon, Brian Beatty, Christine Lee, Michael Granatosky*

Marsupials are known for their intriguing reproductive strategy, characterized by a very short gestation period and highly altricial joeys that are blind, lack fur, and have restricted mobility. Upon birth, joeys must quickly climb and secure a nipple, which is often fewer than the number of offspring, making this a critical selective factor. Here we describe the histological structures of the embryo claw, a key component in its survival. Two embryos of the short-tailed opossum Monodelphis domestica were collected instantly after birth, euthanized, fixed and embedded in paraffin. They were sectioned (10um), mounted on microscope slides, stained using the hematoxylin and eosin protocol, and digitally scanned. The claw exhibited a hypertrophic cartilage line of cells in the distal phalanx, which produces the vascular endothelial growth factor to facilitate bone formation. The periderm typically persists on the surface of the developing epidermis throughout embryogenesis until shortly before birth. However, in opossums, this one-layer thin structure continues to develop after birth. We suggest that this may be necessary to develop a thicker, drier skin that is ready for exposure promptly after birth, even in an underdeveloped embryo. Additionally, an incipient sweat gland was observed in the toe pad region, with space for its development. All these structures support the minimal yet crucial use of the embryo's claw while climbing and could be decisive for their survival.

## The morphology of epipubic bones in marsupials is driven by gait, not reproduction

*Gabby Guilhon, Christine Lee, Michael Granatosky*

Epipubic bones are paired structures found in the pelvic girdle of marsupials, monotremes, and cynodonts, but not in placental mammals. Since their discovery, these bones have been commonly associated with pouch support due to their anatomical position, despite being present in both pouchless females and all males. It has been hypothesized that these bones relate to locomotion and respiration, supporting and stiffening the trunk during running and breathing, but these conclusions were based on a limited phylogenetic sample. In this study, we analyzed the epipubic length and width in males and females from all extant marsupial and monotreme groups to determine whether epipubic bone morphology is more closely related to phylogeny, reproduction, or gait type (i.e., asymmetric or symmetric). Our results showed no significant difference between males and females, refuting the reproduction hypothesis. However, epipubic bone length varied with gait type. Species that primarily use asymmetric gaits (e.g.: kangaroo, Tasmanian devil, brown four-eyed opossum) have longer bones epipubic bones compared to those with symmetric cross-couplet gaits (e.g.: common opossum, koala). This finding supports the locomotion hypothesis and suggests that the primary function of epipubic bones is related to locomotion, likely dating back to their origin in extinct cynodonts. The increased variation in epipubic bone shape observed in animals that adopt asymmetrical gaits supports the interpretation of a release from a cross-couplet locomotor constraint.

## Impact of temperature and stress on shark survival during longlining and tagging

*Clarissa Guillen, Jasmin Graham*

This study investigates the effects of water temperature and stress on shark survival during longlining and tagging operations in the Gulf of Mexico. By examining the relationship between environmental conditions, physical behavior, and mortality rates, we aim to inform sustainable fishing practices and improve shark conservation efforts. Specifically, we measured stress hormone levels upon capture, monitored shark behavior, and recorded mortality rates. Our findings reveal that both water temperature and stress associated with handling can significantly impact shark survival, particularly for vulnerable species and life stages. For example, elevated water temperatures combined with the stress of capture can intensify physiological stress, leading to increased mortality rates. Moreover, higher water temperatures may also indicate a decline in shark populations.

Data collected from Jasmine Graham, the President and Co-Founder at MISS, has been instrumental in this research, providing valuable insights into this shark research. This data has contributed to our understanding of the factors influencing shark survival and informed the development of effective conservation strategies. Our findings highlight the need for targeted conservation measures, including modifications to fishing gear and techniques, to minimize stress on sharks and promote their long-term survival. Additionally, these results highlight the importance of considering environmental factors, such as water temperature, when developing and implementing shark conservation strategies. By further research, we can take proactive steps to protect these vital marine predators.

## Impacts of land development on soil microdiversity and antibiotic production

*Dennis Guillen Castro*

The impact of land development on soil microbial diversity and antibiotic-producing properties is a critical area of investigation due to the escalating expansion of industrialization and the scarcity of effective antibiotics. Low Impact Development (LID) used by development companies aims to preserve ecosystems within their communities. However, the efficacy of LID in maintaining microbial diversity remains uncertain. To address this, soil samples from nine sampling sites—including three undisturbed (UD), three residential (RD), and three Madla Greenway (GW) sites within the VIDA development area and the Texas A&M University-San Antonio campus—will be compared and evaluated. Isolated microbes were screened for antibiotic production and will be genetically characterized to identify microbial compositions at each site. Preliminary findings indicate that undisturbed sites harbor a higher diversity of microbes with antibiotic-producing properties compared to GW and RD sites. This suggests that (LID may not preserve microbial communities as effectively as expected. To better understand our preliminary results, other underdeveloped sites will be examined as controls, and additional Greenway sites will be compared to understand why the GW is not showing higher microbial diversity.

## The 'Bogert Effect' and the evolution of thermal plasticity: a null model approach

*Alex Gunderson*

Physiological acclimation to temperature change is expected to evolve in environments with high levels of temporal temperature variation. This has led to the hypothesis that taxa from habitats with high environmental temperature seasonality should evolve greater capacity for thermal acclimation. However, this hypothesis has low explanatory power, meaning other factors must be in play. Behavioral thermoregulation can reduce selection on thermal physiology (the "Bogert Effect") by reducing the body temperature variation that organisms experience in both space and time. That said, the interplay between behavioral thermoregulation and temporal temperature variation, which should influence the evolution of thermal acclimation, is rarely discussed. I use the classic "null model" approach of Huey, Hertz, and Sinervo (2003) to describe how the Bogert Effect can be applied to understand the evolution thermal acclimation and provide examples with data from lizards.

## Hydration-driven uncoiling of barbule springs in sandgrouse feathers

*Nami Ha, Yang Geng, Maria Martinez, Ling Li, Saad Bhamla*

Namaqua sandgrouse (Pterocles namaqua), inhabiting arid mid-Asian regions, are known for their unique behavior of soaking ventral feathers to transport water to their young. The helical barbules in these feathers enable rapid water absorption and prolonged storage, critical for survival in such environments. Each barbule features distinct helical and straight segments, with the helical regions functioning like springs that uncoil upon wetting. While the coiling-to-uncoiling transition of these barbules has been qualitatively observed, the mechanics behind their uncoiling into a single curl, which facilitates the microscale height necessary for effective water absorption, remain unexplored. This study seeks to systematically characterize the morphological and mechanical properties of these barbules. Our analysis reveals that the barbules, composed of keratin nanofibrils, exhibit a chiral fibril orientation angle of 19°. Using a triboindenter, we determined the elastic modulus (E) of the helical barbule cross-section. Additionally, we calculated key parameters, including bending stiffness (B), elastocapillary length (LEC), and spring constant (K), and compared these with those of other organisms displaying hydration-driven uncoiling behaviors. To further investigate these dynamics, we fabricated paper springs mimicking the barbules' uncoiling behavior, demonstrating controllable uncoiling in response to water exposure.

## Comparison of honeydew excretion between adult and juvenile spotted lanternflies

*Nami Ha, Jacob Harrison, Elio Challita, Elizabeth Clark, Miriam Cooperband, Saad Bhamla*

Spotted lanternflies (Lycorma delicatula) in the Fulgoridae family are insect species that feed on phloem sap rich in sugars and excrete sticky particle-laden honeydew droplets. Understanding the excretion behaviors of spotted lanternflies (SLF) provides insights into how insects at small scales can overcome surface tension and viscous forces. Using high-speed imaging, we explore how adult and juvenile SLF can flick sticky microdroplets without leaving viscous residuals near the stylus. Adult SLF utilize the stylus as a catapult, achieving maximum linear speeds of 2 m/s and accelerations of 15000 m/s2. However, juvenile SLF use the undeveloped stylus as the hinge to expel the honeydew. Different strategies on honeydew excretion by adult and juvenile SLF result in the initial speed of ejected honeydew of 1 m/s and 0.3 m/s, respectively. Reconstructed micro-CT images reveal how internal structures, such as muscles surrounding the stylus, vary between adult and juvenile SLF. For scaling analysis, we quantify the viscosity and surface tension coefficients of fresh honeydew obtained from the field. Our findings reveal that for adult SLF, droplet expulsion is governed by inertia rather than surface tension or viscous forces. In contrast, juvenile SLF primarily rely on surface tension forces to excrete honeydew.

## Predictive simulation of quadrupedal gaits using proximal policy optimization

*Jacob Hackett, Katrina Moore, Monica Daley, Christian Hubicki*

Deep reinforcement learning (DRL) is a prevalent approach to synthesizing quadrupedal gaits in robots. However, it is still relatively new as a predictive simulation tool. As such, gaits produced by these methods embody many non-biological features. For example, common methods such as Proximal Policy Optimization (PPO) produce robotic gaits with stride frequencies over twice that of similarly sized quadrupedal animals. This study seeks to produce animal-like gaits using modern DRL techniques without explicitly rewarding or hard encoding biological features with the intent of predicting animal behaviors in natural environments.

In the tradition of optimal control modeling, we predominantly seek a reward function for DRL to maximize that produces animal-like gait features (e.g. stride frequency, footfall patterns, etc.). Ideally, this reward function should quantitatively replicate these features and explicitly encode biologically plausible costs and considerations (e.g. energy, stability, etc.). Preliminary results show that relaxing reward terms that previously encouraged flat center-of-mass trajectories reduced stride frequency significantly, exhibiting bounding and pronking gaits. Further, training regimens developed by roboticists to maximize gait robustness were empirically responsible for producing such high stride frequencies. Ongoing work seeks to empirically characterize the effects of reward terms common in quadrupedal PPO and present a more parsimonious reward function for predictive simulation. Results will be compared to in-field video data collected of lynx rufus subjects in rough terrain environments. NSF DBI-2319710

## Design and development of a fully autonomous bio-inspired underwater vehicle for extended missions

*Lena Haefele, James Richard, Owen McKenney, Connor McKenzie, Joseph Zhu, Hilary Bart-Smith*

In recent years, bio-inspired autonomous underwater vehicles (AUVs) have attracted considerable attention due to their agile maneuverability, high swimming speed, and impressive efficiency. Current research in AUVs has achieved significant advances in hydrodynamic efficiency by employing optimal kinematic strategies inspired by biology. While some algorithms have been developed for basic autonomous tasks, most AUVs still face limitations in operational duration. In this study, we developed a fully autonomous vehicle based on our previous Mantabot design. The vehicle is equipped with stereo vision cameras for enhanced object detection and utilizes the state-of-the-art Raspberry Pi 5 for fast video processing. We also developed a control algorithm that integrates vision, IMU, and other sensor inputs, enabling robust navigation. To address the challenge of long-duration missions, we implemented a wireless charging strategy using series-series inductive power transfer technology. Our Mantabot is capable of recognizing tank boundaries and avoiding collisions through real-time processing of visual and sensor data. Additionally, it can autonomously search for and identify a docking station when its battery levels are low, navigate towards it with precision, and dock for wireless charging. This capability not only extends the operational duration of the vehicle but also allows it to undertake longer and more complex missions without human intervention, thereby enhancing its utility for extended underwater explorations and research applications.

## Improved method for producing of particles to trace water flow with higher contrast in XROMM studies

*Lukas Hageneder, Andres Vanhooydonck, Sam Van Wassenbergh*

XROMM (X-ray Reconstruction of Moving Morphology) has become an invaluable tool for the analysis of functional morphology in recent years. With growing interested on aquatic feeding mechanics, it has become increasingly important to employ effective methods water flow tracing in this field of research. To address this need, a new type of radio-opaque particles were developed with densities closely matching that of water, bringing them close to be neutrally buoyant and hence allowing to trace the water flow. To do so, a homogenous mixture of metallic powder, air-filled microspheres, and a bonding agent was used. These particles offer improved contrast, faster production over previously used alternatives, and the new production method permits full adjustability of particle size through the application of 3D printing of the production tools. Results show that the new particles provide significantly enhanced visibility and contrast against the background, regardless of their orientation, due to their homogeneous nature. This advancement paves the way for more straightforward and reliable auto-tracking of water flows invisible to the naked eye using X-ray systems.

## Effect of Formalin Preservation on Lizard Toe Pad Shape

*Travis Hagey, Cain Petty*

Formalin is used to preserve specimens by creating cross-links that prevent bacterial decay and effectively preserving them. However, there is evidence of shrinkage occurring during preservation by a small amount ($\sim$ 1-3%). This shrinkage could affect our ability to accurately measure preserved specimens. We quantified the change in shape in geckos/anoles before and after preservation. 23 anoles (16 Anolis carolinesis and 7 Anolis sagrei) and 9 Phelsuma laticauda were collected in Hawaii in 2018. We photographed their toe pads, collected morphological measurements, and then euthanized them. After euthanasia, they were preserved in formalin for 12-24 hours and then kept in 75% ethanol until March 2023. They were then rephotographed and remeasured. Measurements were taken externally using calipers. Toe pad shape and area were measured using three programs: TPSDig, ImageJ, and R. TPSDig was used to record landmark coordinates on our toe pad photographs. ImageJ was used to record area of the lizard toepads. Lastly, R was used to compare toe shape and area of the pre and post preservation toepads and generate plots to visualize our results. Results will be used to dictate if a change in preserved specimens is significant enough to impact future studies using preserved specimens.

## The Mechanical Properties of Shark Skin vary across Ecomorphotypes

*Madeleine Hagood, Joseph Alexander, Marianne Porter*

Shark skin is a composite of dermal denticles embedded in a network of collagenous fibers that make up the dermis. During swimming, this network experiences stress along two distinct axes as forces are transmitted along the body: stiffening along the hoop axis and extending farther longitudinally. The skin is hypothesized to behave as an exotendon, providing mechanical advantage during locomotion and improving swimming performance. Due to variation in the ecology, habitat, and growth patterns of different shark species, we quantified the mechanical behavior of shark skin across 20 species to compare mechanics in an ecological context. Shark species were grouped into one of five ecomorphotypes based on migratory behavior, growth rate, and habitat ecology; benthic, small-bodied non-migratory, medium-bodied migratory, large-bodied migratory, and deep-water medium-bodied non-migratory. Skin samples oriented along the longitudinal and hoop axes were tested in uniaxial tension to failure. We generated stress-strain curves and calculated the tensile strain, strength, stiffness, and toughness of shark skin. We found that the deep-water species had stronger and tougher skin than small-bodied and large-bodied pelagic sharks, and that medium-bodied sharks had stiffer skin than large-bodied species. These results indicate that the mechanical behavior of shark skin may be adapted for ecological and morphological specificity. This work was supported by the United States National Science Foundation (IOS award 194713).

## Assessing the genome of pterobranch hemichordates to explore deuterostome evolution

*Kenneth Halanych, Kevin Kocot, Andrew Mahon*

Pterobranchs are a poorly known group of colonial hemichordates that represent the last major deuterstome body plan to have its complete genome sequenced. Like acorn worms, or enteropneusts, they have a tripartite body plan and a relatively diffuse nervous system. Additionally, individual zooids tend to be > 5mm in size. Pterobranchs are well represented in fossil history as they include graptolites, but today there are only 23 extant species recognized. To better understand pterobranchs' role in deuterostome evolution, we sequenced two species of pterobranchs, For Cephalodiscus nigrescens, we developed a chromosome-level genome assembly using PacBio and DoveTail Hi-C contact mapping, and for Cephalodiscus fumosus we constructed a well-scaffolded PacBio genome. Both were collected during research cruises to Antarctica, as pterobranch diversity is highest in the Southern Ocean. Their genomes are smaller, 284Mb and 213Mb, and more compact than known genomes of acorn worms. BUSCO sores (97.0% and 94.5%, respectively) indicate the genomes are complete. Here we explore the architecture of the pterobranch genome and place observations of the genomes (e.g, gene family expansion and loss, synteny, repetitive elements) in the context of deuterostome evolution.

## Characterizing interactions between forced sinusoidal gravitropism and circumnutation in rice roots

*Madison Hales, Aradhya Rajanala, Yu Yang, Christopher Pierce, Mingyuan Zhu, Philip Benfey, Noah Cowan, Daniel Goldman*

Rice roots (O. sativa) navigate their natural environments using strategies that incorporate various levels of sensory feedback. One class of these strategies are tropisms, behaviors in which a root alters its growth trajectory to grow towards or away from stimuli such as light (phototropism), touch (thigmotropism), or gravity (gravitropism). Another strategy that aids in soil navigation is circumnutation (Taylor et al PNAS 2021), the helical motion of the root tip as it penetrates soil. While these strategies are both actuated by differential cell elongation, their interactions are not well understood. To probe possible interactions of these different behaviors, we applied a sinusoidal gravitropic stimulus to rice roots growing in a clear gel model substrate at frequencies sweeping from much lower (0.077 cycles/hour) to much higher (6 cycles/hour) than the typical circumnutation frequency of 0.5 to 1 cycles/hour, tracking root tip angle versus time. At stimulus frequencies far from the circumnutation period, circumnutation was superimposed on the gravitropic response, such that each oscillation frequency was distinct in the frequency domain. However, at applied stimulus frequencies with periods near the natural circumnutation period, the relationship between these mechanisms was more complicated, with bouts of synchronization and cancellation of the two responses. The interaction between circumnutation and gravitropism suggests a shared regulatory mechanism, where asymmetric auxin accumulation induces localized inhibition of cell elongation, resulting in dynamic root bending.

## Effects of thermal gradients on age and growth characteristics in largemouth bass

*Whitney Hall, Michael Newbrey, Jennifer Newbrey, Ashley Desensi, Brent Hess*

Thermal gradients impact fish species differently, owing to variations in their ecological niches and physiological adaptations. We assessed the effects of thermal gradients on 75 populations of Largemouth Bass (Micropterus salmoides) by integrating data from studies conducted across a wide geographical range extending from 32.3° to 45.2° latitude. Age and growth data were compared to average maximum mean annual temperature (MATMax°C), 24-hour average (MAT24hr°C), and average minimum (MATMin°C) temperatures across different latitudes. The relationships between these three thermal indices and state records for size ($L\infty$), longevity, and total length at ages 3, 5, and 8 (TLAge3,5,8) were examined using least squares regression. Significant positive correlations were found between the three thermal variables and TLAge3,5,8. The R2-values were larger in younger fish and slightly lower by age 8, suggesting that thermal conditions have a greater impact on early growth stages, with reduced influence as fish age. The three thermal indices demonstrated a significant negative correlation with longevity, indicating that warmer temperatures reduce lifespan by 11 years. However, none of the thermal indices significantly affected $L\infty$, suggesting that other factors such as genetics may have a greater influence on the maximum size that a Largemouth Bass can achieve, irrespective of thermal conditions. Although Largemouth Bass have demonstrated various adaptations to warmer temperatures, such as seasonal and vertical migration and adjustments to metabolic rate, the projected rise in global temperatures may surpass their adaptive capacities leading to potential disruptions in growth patterns and longevity.

## How chitons coexist: metabolic rates and thermal tolerances differ among New World Tropical Chiton

*Adriana Halvonik-Sanchez, Amy Maas, Daniel Speiser*

Understanding how closely related species coexist in natural habitats has been a longstanding goal in evolutionary ecology because species coexistence is important for the production and maintenance of biodiversity. Heterogeneous environments are particularly interesting for studying coexistence because the increased habitat complexity can support greater species diversity. In rocky intertidal habitats, oxygen, salinity, and temperature levels can vary drastically within a few meters or centimeters, leading to the formation of numerous microhabitats in which invertebrates with distinct niche preferences can live. Metabolic rates influence the spatial distributions of intertidal invertebrates, so comparisons between species may reveal niche specializations. Thermal conditions can also influence spatial distributions of invertebrates, with the range of physiological tolerance determining what thermal niches a species can occupy. We hypothesized that among sympatric tropical chiton species, those inhabiting high-intertidal microhabitats would have lower metabolic rates but higher thermal optima than those inhabiting low-intertidal and subtidal environments. Metabolic rate was estimated as oxygen consumption in seawater at ambient temperatures (∼23-29°C), whereas thermal tolerance was estimated as the change in heart rate with increasing seawater temperature (25-41°C). It was found that high-intertidal species exhibited lower metabolic rates and higher thermal optima than low-intertidal and subtidal chitons. This study demonstrates that physiological differences among closely related sympatric species can influence their spatial distributions and perhaps contribute to their coexistence.

## Beta-N-methylamino-L-alanine effects on the visual-motor system in adult zebrafish

*Dani Hamilton, Sherri Emer*

Beta-N-methylamino-L-alanine, or BMAA, is a neurotoxin produced by cyanobacteria, which can reproduce rapidly resulting in harmful blue-green algae blooms that may negatively affect aquatic and terrestrial life, including humans. While many environmental toxins are well studied in developing animal models, particularly zebrafish embryos and larvae, studies in adult fish are limited. Thus, our goal was to use adult zebrafish to test the hypothesis that BMAA exposure negatively affects the central nervous system during adulthood. We previously observed in BMAA-exposed fish significantly decreased locomotion during swimming tests and elevated apoptosis in brain regions that function in visual processing. To further understand these effects, here, eyes and brains of fish exposed to BMAA were used in conjunction with immunohistochemistry to evaluate neuroplasticity, locomotion, and apoptosis markers using antibodies for brain-derived neurotrophic factor (BDNF), dopamine receptor, and caspase, respectively. In preliminary assessments, we observed in BMAA-exposed fish BDNF labeling in the brain, plus caspase and minimal dopamine receptor labeling in the brain and retina. Further analysis of behavioral tests and electroretinography results are planned to evaluate visual preference and possible eye damage that could be early indicators of neural injury in the brain. Collectively, these results provide a detailed story of how a common environmental neurotoxin may impact visual-motor pathways in the central nervous system in an adult animal model that is capable of neural repair following damage.

## Conditioning sea turtles to learn magnetic directions

*Will Hammond, Dana Lim, Kenneth Lohmann, Catherine Lohmann*

A wide array of animals, including birds, insects, and sea turtles, sense and use the Earth's magnetic field to direct their movements. Considerable evidence exists that birds and sea turtles hatch with magnetic directional preferences that may be inherited. In loggerhead sea turtles, such directional preferences are exhibited in response to magnetic field markers that exist in oceanic regions along their migratory route. To determine whether turtles can learn magnetic directional preference after hatching, we conditioned juvenile loggerhead turtles (Caretta caretta) to associate magnetic compass directions, either north or south, with food rewards. We placed turtles singly into the center of a two-arm maze inside a magnetic coil system which allowed manipulation of the magnetic field around a turtle. During training, the positions of magnetic north and magnetic south were alternated randomly between trials, and turtles were given a food reward for selecting the correct magnetic direction. We set our learning criterion at 9 correct choices out of a turtle's last 11 attempts (Exact Binomial Test, $p = 0.03$). Our results show that turtles can achieve this criterion, suggesting that turtles have the ability to learn new magnetic compass directions.

## A developmental atlas of *optix* expression in the *Vanessa cardui* imaginal wing disc

*Chloe Hample-Forcier, Dave Angelini, Christina Cota*

Butterflies inhabit many differing ecological communities due in part to their variety of different wing patterns, colors, and textures. Due to the importance of butterflies as an emerging model organism it is crucial to understand the wing's developmental trajectory in greater detail. We aim to create a developmental atlas of larval wing development in Vanessa cardui, by analyzing imaginal discs from each day since the caterpillar's hatching throughout the larval stage, with descriptions of morphological traits, and measurements of disc size and vein length, and in comparison to overall body size. Hybridization chain reaction (HCR) will also be used to determine the time series of expression for genes related to wing patterning, such as decapentaplegic (dpp), in imaginal discs from a variety of developmental stages. Because of the established importance of optix in the development of color patterns, understanding the timeline of how and when optix is expressed within butterflies will also assist in understanding wing development and patterning. Research into the roles that optix and other associated genes play in the fundamental ground plan of pigmentation patterns will provide an important resource, making progress towards establishing Vanessa cardui as a model organism for developmental genetics.

## Elucidating oyster reef biodiversity using eDNA

*Zinia Hampleton, Matthew Kimball, Robert Dunn, Shelby Ziegler, Mercer Brugler*

Current methods to evaluate the biodiversity of marine organisms living on an intertidal oyster reef include walking on the reef to take physical samples and either measurement. In doing so, resident organisms are likely disperse off the reef or burrow into the pluff mud or hide within the complex 3D structure provided by the oyster clumps (and thus are missing from surveys). Other residents may be small and/or parasitic or may represent cryptic species. We are sampling environmental DNA (eDNA) from oyster reefs in four National Estuarine Research Reserves that span from Florida, Georgia, South Carolina and North Carolina. To do so, we collected 2 liters of seawater from the top of the oyster reef on the flood tide and another 2 liters of seawater in the middle of the creek, the latter of which serves as a negative control. We filtered the seawater across a nitrocellulose filter, extracted and quantified DNA, used PCR to amplify genes of interest to target metazoans, fish, and decapods, and had those PCR products sequenced at Azenta using their EZ-Amplicon sequencing service (MiSeg 2 × 250bp). Azenta returned upwards of 1.5 million reads (sequences) per sample. We are using bioinformatics to identify who the DNA sequences belong to and then comparing those IDs with what was physically caught on the oyster reefs using Fyke nets and crab traps as well as an ARIS underwater sonar system.

## A quantitative analysis of the morphology-function relationship in *Polypterus senegalus* armour

*Linfang Han, Emily Standen*

Dermal armour has diversified in morphology throughout vertebrate evolution, impacting its function. To understand the evolutionary origins of armour in osteichthyan fishes, we studied the structural changes of the plesiomorphic ganoid scales of Polypterus senegalus over ontogeny. We link anatomical changes in tissue structure and shape with changes in mechanical properties of scales and skin in these fish. We categorized fish into four age groups and measured morphometric characters of the ganoid scales. Using material testing, we also compared the bending and torsional rigidity contributed by armour in these groups. We found an increase in scale size across all dimensions as fish mature and a change in shape, becoming more rhombic with age. Material testing results indicate that armour does not significantly contribute to torsional rigidity at any age but contributes to bending rigidity as the fish transit from juvenile to adult. As fish mature, the overlap between larger rhombic scales relies more on the protruding anterior process and the organized peg-and-socket joints, forming a continuous integument protecting the body. Improved protection comes at the cost of reduced flexibility. The joints between fish scales allow for a considerable degree of sliding and rotational movement during torsion. However, the oblong anterior process in mature fish restricts the movement of scales in non-horizontal planes during bending.

## Climbing performance in urban and natural populations of green anoles and an introduced competitor

*Maxwell Handen, Maya Philips, Austin Garner*

Scansorial animals require firm contact with the substrate to induce sufficient forces during climbing to resist gravity. Anolis lizards accomplish this through their subdigital adhesive pads and claws which enhance interactions with the substrate through intermolecular adhesion, friction, and mechanical interlocking. Human-made structures and surfaces substantially alter the locomotor environment of Anolis lizards exploiting urban habitats, resulting in significant changes to morphology, performance, and behavior. Although several studies have discovered that urbanization significantly impacts climbing performance in Anolis, these studies have focused on ascending locomotion (i.e., anoles moving uphill). Descending locomotion (i.e., moving downhill) is an often-overlooked aspect of animal locomotion, imposing different physical demands and constraints on the organism. As such, urban and natural populations of Anolis may perform differently and/or use different strategies while descending from arboreal habitats. Here we studied the individual and interactive effects of substrate incline and running orientation on climbing performance in urban and natural populations of the green anole (Anolis carolinensis), as well as an urban population of an introduced competitor, the brown anole (Anolis sagrei). Our findings directly add to our understanding of how scansorial animals effectively move in ecologically relevant conditions and how human habitation and species introductions affect biological populations and communities.

## Love is blind, but worms are not: optical adaptations in sexually mature nereidid polychaetes

*Mary Colleen Hannon, Karen Osborn, Jan Hemmi*

Nereidid annelids are among a group of polychaetes that reproduce via epitoky, a process where ordinarily benthic worms enter the water column to spawn in mass numbers. Prior to spawning, the benthic form, called an atoke, undergoes a metamorphosis that includes restructuring of muscles, expansion of parapodial structures, and rescaling of their four, single-lensed, eyes. Visual systems are metabolically expensive to establish and maintain, suggesting they are equally valuable to the success of the animal. Since these epitokes only spend one to two nights in the water column prior to death and evidence suggests they depend on chemotaxis to find mates, it is surprising to find such extensive modification to their eyes. Using μCT, we reconstruct their field of view, lens geometry, and photosensitive tissue layers, of the nereidid species Alitta succinea, to identify differences in visual capabilities between non-reproductive and reproductive forms. By modeling their vision based on these physical characters, we will be able to predict how vision is involved in spawning behavior.

## Who are you calling a shrimp? Evaluating behavioral strategies in invasive stomatopods

*Sophia Hanscom, Jackie Benson, Megan Porter*

Animal behavior can have enormous ecological impacts on a species' ability to invade new habitats and compete for resources. Behavioral differences in traits such as aggression and boldness have been shown to play an important role in the interactions between native and invasive species. Previous studies have found two behavioral strategies that contribute to invasive species success: behavioral syndromes and the ability to learn. Stomatopods are marine crustaceans recognized for their spectacular visual systems and forceful raptorial appendage strikes. While behavioral comparisons have been made between stomatopod species through territorial contests, the differences in behavioral traits within a smasher species, specifically in the context of invasive species and success in a non-native range, have not been thoroughly studied. This study aims to characterize boldness and aggression within and among individuals of the invasive stomatopod Gonodactylaceus falcatus to determine if either behavioral strategy is present, document overall behavioral variation, and gain insight into how these behaviors may affect intraspecific interactions. Following individual behavioral assays, randomly selected pairs were placed in territorial contests to analyze the impacts of individual behavior on fighting sequence and contest outcome. Studying invasive individuals will allow for inferences regarding their pathway to success and provide a repeatable experimental setup for future tests of native species to understand how this invasive species may impact its sympatric native counterpart.

## Local population variation in life history traits of the Eastern mud snail Ilyanassa obsoleta

*Kora Hansen, Robert Podolsky*

An organism's life history involves how it allocates resources at different stages of ontogeny and is essential to understanding selection pressures over the life cycle. The tradeoff between egg size and number is a fundamental focus of life history theory. In free spawning species, temperature differences across broad geographic ranges can significantly affect this reproductive tradeoff. However, relatively little is known about this pattern in species with embryos that are encapsulated, which can have physiological consequences for development. Furthermore, to assess latitudinal patterns it is also necessary to understand how much variation exists in response to local variation in environmental conditions. We examined variation in adult and embryo characteristics–including adult size, capsule size, egg size, egg number, and egg energy content–for five populations of the Eastern mud snail (Ilyanassa obsoleta) local to Charleston, SC. Adult size, capsule size, and egg number varied significantly among populations, and measures of egg size and energy content are underway. This variation will ultimately be compared to data on latitudinal variation in I. obsoleta from a larger study spanning populations across much of their range from Florida to Maine. The goal of this work is to evaluate the degree to which latitude vs. local processes drives variation in these life history traits. It is especially important to understand these patterns for widely distributed populations given current warming ocean temperatures.

## Postural stability during locomotion is species-specific and dependent on limb posture

*Claire Hanson, Alexander Klishko, Seyed Mohammad Ali Rahmati, Hangue Park, Boris Prilutsky, Turgay Akay*

Postural stability is a major requirement for functional locomotion. Crouched gaits of some animals, e.g. mice, may increase stability compared to animals with more extended leg postures, e.g. cats, horses, and humans. We compared lateral dynamic stability between cats and wild-type mice during treadmill walking at speeds of 0.4 m/s and 0.1 m/s, respectively, corresponding to comparable Froude numbers of 0.065 and 0.05. We obtained lateral displacements of the extrapolated center-of-mass and center-of-pressure of five wild-type mice walking on a treadmill with a transparent belt. The same kinematic variables were obtained for four cats walking on a treadmill using 3D motion capture. The normalized margin of lateral dynamic stability (the dimensionless impulse required to destabilize the body) was over 5 times greater in mice than in cats. This indicates that mice have significantly higher lateral postural stability during walking than cats due to their crouched posture during gait.

## Scorpions use flexible, multi-jointed tails for rapid defensive strikes

*Sophie Hanson, Jacob Harrison, Saad Bhamla*

Scorpions (Buthidae) rapidly extend their tail to strike their target with their notorious stinger. This dynamic movement requires rapid actuation, controlled extension, and high mobility of multiple joints in the segmented tail (metasoma). It is currently thought that scorpion strikes are directly powered by muscle, yet a finer understanding of the integrated mechanics across each segment is required to more completely understand the mechanism(s) that power such a dynamic movement. To investigate strike mechanics, we quantify kinematics (duration, speed, acceleration) and mobility (relative angle and rotation of each metasomal segment) of defensive strikes in Tityus silvestris. We collected scorpions in the Peruvian Amazon Rainforest and filmed strikes using high-speed videography. Using pose estimation software, we successfully tracked and analyzed 32 strikes from 7 individuals (body mass: 0.273 $\pm$ 0.06 g). Strikes occurred over an average of 166.53 ms (33.33–680 ms). We found that scorpions extended their metasoma and telson (stinger) independently of one another, providing multiple degrees of freedom. Tracking of each metasomal segment revealed that the tail is highly flexible, achieving 180 degrees in extension. Taken together, our findings will inform the design of soft-actuated robotics with compliant, highly mobile joints integrated across a segmented body.

## Ecomorphology's role in the limb skeleton of the polyphenic eastern newt

*Aaron Hardgrave, Richard Carter*

Unlike the common amphibian with two major life stages, the Eastern newt (Notophthalmus viridescens) has a life cycle typically split into three phases, commonly called a triphasic life cycle. The larvae are fully aquatic, eventually metamorphosing into terrestrial juveniles called efts. Upon sexual maturity, the eft will metamorphose into a semi-aquatic adult whose external morphology resembles other aquatic salamander species. This newt can also undergo polyphenic, alternative life cycle strategies that are not as common, including an aquatic juvenile stage and a facultatively paedomorphic adult stage. Since the different life stages of these salamanders occupy different ecological niches (terrestrial vs. semi-aquatic vs. fully aquatic) throughout their lives and, therefore likely experience various physical forces on their skeletons, they provide a unique model to study musculoskeletal changes across ontogeny and ecology. We hypothesize that ontogenetic niche shifts and the associated shifts in locomotion biomechanics will coincide with shifts in the morphology of limbs. Using micro-computed tomography (µCT) and geometric morphometrics (GMM), we quantified shape changes of limb bones across different life stages (terrestrial juvenile, aquatic juvenile, paedomorph, adult). Our findings indicate a correlation between the form and function of specific bones in the limbs, with ecological differences and the associated biomechanics being the main contributors to these variances.

## Avian host corticosterone is not affected by observation of diseased conspecifics

*Bennett Hardy, Madeleine Chang, Sean McCallum, Sophia Santangelo, Patricia Lopes*

Organisms commonly respond to stressors in their environment by increasing the secretion of glucocorticoid hormones (e.g., corticosterone; hereafter CORT) via activation of the hypothalamic-pituitary-adrenal axis. While increased CORT is acknowledged as a response to predation risk by organisms inhabiting a landscape of fear, new research raises the potential for changes in CORT as a response to the risk of parasitism by organisms in a landscape of disgust. An increase in CORT of a healthy, uninfected individual in response to their perception of the risk of parasitism in their environment could change their susceptibility to parasitism, highlighting a significant role for CORT to alter host-pathogen dynamics. To investigate the effects of parasitism risk on host physiology (i.e., CORT), we conducted an experiment where healthy domestic canaries (Serinus canaria) observed canaries either infected with Mycoplasma gallisepticum (MG), which present behavioral and visual symptoms of infection, or symptom-free, sham-infected controls. We measured CORT from blood plasma samples collected after either long-term (days) or short-term (one hour) observation of MG or sham infected individuals. We found no difference in CORT levels between observers of MG or sham-infected birds at either time point. We suggest further research should investigate changes in CORT at finer scales to ensure a complete picture of CORT profiles in response to parasitism risk.

## Ordovician Vertebrates and the Origin of Bone Remodeling

*Yara Haridy, Neil Shubin*

Bone remodeling is an essential physiological process where bone resorbing cells, osteoclasts, remove bone tissue and osteoblasts deposit new bone tissue. The remodeling process is critical for growth, mineral homeostasis, tooth eruption and fracture repair. Additionally, remodeling is correlated with metabolic rate, and therefore has been used extensively in paleontology as a marker for ancient physiology, yet little is known about its evolutionary origin. Previous studies found histological evidence of remodeling in a late Devonian 'placoderm', this was hypothesized to result from a shift in growth rate due to the origin of jaws and predation. While some evidence of resorption has been found in basal jawless vertebrates, the accepted paradigm is that these early skeletal tissues were simpler and grew by accretion and only had superficial resorption. Here we use high resolution synchrotron tomography, FIB-SEM imaging and traditional histology to show that the Middle Ordovician jawless vertebrate Astraspis had extensive secondary osteons, classic markers of vascular led internal bone remodeling. Interestingly, Astraspis like other heterostracans has bone that lacks osteocytes, a cell type that appears later in evolution but is thought to be critical in bone remodeling in modern gnathostomes. These results in shift the origin of remodeling back ~100 million years, supporting the hypothesis that the essential physiological tool kit that our modern bones demonstrate appeared at the origin of vertebrate skeletons.

## Replacing exams with comics: Moving toward universally designed assessment

*Cindy Harley*

Although exams are often used to assess student performance, their implementation as high-states assignments is problematic for a multitude of reasons. For example, exams result in a stressful environment demonstrated to be statistically more likely to adversely impact neurodivergent and minority students regardless of their content knowledge. Furthermore, beyond assessment of content knowledge exams do little to develop career related skills. Thus I wanted to create a more authentic means of assessment which better develops transferable skills and decreases impacts of external influences on test performance. To that end, following the principles of Universal Design for Learning (UDL), I have created what I believe to be a Universally Designed Assessment mechanism using comics to assess student learning while teaching them how to communicate scientific ideas, interrelate ideas, take notes, and take ownership of the information that they are learning. Through four semester projects students address the same topics that would be present on a given exam, but express their understanding in a way unique to them. In addition, students engage in peer review which enables them to learn how to give and implement constructive feedback while reaffirming their understanding of content. Preliminary data have shown reductions in equity gaps related to grades and retention. Students have self reported that this form of assessment leads to longer term recall, increased learning, and skills enhancement.

## Homeostasis: the game– a card game for teaching about the endocrine system

*Cindy Harley, Elizabeth Leininger*

Understanding of homeostasis requires system level thinking and abstract reasoning to appreciate that systems are in a state of dynamic stability. As such, homeostasis continues to be a difficult topic for students to understand. Further, teaching homeostasis in a lab setting presents a road block for instructors attempting to engage students because many hormones work over time periods that far exceed a typical lab period. Simulations related to homeostasis typically do not excite and engage students the way a hands-on activity would. To overcome these obstacles we created Homeostasis: The Game. During the game, teams of students act collaboratively as the endocrine system playing hormone cards to help 'Bill,' a person who makes poor life decisions, maintain homeostasis through monitoring the variables of pH, blood pressure, and blood glucose. Student understanding was assessed before and after gameplay in introductory biology settings at two public colleges, one small public liberal arts college and one small state university. As a result of playing the game, students on average exhibited increases in their understanding of homeostasis and decreases in several misconceptions about homeostasis. Additionally, students were able to correctly indicate more information about specific hormones. Thus, through using a game that fits easily within a lab period, we have created an active learning experience which effectively increases student understanding about homeostasis and is easy for instructors to implement.

## AutoVert: Semi-Automatic segmentation of repeated structures in 3D Slicer

*Anna Harner, Cassandra Donatelli, Jonathan Huie*

The digital segmentation of anatomical structures is a fundamental aspect of many medical and biological studies. Segmentation involves digitally labeling a piece of morphology represented by an image stack typically generated from a CT or MRI scan. However, this process can be time consuming and a limiting factor in large comparative studies. Semi-automatic and fully-automatic segmentation methods have been developed to address this problem. However most tools are specialized for one task (e.g. locating tumors), cannot handle diverse morphologies, or require large training datasets. Here, we present AutoVert, a tool implemented in 3D Slicer to semi-automatically segment repeating structures such as vertebrae, ribs, or armor plates. We modified Meta's 2D "Segment Anything" model to segment 3D data by iteratively segmenting out the structure in a series of images. Because "Segment Anything" has already been trained on 1.1 million images and 1.1 billion masks, AutoVert does not require additional training data to generate high quality segments. With the 3D Slicer user interface, users will be able to select and segment desired structures with a few clicks or by defining a bounding box. We found that our module can create a segmentation 6x faster than existing 3D Slicer methods. Though AutoVert was initially designed to segment repeating structures, the module also works for individual structures (i.e. skull, femur, etc.).

## Hybrid breakdown and Haldane's rule in ZW taxa: A physiological perspective

*Natalie Harris, KayLene Yamada, Geoffrey Hill, Brian Counterman, Wendy Hood*

The fall armyworm (Spodoptera frugiperda) has two sympatric strains (corn and rice). The strains mate at different time periods during the night, have different fertility rates, and previous research revealed that their hybrids have reduced fertility and behavioral differences. We investigated the mitochondrial respiratory differences between the parental strains and their hybrid offspring to determine if differences appear to be the result of mito-nuclear incompatibilities or are simply the result of poor cofunction by nuclear genomes from the two strains. We specifically tested if combining the N genome of one strain with the mitochondrial genome from the other results in a reduction of respiratory efficiency and energy production that could explain the lower fitness of hybrids. Haldane's Rule predicts that the heterogametic sex (females) hybrids should show the greatest dysfunction, due to the exposure of deleterious mutations on the sex chromosome. We found clear evidence of reduced respiratory efficiency and energy production of hybrids relative to parentals, and differences between the strains. Interestingly, hybrid females don't show greater dysfunction than hybrid males. Our results indicate an interesting pattern between the two crosses and significant respiratory dysfunction in the hybrids compared to the parental strains. The presentation will discuss if and how these results may support a role of mitonuclear incompatibilities and the sex chromosomes in driving the reduced hybrid fitness that keeps these strains reproductively isolated.

## Juvenile sharpshooters use hydrophobic hairs to eject their waste droplets

*Jacob Harrison, Elio Challita, Pankaj Rohilla, Nami Ha, Thu Truong, Ryan Kang, Elizabeth Clark, Saad Bhamla*

Adult sharpshooters (Cicadellidae) use a catapult mechanism to eject droplets of excreta. This mechanism conserves energy, critical as sharpshooters feed exclusively on xylem-sap, a nutrient-poor food source (95% water). However, in sharpshooters, none of the nymphal instars possess the anal stylet needed for the adult's catapult mechanism. Here we examine how juvenile sharpshooters (0.15 - 0.8x smaller than adults) are capable of fluid ejection without the use of the anal stylet. We collected high-speed videography of fluid ejection in juvenile sharpshooters from three species, Homalodisca vitripennis, Graphocephala atropunctata, and Graphocephala coccinea (167 trials; $N = 4$-6 individuals per species, 1-13 trials per individual). Juvenile sharpshooters possess hydrophobic hairs surrounding the anal pore that deform waste droplets as they form through elastocapillary interactions. Eventually, the deformed droplet debonds from the anal pore, rapidly returning the droplet to a spherical shape and ejecting the droplet. Droplet formation takes $88 \pm 27$ ms and the droplet is ejected at $0.1 \pm 0.05$ m/s. Micro-CT scans of juvenile sharpshooters show the anal stylet develops within the abdomen, just beneath the anal pore, but does not appear to play an active role during fluid ejection in juveniles. These experiments inform how sharpshooters accomplish waste excretion across ontogeny and provide insights into the emergence of biomechanical systems across developmental stages.

## Teaching curiosity: lessons from the in-situ Jungle Biomechanics Lab

*Jacob Harrison, Justina Jackson, Geoffrey Gallice, Johana Reyes, Jaime Nina, Saad Bhamla*

The in-situ Jungle Biomechanics Lab is a two-week field research experience in the Peruvian Amazon Rainforest for early-career scientists, undergrads to postdocs. This NSF-funded program helps participants learn how to bring their interdisciplinary science into the field. However, one of the JBL program's goals is to offer opportunities for scientists to make novel observations in biodiverse habitats and help them find new curiosity-based lines of questions. Fostering creativity in the field within a short time frame can be challenging. Facilitating curiosity-based research is often overlooked in science education, but we argue it is a critical part of developing future generations of scientists. Here we discuss the in-situ Jungle Biomechanics Lab program, the research facilities, and community outreach programs. We show our approach to making an inclusive field research experience and how critical this is for fostering creativity in the challenging environments of the field. These lessons inform methods for engaging and collaborative interdisciplinary field research and provide insights on establishing collaborations with local communities in the field.

## Investigating the role of hydrogen peroxide and its links to nutritional stress in social bees

*Audrey Harrod, Lewis J. Bartlett*

Infectious disease is a challenge for eusocial insects living in large social groups, resulting in a plethora of defensive mechanisms. One example is the production of hydrogen peroxide (H2O2) within honey stores. H2O2 is synthesized by honeybee production of glucose oxidase (GOX) and maintained within honey stores at varying concentrations as a proactive defense against microbial growth. The GOX required for the oxidation of H2O2 is costly to produce, and the oxidative stress from H2O2 consumption is costly to tolerate. Developing larvae are also fed honey containing H2O2, to which they exhibit a high tolerance. Despite the high cost of H2O2 production and tolerance, it is a constitutive part of the honeybee social immunity response though it remains little investigated and the extent of its application, as well as the factors impacting production, are currently unclear. This poster presents the preliminary results of a study investigating the link between supplementary nutrition and social immunity by comparing H2O2 production in honeybee and bumblebee colonies supplemented with different sugar feeds during periods of low nectar flow.

## Ancient climate changes drive mode and tempo of cave colonization in North American cavefishes

*Pamela Hart, Melissa Ricon-Sandoval, Fernando Melendez-Velasquez, Emily Troyer, Ricardo Betancur-R, Jonathan Armbruster, Orran Bierstein, Brendan Gough, Matthew Niemiller, Dahiana Arcila*

Studying organismal evolution in extreme environments has led to breakthroughs and has inspired advances in human health, technology, and even the basis of life. Caves and cavefishes offer an ideal system to study evolution in and adaptations to harsh environments because multiple lineages have independently colonized these habitats, turning them into natural laboratories with replication. Within our study group, the North American amblyopsid fishes (Percopsiformes, Amblyopsidae) contain three levels of cave evolution: cave, surface-cave, and surface. This group has experienced at least three independent colonization events into cave environments. The timing of amblyopsid fishes' evolution, their colonization of caves, and the genetic mechanisms underlying extreme morphological phenotypes (e.g., lack of pigmentation, blindness) remain mysterious. To tackle this knowledge gap, we estimated a new phylogeny using 1105 exon markers that aligns with previous phylogenomic reconstructions, including the eyed facultative cave-dwelling genus nested within the blind cavefishes. Employing a total-evidence dating Bayesian approach and integrating extant and fossil percopsiform species, we proposed a new time of evolution for the group. Evolutionary model fitting supports global climate changes during the Paleogene and Neogene spurred cave colonization. We identified both intensified and relaxed selection in troglomorphic candidate loci generated by whole genome sequencing. This study helps our understanding of organismal evolution in extreme environments by adding insights into the timing and specific genetic factors associated with cave colonization events.

## 'Magic Box' perspectives: audience impact on decision-making and stress in Zebra Finches

*Ashlyn Hartman, Emily Brandow, Jason Davis*

Zebra finches (Taeniopygia guttata castanotis) are a highly social species that offer a unique perspective on how social context influences individual behavior. This study examines how the presence of social cues affects decision-making and stress in finches when one bird observes another encountering a novel item. During testing, two finches are socially isolated in double-cage dyads, where one finch is exposed to a "mystery box" with a novel item and the other has access to a millet-filled treat box. Both birds can see each other, but neither bird can see what is in the other bird's box. Behaviors are quantified from video and a post-test blood sample is taken from each bird to compare corticosterone and catecholamine metabolite levels to baseline. This procedure allows us to explore how audience effects, including sex variation, and observation of others response influence stress reactivity and neophobia/neophilia.

## It's easy being green: the role of a highly stable serpin in the camouflage of glassfrogs

*Grace Harvey, Vignesh Ravichandran, Jesse Delia, Carlos Taboada*

Blue coloration in animals is achieved via a variety of mechanisms, but mostly commonly it involves structural arrangements that reflect specific wavelengths of light. In general, blue pigments are rare in nature. However, many frogs use serpins that bind the blood-derived pigment biliverdin (BV), resulting in a blue-green pigment used in cryptic coloration. This function is surprising, as serpins are a superfamily of serine protease inhibitors with multiple functions (eg. regulation of inflammation). While glassfrogs (Centrolenidae) have biliverdin-binding serpins (BBS) that are responsible for their green hues, little is known about the biophysical properties of BBS and the resulting phenotypic outcomes. Using multiple biochemical approaches, BBS from the powdered glassfrog, Teratohyla pulverata (tpBBS) was purified, sequenced and analyzed. We found the spectral features show similarities to other BBSs, but with the visible light absorption peak shifted towards the near-infrared. To test temperature effects on tpBBS optical properties, we conducted thermal ramps of native tpBBS, revealing the protein's high-temperature stability. Mass spectrometry of native and cross-linked protein indicated that most tpBBS is naturally truncated in vivo, which might account for its stability. The highly specific cleavage site suggests that tpBBS might be recognized by a particular protease, indicating other potential biological functions. The role of tpBBS's in camouflage and other potential physiological functions will be discussed in the context of protein functional innovation and diversification.

## Opsin localization using HCR-FISH in scallop larvae provides new insights into larval photoreception

*MD Shazid Hasan, Jorge Audino, Kyle McElroy, Jeanne Serb*

Organisms utilize sensory receptors, including the prominent seven-transmembrane G-coupled protein receptor (GPCR) superfamily, to detect environmental stimuli, hormones, and neurotransmitters. Notably, opsins, a subgroup of GPCRs, play a crucial role in animal vision. Genomic annotations combined with phylogenetic analysis have shown significant variation in opsin genes among pteriomorphian bivalves, including surprisingly high genomic abundance of r-opsin and xenopsin copies. Intriguingly, we found that these opsin genes are expressed at comparatively higher levels in larvae than in the photosensitive adult mantle. This led us to ask: where are these opsin types expressed in larvae, how might they play a role during the pelagic lifecycle, and what are their potential involvement in metamorphosis? To address these questions, we used the Hybridization Chain Reaction (HCR)-Fluorescence in situ hybridization (FISH) technique to determine the location of opsin expression in the pediveliger larvae (7 days post-fertilization) of Argopecten irradians. We found that expression patterns differ among opsin types. For example, retinochrome was highly expressed in the mantle margin, but did not overlap with r-opsin expression. Understanding the spatiotemporal expression patterns of opsins across bivalve life stages will be essential for elucidating their role in species-specific developmental cues.

## The Role of Information Representation in Fostering Bio-Inspired Designs in Engineering

*Hadear Hassan, Astrid Layton*

Engineering designs inspired by the natural world encompass many innovative and novel solutions to human problems, often solving problems where engineers had initially only seen trade-offs. Most bio-inspired engineering designs however have been the result of either chance observation or dedicated study, hindering efforts to have biological inspiration become a mainstream tool. Efforts have been made to develop normative bio-inspired processes and identify approaches that can aid the non-experts in biology find and successfully implement a bioinspired strategy, however true accessibility is still lacking. This work uses classroom studies to understand the impact of information representation on engineering design creativity under a biologically inspired engineering umbrella. Small teams of students were provided with a common problem description, followed by different sets of biological information. This biological information was made up of various technical levels of figures, discipline-specific terminology, and reading levels. The students were tasked with generating bio-inspired design solutions using the provided biological information. Sketches and feedbacks from students provide insight into a possible connection between information representation (text vs. images, reading level, disciplinary overlap, ideation novelty and diversity scores) and bio-inspired engineering designs. Using images and different levels of technical complexity in the text are possible routes for improving successful interdisciplinary knowledge transfer in ways that broaden the accessibility of problem driven interdisciplinary design.

## Influence of developmental temperature on hatchling metabolic rates in prairie lizards

*Benjamin Haussmann, Garret Peterson, Travis Robbins*

In ectotherms, the temperature at which an embryo develops can influence morphology and physiology of the individual post-hatch. These temperature-induced phenotypes can impact life history traits and fitness. For those ectotherms that span large geographic ranges, populations often exist along thermal clines and experience different embryonic thermal regimes that may cause differences in post-hatch phenotypes. For instance, metabolic rates of hatchlings can experience variation caused by embryonic developmental environments. Because metabolism regulates energy used in all aspects of life, shifts in ontogenetic metabolic rates can influence a variety of fitness related phenotypes. This study investigates the effect of embryonic developmental temperature and population of origin on hatchling metabolic rates in the prairie lizard, Sceloporus consobrinus. Embryos from thermally distinct populations experienced an embryonic developmental treatment of either 25°C or 31°C. We measured metabolic rates of hatchlings from both treatments at eight weeks of age. Regardless of population, hatchlings who experienced the 25°C developmental treatment had higher metabolic rates than hatchlings who experienced the 31°C developmental treatment. Our findings also potentially indicate that populations from cooler environments (northern latitudes) have increased metabolic rates compared to populations from warmer environments (southern latitudes). The increased metabolic rate in hatchlings developed at 25°C may be a compensatory growth response related to delayed hatching.

## What shape is magnetic information?

*Hazel Havens*

Despite compelling behavioral evidence that phylogenetically diverse animals can sense Earth's magnetic field and use it to navigate, the sensory and processing structures underlying this ability have yet to be conclusively identified in any species. In addition to limiting how we are able to study the magnetic sense, this uncertainty also necessitates that we make assumptions about the shape (or parameterization) of magnetic information encoded by animals. Commonly, we describe the magnetic information available to animals as a combination of magnetic intensity (overall strength of the field), inclination angle (angle between the field and Earth's surface), and azimuth (horizontal angle of the field). These components, however, are orthogonal decompositions of a fundamentally contiguous, three-dimensional signal. While this kind of signal decomposition is a common strategy in human-engineered systems, animals do not always employ similar strategies for processing sensory information. Here we explore whether animals might encode the magnetic field in ways other than as separate orthogonal components and, in particular, what benefits encoding the magnetic field as a contiguous signal might confer.

## Are studies with big, significant results cited more? Citation bias in ecology and evolution

*Justin Havird, Keri Greig, H. Chapman Tripp, Julia York, Zarluis Mijango-Ramos, Jess Sterling, Erik Iverson, Anat Belasen, Joseph Dubie, Tianyi Xu, Bahar Kasgari, Ryan Weaver*

Bias can exist at any part of the modern scientific process, from what studies get funded to how they are conducted and ultimately how they are disseminated. Publication bias is often considered in meta-analyses and occurs when the outcome of a study affects its likelihood to be published. For example, non-significant results may be less likely to be published. A related idea is citation bias, in which studies with large, significant effects are cited more than those with moderate or non-significant effects. While citation bias has been documented in medical studies, some have suggested it may be less prominent in ecology/evolution because publications in these fields often present multiple results and complex narratives. To quantify this, we examined meta-analyses in the ecology/evolution literature, each of which contained numerous studies that addressed the same hypothesis. We asked whether citation rates correlated with quantified effect sizes within each meta-analysis and if citation rates were higher in studies reporting significant vs. non-significant effects. Here, we report preliminary data from this analysis along with consideration of how to detect and mitigate biases in ecology/evolution.

## Dorsal-ventral patterning mechanisms across the fin to limb transition

*Brent Hawkins*

Tetrapod limbs require dorsal-ventral (DV) polarity for their function. The genes En1, Wnt7a, and Lmx1b are essential to establish DV patterning in mouse limbs. However, it is unclear how conserved these mechanisms are, or if DV polarity arose uniquely in the tetrapods. Using high resolution in situs we show that en1, wnt7a, and lmx1bb are expressed in non-overlapping, DV resolved domains of the developing zebrafish pectoral fin, as in limbs. While somatic deletion of lmx1bb is lethal, mosaic loss-of-function results in loss of dorsal identity, causing a "double ventral" phenotype of the pectoral fin. Next, we identified limb-specific lmx1b regulatory elements conserved across gnathostome evolution. As in mouse, targeted removal of an identified 'master regulatory hub' from the zebrafish lmx1bb paralog recapitulated the double ventral phenotype while retaining viability. These results indicate that both the function and regulation of Lmx1b to specify dorsal identity were present in the bony fish ancestor prior to the fin-to-limb transition and has been conserved in teleosts and tetrapods. Surprising, although many developmental genetic mechanisms that pattern paired appendages can be traced to their origin in unpaired fins, we find that these fins are unaffected in our lmx1bb mutants, suggesting that lmx1b may have evolved divergent function and regulation in paired appendages. Furthermore, an analysis of engrailed gene function suggests an unexpected shift in ventral patterning during tetrapod limb evolution.

## Differences in tail use during steady swimming in bluegill and pumpkinseed sunfish

*Olivia Hawkins, Andrew Clark, Eric Tytell*

Bluegill (Lepomis macrochirus) and pumpkinseed (Lepomis gibbosus) are closely related sunfishes that have very similar body shapes and tend to live in the same habitats. Because of these similarities, we hypothesized that they would also swim in a similar way. Surprisingly, we found that they seem to swim differently, using different tail beat frequencies and amplitudes when swimming at the same speed. Our aims were to 1) understand how amplitude and tail beat frequency change as swimming speed increases for both species, and 2) determine if there are differences in the recruitment of posterior red and white muscle between the two species. We filmed bluegill and pumpkinseed sunfish in 3D at 100 fps across swim speeds of ~0.5-2.4 BLs-1 and then used electromyography (EMG) to record muscle activity in bilateral red and white muscle. We find that at higher speeds, pumpkinseed increase their tail-beat frequency more than bluegill as swimming speed increases. Such differences in the steady swimming behavior of pumpkinseed and bluegill lead to similar outcomes, which suggests that there may be hidden functional or morphological diversity influencing the observed ecological separation of centrarchid fishes.

## Assessing leukocyte populations in watersnakes from Arkansas using flow cytometry

*Natalie Haydt, Grant Dawson, Jeremy Chamberlain, Daniel McDermott, Lori Neuman-Lee*

Quantifying white blood cell, or leukocyte, populations has long been employed to assess health in animals. To identify and quantify leukocytes in a high-throughput manner for model organisms, flow cytometry is often used. Unfortunately, flow cytometry procedures often rely on fluorophore-bound antibodies to tag cells for identification and most commercially available antibodies are specific to model organisms (e.g., humans and laboratory rodents). Thus, flow cytometry has rarely been used to assess cells in non-model organisms. In our study, we developed a flow cytometry procedure to both identify and quantify populations of three types of leukocytes in snakes. We then conducted a case study to assess azurophils, heterophils, and lymphocytes before and after a standardized stressor among three species of watersnake (Nerodia erythrogaster, N. fasciata, and N. rhombifer) from a northern and southern site in Arkansas, US. We examined variability between species, sites, and sex, as well as the impact of time since stress on leukocyte populations to better understand the ecoimmunology of snakes in Arkansas. We found high individual variability in leukocyte populations that were identifiable and repeatable across time, species, and sex in both Arkansan sites. The level of repeatability and ability to isolate specific leukocyte populations provides compelling evidence that flow cytometry is a viable option for assessing immunological status of wild snakes and other non-model organisms. Our work demonstrates that flow cytometry can be harnessed to gain baseline predictions of immune responses in both model and non-model organisms to stressors in different environments.

## Myelin-like Ensheathing Glia in Neck Connective Neurons of a Large, Agile Flying Insect

*Karrah Hayes, Leo Wood, Varun Sharma, Simon Sponberg*

Flying insects precisely control fast maneuvers in a way that demands bringing sensory and motor information to and from the brain in very limited time. Given this information is mediated through one connective, the neck connective, understanding how many neurons carry signals and the speed at which those signals are carried is key to understanding agile flight. Thus, we hypothesized that the neck connective of a large hawkmoth, Manduca sexta, may have adaptations enabling fast signal conduction. Since the adult Manduca central nervous system (CNS) has approximately 4.5 times more neurons than adult Drosophila melanogaster, we also expected to count 4.5 times more neurons than Drosophila's 3738 neurons. We imaged neck connectives of Manduca using transmission electron microscopy and aligned images into a large mosaic, manually segmenting axons to estimate neuron count and axon sizes. We discovered fewer neurons than expected from scaling CNS size. In addition, most axons were insulated by layers of glia similar to vertebrate myelin. We found that axon area was log-normally distributed around 1 µm2 and that as an axon's radius increases, its ensheathing layer scales 1:1 for axons with radii greater than 1 µm. Our data indicates neuron count in the neck connective does not scale with brain size and suggests that ensheathing glia may accelerate conduction velocity for large insects that would typically experience long conduction delays.

## Glaciations promote genetic differentiation and secondary contact in populations of pelican spiders

*Nicolas Hazzi, Hannah Wood*

Eriauchenus workmani is an endemic species of pelican spider (Archaeidae) occuring in the montane rainforest areas of Madagascar, with high morphological variation in somatic features within and between localities across its distribution range. In this study we addressed whether the high morphological variation of E. workmani is attributed to different cryptic species, some of which co-occur in sympatry. We sampled hundreds of loci across the distribution range of this species and implemented population genetic analyses, species delimitation methods, demographic models and ecological niche analyses to address species boundaries and phylogeography history. We found four genetically distinct groups, three of which cohabitate in sympatry. Demographic models suggest that there was population expansion during the last maximum glacial period and population contraction during the Holocene. Ecological niche models also indicate distribution expansion and connection of populations during glacial periods as opposed to the current warm periods when the distribution range of the species is fragmented on different mountain peaks. Different species delimitation methods suggest one species with some secondary gene flow between populations. Thus, we hypothesize that while interglacial warm periods contribute to the contraction and allopatric genetic differentiation of populations of E. workmani, glacial periods contribute to the expansion and secondary contact of these populations, causing the build-up of sympatric genetic differentiate populations in montane rainforest areas.

## A fine-grained segmentation tool for micro-CT images

*Yichen He, Marco Camaiti, James Mulqueeney, Marius Didziokas, Lucy Roberts, Anjali Goswami*

Extracting regions of interest is a fundamental task in the data extraction phase of morphological studies. Beyond separating the specimen from the background, researchers often need to isolate sub-regions within scans, which typically involves time-consuming annotation. Many AI-based methods have been developed to automate annotation in 2D image datasets, which often surpass traditional methods in accuracy and require fewer manual inputs. However, segmenting fine-grained structures in micro-CT scans, which provide three-dimensional spatial information, presents unique challenges, including making AI-based segmentation both difficult to tune and computationally expensive. Additionally, creating high-quality 3D training sets can be time-intensive.

In response to these challenges, we introduce an open-source toolkit that integrates traditional computer vision methods to segment micro-CT scans into fine regions. The parameters for this toolkit, such as setting thresholds, are intuitive and user-friendly, and the computations can be run on standard computers without GPUs. We demonstrate the toolkit's capabilities in two disparate examples: (i) a semi-automatic workflow for isolating skull bones and generating sutures on mammalian skull scans; and (ii) a fully automatic workflow for separating individual chambers of planktonic foraminifera with over 95% accuracy. Additionally, we provide an AVIZO addon version of this toolkit, enhancing its accessibility and integration with existing workflows. This toolkit thus provides a versatile, accessible alternative for researchers needing fine-grained segmentation on micro-CT scans without the need for advanced computational resources.

## Proteomic analysis of the decapod molting gland (Y-organ) in response to PKG inhibition

*Talia Head, Lars Tomanek, Donald Mykles*

Physiological regulation of molting in decapods is predominantly coordinated by two hormones, the peptide molt-inhibiting hormone (MIH), and steroid molting hormones termed ecdysteroids. MIH is produced and secreted by the X-organ/sinus gland complex located in the eyestalk ganglia, and negatively regulates the production of ecdysteroids in the molting gland (Y-organ, YO). MIH signaling begins with a cAMP-dependent triggering phase followed by a cGMP-dependent summation phase which ultimately leads to inhibition of mTORC1. Previous work revealed that two cGMP-dependent protein kinases (PKG1 and PKG2) have opposing roles in modulating ecdysteroidogenesis via MIH signaling in YOs. Specifically, PKG1 plays a dominant role in MIH signaling by inhibiting ecdysteroid synthesis, while PKG2 counters that inhibition and maintains basal ecdysteroidogenesis in the intermolt YO. This study aims to use sample multiplexing alongside phosphopeptide enrichment in LC-MS/MS to identify potential substrates of PKG in the YO. Transcript expression of PKG1 is two orders of magnitude greater than that of PKG2 in the intermolt YO, and preliminary proteomic data identified peptides from PKG1 but not PKG2. This data indicates that protein expression may roughly follow transcript expression for the two PKG isozymes, providing a basis for the differential effects of their opposing roles. Supported by NSF grants to DM (IOS-1922701) and LT (IOS-1922718 & IOS-23221487).

## scAnt – an open, low-cost platform to create coloured 3D models of insects

*Oscar Healy, Fabian Plum, Hendrik Beck, David Labonte*

Digital 3D models of arthropods are an excellent tool for education, outreach, and conservation. Models with accurate shape, texture, and colour information are the gold standard for digital specimen preservation, but no automated, low-cost solutions exist to create them. We present scAnt, an affordable, open-source photogrammetry platform designed to digitise insects and other small objects. Using a motorised gimbal arm, the target object is rotated relative to a camera to take images from different perspectives. For each perspective, the camera translates perpendicular to the image plane, and takes images at regular intervals, to then permit focus stacking to generate one Extended Depth of Field (EDOF) image per perspective. The EDOF images are masked with an automated routine, and can be processed further with a photogrammetry software of choice to create digital surface models that accurately retain anatomy, texture, and colour. Because it utilises cross-polarised light, and produces high quality focus-stacked images, scAnt can successfully reconstruct challenging elements such as high-aspect ratio structures or shiny surfaces. All code (github.com/evo-biomech/scAnt) and building instructions (www.thingiverse.com/thing:4694713) are freely available, in the hope of broadening access to 3D insect digitisation. 3D models created with scAnt can also be used to create synthetic data to train machine learning tools downstream, bolstering the limited data availability in the field of entomology.

## Exploring performance in complex morphologies using theoretical morphospaces

*Nicholas Hebdon, Ella Kim, Redah Jessani, Nichole Wheeler, Eusabeia Silfanus, Amanda Janis, Vivian Nguyen, Mia Pham, Lindsay Waldrop*

When studying the evolution of form-function relationships of organisms today, we often turn to ever-improving digital models and computational tools. However, organismal morphologies are typically complex and can be difficult to capture in their full fidelity. Adding to this challenge, this complexity makes modeling functional relationships computationally intensive, and if one wishes to explore how performance a morphospace, computationally prohibitive. To explore these spaces with limited time and resources, we must look to approaches that allow us to abstract away some of this complexity. This can be done by leveraging the digital medium we are already working within to construct and explore theoretical morphospaces. Theoretical morphologies have already been employed to explore form-function relationships and why certain morphological configurations are more prevalent than others. Here we show additional applications of theoretical morphology focusing on modern canids. Starting from a foundation of geometric morphometrics collected from museum specimens, we create a simplified 3D geometry that can be modified following simple Euclidean morphological variables decomposed from principal component axes. We explore the airflow within these simplified geometries by coupling them to simple quantitative measures of complexity of nasal passage that can be directly incorporated into computational fluid dynamics simulations. This approach allows us to form a first-order understanding of this system in a fraction of the time required working at the system's full complexity.

## CSI- Cryptic Species Investigation: The Case of Octopus americanus

*Colleen Hecker, Chelsea Bennice, Michelle Cavallo, W. Brooks*

Long regarded as a cosmopolitan species, the common octopus (Octopus vulgaris) now represents a cryptic species complex called the Octopus vulgaris Species Complex (OVSC). The OVSC comprises closely related, geographically distant taxa, displaying subtle morphological discrepancies and genetic divergence. Recent reports indicate that the OVSC taxon in the western Atlantic Ocean, Caribbean Sea, and Gulf of Mexico (formerly known as O. vulgaris types I and II) represents the recently reinstated OVSC species, Octopus americanus. This reclassification remained uninvestigated in southeastern Florida, a known hotspot for cephalopod biodiversity. To investigate this name change for southeastern Florida's OVSC taxon, we employed an integrative approach consisting of species-specific morphological analyses and molecular phylogenetic analyses. Morphological analyses revealed southeastern Florida's OVSC taxon to have similar gill counts and enlarged sucker placements to O. americanus, differing from O. vulgaris sensu stricto. Radular morphology closely resembled the description of O. americanus in comparison to OVSC taxa. Molecular phylogenetic analyses carried out for mitochondrial (16S and COI) and nuclear (rhodopsin) genes consistently clustered southeastern Florida's OVSC taxon into a monophyletic group with O. americanus. These results support that southeastern Florida's OVSC taxon represents O. americanus, and that this name change is appropriate for this species in this locality. An integrative approach to species delineation is crucial for cryptic species, especially those that play significant roles in marine food webs, ecotourism, and fisheries.

## The impact of zoo visitor presence on meerkat social behavior

*Sarah Heckmann, Kelly Diamond*

Meerkats (Suricata suricatta) are animals that live in packs, but how might zoo visitor presence affect captive meerkat social behavior? Wild meerkats have been observed interacting with one another using various behaviors including play, foraging, safety, and comfort. These behaviors may or may not increase social cohesion, or closeness, within the community. Further, little is known about how human presence may influence social behaviors and cohesion. The goal of this study was to examine how play might impact social cohesion in a captive population of meerkats as well as how zoo visitor presence might play a role in their behavior. We used a camera to film the 6-meerkat pack at the Memphis Zoo in 45-minute increments while counting the number of visitors passing by the exhibit on different days and times to capture different levels of visitor activity. The footage was then analyzed by calculaitng the amount of time each indidivudal spent performing different behaviors. Preliminary results suggest that at times of increased visitation, the meerkats displayed lower rates of play and foraging but it did not appear to impact their social cohesion. This indicates that meerkats may decrease social behaviors when larger groups of people are present, but human presence might not impact how the individuals behave towards each other.

## Does body mass drive limb shape disparity and locomotor diversity in mammals?

*Brandon Hedrick, Priscila Rothier*

Body mass is a fundamentally important phenotypic trait and its evolution across a lineage can drive major macroevolutionary changes, impacting nearly every aspect of a species ranging from ecology to physiology to biomechanics. Terrestrial mammals range in body mass across six orders of magnitude, from the Etruscan shrew to the African elephant, and present an ideal group with which to examine how body mass impacts evolution in terrestrial taxa. We propose a novel framework to address the impact of body mass on the macroevolutionary patterns of ecomorphological diversification, focusing on mammalian forelimb morphology. Our approach accounts for the continuous nature of body mass variation to determine how increases in body mass affect forelimb shape disparity, ecological diversity, and phylogenetic diversity. We collected forelimb morphometric data from 666 species of mammals, spanning 95% of extant family-level diversity of terrestrial lineages. We find that forelimb disparity increases with increasing body mass despite drops in ecological and phylogenetic diversity at higher body masses. This supports the hypothesis that smaller mammals are capable of exploiting lots of different locomotor modes without requiring substantial morphological changes in their forelimbs. However, larger mammals must change their forelimbs to adapt to novel locomotor modes likely due to increased biomechanical constraints. Our approach additionally provides a framework for investigating how body mass has affected macroevolutionary patterns in other groups of animals.

## Linking pectoralis muscle dynamics to wing motion in two bird species over a range of flight speeds

*Tyson Hedrick, Bret Tobalske, Andrew Biewener*

Bird flight muscle function and flapping wing kinematics have both been subject to sustained investigation, along with many other aspects of avian flight physiology and biomechanics. However, the degree to which variation in flight muscle contractile dynamics translates to variation in flapping kinematics is more often assumed than demonstrated. Here we use historically collected experimental bird flight data from 2002 encompassing multi-camera videography for 3D kinematics, pectoralis muscle sonomicrometry measurements to quantify muscle length change and shortening velocity, and a strain gauge mounted to the deltopectoral crest of the humerus to quantify pectoralis muscle force. These measurements were made from five cockatiels (Nymphicus hollandicus) and three ring-necked doves (Streptopelia risoria) flying at speeds from 1 to 15 m/s in the Concord Field Station wind tunnel. Along with the requisite 1:1 coupling between pectoralis contractile frequency and flapping frequency, these data reveal a loose relationship between muscle dynamics and externally measured wing kinematics, suggesting substantial roles for intrinsic wing muscles to alter the details of wing motion.

## Polish Crested Chickens: a big-headed breed as a promising model system for hydrocephalus

*Roenell Heerbrandt, Akinobu Watanabe, Scott Landman, Abdullah Ansari, Mohit Shah, Meredith Taylor*

Hydrocephalus is characterized by expanded brain and cranial vault due to excess cerebral spinal fluid within the ventricles. It occurs in 1 in ∼1000 births in the United States, and thus, there is a genuine need for an effective model system. However, a cost-effective model system that shows an extreme, yet viable, phenotype for hydrocephalus remains limited due to reliance on rodent models that only exhibit moderate phenotypic symptoms of hydrocephalus. Here, we assess the utility of Polish crested chickens (PCC), which show an aberrant brain configuration with cerebral herniation, as a comparative model organism. Previous studies have hypothesized, with limited evidence, that hydrocephalus may be implicated in the 'dumbbell-shaped' brain morphology characteristic of PCCs. Here, we use diffusible-iodine contrast-enhanced computed tomography (diceCT) imaging to compare the brain ventricle volumes between PCCs and standard white leghorn chickens (WLC). Prior to staining, we also used the hydrogel STABILITY technique to prevent the ventricles from collapsing for more accurate volumetric measurements. From comparing brain and ventricle sizes between the two breeds, we find that PCCs have significantly larger ventricles (up to eight times) while brain tissue volume remains comparable. This result provide strong morphological evidence that excess cerebrospinal fluid is a major driver of the unique brains of PCCs; therefore, this study marks PCCs as promising model for future hydrocephalus research and studies.

## Investigating the Role of the enzyme Monoamine Oxidase in Aggression

*Lily Hefner, Marosh Furimsky*

This research project studied the role of the enzyme monoamine oxidase (MAO) on aggressive and anti-social behavior in zebrafish. MAO plays an important role in the regulation of neurotransmitters; normal production helps to stabilize mood, regulate emotion and control outbursts. However, low MAO expression is correlated with trouble concentrating, high impulsivity and poor emotional control. Gaining traction as the "warrior gene", low MAO expression was hypothesized to cause violent behavior in humans. Although this proposition is likely untrue, there remains some merit to the premise. For further study, this project introduced the pharmacological inhibitor clorgyline to zebrafish, chosen for their high homology to humans. Clorgyline specifically and irreversibly binds to MAO at the active site. The effect of the disrupted pathway was quantified in two ways: zebrafish behavior and gene expression. Tracking software quantified behavioral patterns in a novel tank, in a mirror test, and in shoals; increased boldness and aggression, as well as declined sociability, were measured in treated zebrafish. Relative gene expression was measured by PCR and gel electrophoresis to confirm the effect of the clorgyline on both the target gene MAO and other genes in the pathway. This project contributes to a growing body of research on the biological, and especially molecular, influences of aggressive behavior.

## A hemichordate cell atlas and the evolution of neuron type identity programs

*Jenks Hehmeyer, Chris Lowe, Heather Marlow, Daria Harris*

Metazoans harbor a diversity of cell types; in particular, some bilaterians possess a high diversity of morphologically and molecularly distinct neurons. How and when neural cell type diversity originated remains unclear. Data from model bilaterians provide limited evidence for the homology of individual neuron types from members of different phyla, but raise the possibility of shared mechanisms by which transcriptional regulation can contribute to a high diversity of neural populations. To gain further insight into the evolutionary history of neuron types and the processes contributing to their diversity, we applied single cell RNA sequencing to the hemichordate worm Saccoglossus kowalevskii, and carried out comparisons with data from other bilaterian phyla. We identify a high molecular diversity of neurons in this brainless, behaviorally simple worm, and confirm that hemichordates utilize the same neurotransmitter synthesis and secretion pathways as other bilaterians. However, cross-species comparisons demonstrate that, with the exception of these pathways, the effector gene coexpression modules utilized by hemichordate neuron populations show limited similarities to those from other phyla. Hemichordate neuron types, like those of model bilaterians, possess highly specific expression of sets of homeodomain transcription factors, but the combinations used are distinct from those observed in other species. These results suggest that, following the divergence of the bilaterian phyla, there was large-scale turnover and elaboration of the neuron type transcriptional regulatory circuits.

## A brief introduction to the symposium

*Britt Heidinger, Gabrielle Names, Jennifer Grindstaff*

Around the world, human-induced environmental changes are rapidly modifying ecosystems, often with important consequences for individual fitness and population viability. Physiological mechanisms are expected to play an important role in allowing organisms to respond to changing environmental conditions because they are often sensitive to environmental factors and coordinate complex changes across phenotypes. Through natural selection and/or phenotypic plasticity, changes to these physiological mechanisms may allow organisms to better cope with changing environmental conditions. They may also constrain responses to environmental changes because physiological mechanisms often integrate across suites of phenotypic traits, potentially leading to maladaptive phenotypes. The physiological mechanisms that mediate responses to environmental changes, their consequences for fitness, and the relative importance of selection and plasticity in shaping these physiological responses remain poorly understood. The goal of this symposium is to bring together a diverse group of researchers across academic stages and disciplines who study the physiological mechanisms that mediate responses to rapid environmental change in a wide range of animal and plant taxa, and across levels of analyses. This dialogue will advance our understanding of the physiological mechanisms involved in responses to human-induced rapid environmental changes, which is essential for predicting evolutionary consequences and population declines in response to changing environmental conditions. The organizers will begin the symposium with a brief introduction.

## Effects of maternal water restriction on offspring energetics and renal morphology in Octodon degus

*Sarah Heissenberger, Sarah DuRant, Maya Tipton, Daniela Kim, Kaja Arusha, Luis Luis, Daniela Rivera, Francisco Bozinovic, Grisel Cavieres, Daniela Vera, Pablo Sabat, Carolyn Bauer*

Maternal cues may be adaptive when the maternal environment "matches" that of the offspring. The ability of mothers to potentially adjust offspring phenotype in response to low water availability is not well understood, yet could inform conservation as a mechanism of enhanced population persistence for species of arid habitats during drought conditions. One such species is the common degu (Octodon degus), a rodent native to central Chile, which recently experienced a ten-year drought. To determine what stage (pre- vs. post-natal) offspring programming is most sensitive to maternal water cues, we compared four treatment groups: controls received ad libitum water throughout pregnancy and lactation, while water-restricted mothers received 75% of average daily water intake. A third group was restricted 75% only during pregnancy, and a fourth 75% only during lactation. Previous results from the current study found that any type of maternal water restriction reduced offspring mass and skeletal growth but enhanced urine concentrating ability, which could have occurred via changes in metabolism and kidney structure, respectively. Thus, we measured a subsample of pups at weaning via flow-through respirometry to determine resting metabolic rate (RMR) and total evaporative water loss (TEWL). We also extracted kidneys to measure relative medullary thickness (RMT). We compared RMR, TEWL, and RMT among maternal water restriction groups to identify at what perinatal stage offspring may be most sensitive to water cues.

## Fine dining with southern resident killer whales: habitat characteristics of predation locations

*Sophia Hemsi, Brad Hanson, Jennifer Tennessen, Marla Holt, Candice Emmons*

A primary risk to the recovery of endangered Southern Resident killer whales (SRKW) is the limited availability and accessibility of their preferred salmonid prey in a core part of their summer critical habitat. A key limitation to protecting foraging opportunities is a lack of understanding of how environmental features are associated with foraging. Our study aimed to identify marine habitat characteristics that predict SRKW foraging. We used foraging data from high-resolution sound and movement tags (DTAGs) attached to SRKWs and concurrent focal follows to pinpoint foraging locations during September 2010, 2012 & 2014. Environmental data, including bathymetry, distance to shore, slope, and substrate, were matched to whale locations on a dive-by-dive basis. We then built generalized linear mixed models to identify environmental factors that predicted foraging behavior as well as their spatiotemporal distribution patterns. Preliminary results indicate a significant negative effect of water depth, suggesting SRKWs are less likely to search for prey in deeper waters. Additionally, a marginally significant effect of sex suggests possible differences in prey searching behavior between males and females. These findings will improve our understanding of SRKW ecology and behavior, particularly in relation to habitat use and seasonal occurrence. Identifying key habitat features associated with SRKW foraging areas can better inform conservation and management efforts to protect and recover this endangered marine mammal population by promoting foraging opportunities.

## Cross-reactivity of mammalian steroid hormone receptor antibodies on fish hormone receptors

*Tia Hendel, Andrew Anderson*

Gonadal steroid hormones are fairly conserved as sex-biased signals in vertebrates and their associated receptors are likewise thought to be conserved in their binding. Evidence suggests that hormone receptor antibodies developed in mammals successfully bind to receptors in a cichlid (Astatotilapia burtoni) for estrogen and androgen receptors. We use two species of fishes in our research, a cichlid (Julidochromis transcriptus) and a pipefish (Syngnathus scovelli), and want to verify the cross-reactivity of androgen and estrogen receptor antibodies developed in mammals for future studies. Using various tissues taken from our animals we performed a Western blot with the antibodies to confirm reactivity and found some evidence of cross-reactivity for the androgen and estrogen receptors.

## Amino acid analysis of extrafloral nectar in three species of Australian *Solanum* (Solanaceae)

*Kaitlin Henry, Chris Martine, Melody Sain*

Structurally complex extrafloral nectaries (EFNs) are currently known to occur on the back of the corollas in only three species of Australian dioecious Solanum. These species, Solanum tudununggae, Solanum dioicum, and Solanum cunninghamii secrete extrafloral nectar, in which, little is known about the characteristics of the nectar - although botanists have noted abundant ant activity around these nectaries. Research has shown relationships between trophic resources from plants and ant species. These diverse relationships, spanning far back into Earth's history, have allowed for the evolution of antagonistic and mutualistic relationships between plants and ants that have given rise to abundant biodiversity in terrestrial ecosystems. Previous literature has shown correlations between the composition of extrafloral nectar, specifically nutritional amino acids, and ant preference. This ex-situ project uses high-performance liquid chromatography (HPLC) to analyze the composition of extrafloral nectar, specifically the presence of amino acids. Through HPLC analysis of nectar, I hope to detect amino acids that have been shown in previous studies to be nutritionally essential and preferred by ants. We hypothesize that the presence of essential amino acids could suggest a mutualistic relationship between these three species and their local ants, with the plant providing essential nutrients to the ant population and the ants offering protection against herbivores.

## Investigating the role of the hippocampus in modulating neophobia in house sparrows

*Marquise Henry, Blake Dusang, Melanie Kimball, Ella Cochran, Christine Lattin*

Neophobia, an aversive response to novel objects, foods, and environments, is a trait that affects the adaptability of animals to the continuous urbanization of landscapes worldwide. However, the causes of neophobia within and across species are poorly understood. While the ventral hippocampus in mammals helps mediate responses to novelty, few studies have investigated whether specific parts of the avian hippocampus are involved in neophobia. In this study, we assessed the role of the caudal and rostral hippocampus in neophobia in house sparrows (Passer domesticus) using novel object trials. Sparrows were assessed for neophobia based on their approaching and feeding latency in the presence of novel objects. Following five days of novel object and control trials, sparrows received bilateral electrolytic lesions targeting either the caudal ($n = 17$) or rostral regions ($n = 16$ of the hippocampus, two regions proposed to have similar functions to the mammalian ventral and dorsal hippocampus, respectively, or underwent surgery without lesioning (sham, $n=32$). Two days after surgery, sparrows were exposed to a second round of novel object and control trials to assess potential changes in approach and feed latency. Preliminary results suggest that lesioning the rostral hippocampus decreased neophobia more than caudal lesions or sham surgeries. This study helps clarify the role of the hippocampus in responding to novelty and adds to our understanding of hippocampal structure across different vertebrate taxa.

## The role of glucocorticoid receptors in mediating neophobia behavior in a wild bird

*Marquise Henry, Melanie Kimball, Ella Cochran, Blake Dusang, Will Frazier, Keegan Stansberry, Tosha Kelly, Emily Stelling, Christine Lattin*

Avoidance of novel stimuli (neophobia) affects how wild animals interact with their environment and may partly determine whether animals persist in urban and suburban landscapes. The neuroendocrine mediators of neophobia are poorly understood, although our past work demonstrated that experimentally reducing circulating corticosterone in wild-caught house sparrows (Passer domesticus) also decreased neophobia towards novel objects placed near the food dish. In this experiment, we directly tested the role of one of the two types of corticosterone receptors, the glucocorticoid receptor (GR), in neophobia in house sparrows by administering a GR antagonist (RU486, n=10) or a vehicle control (peanut oil, n=10) over 5 consecutive days and measuring responses to novel objects both pre- and post-treatment. We also measured baseline and stress-induced corticosterone in all sparrows on the final day of behavior trials. To better understand the effects of RU486 on corticosterone over time, in a separate group of sparrows we administered RU486 or vehicle over 5 days and took multiple blood samples to assess baseline and stress-induced corticosterone. Overall, we found no effect of subcutaneous RU486 injections on neophobia behavior. However, we did find that RU486 injections significantly decreased stress-induced corticosterone levels starting one day post-injection, and baseline corticosterone levels starting five days post-injection, compared to vehicle-injected controls. Overall, these results suggest that GR is not involved in mediating neophobia behavior in house sparrows.

## Conditioned place preference using food reward in a poison frog, Dendrobates auratus

*Tab Henry, Sabrina Burmeister*

Learning studies have been a mammal dominated field since inception, but frogs offer the closest comparison to ancestral tetrapod brains and express diverse behavioral adaptations. In frog learning studies, few have tried to motivate subjects using food rewards due to frogs' lower metabolism and the difficulty of controlling live food, instead rewarding frogs with access to water or shelter. We used conditioned place preference to test the motivational effects of food rewards by measuring the amount of time green and black poison frogs (Dendrobates auratus) spent in distinct areas of a rectangular arena with a central neutral zone. We measured initial place preference in a pretest and designated the non-preferred area as the conditioned-stimulus positive (CS+) chamber where fruit flies were administered every other day during training. During the pretest, individuals expressed significant preferences for one chamber over the other ($p < 0 .05$). After 14 days of training, a post-test was conducted and the time spent in each area was measured. The posttest revealed that training significantly reduced the preference for the originally preferred chamber ($p=0.04$) and doubled the time that frogs spent in the CS+ chamber where food was presented during training ($p=0.09$). This study shows that food can be used as a motivator in frogs, thus offering more direct comparisons of learning between frogs and other tetrapods.

## Using rotifers as a model for zooplankton visual development and susceptibility to chemicals

*Camron Hens, Joseph Covi*

Diapause is an extreme state of embryonic dormancy which allows zooplankton to survive harsh conditions and wake up hundreds of years later to continue their life-cycle. The physiology of embryonic dormancy that zooplankton exhibit has been studied extensively, but we still do not know how light awakens embryos from dormancy. To determine the role of light in terminating dormancy, dormant rotifer (Brachionus calyciflorus) embryos were hatched in a temperature-controlled incubator under four different lighting conditions: white light only, blue light only, red light only and no light.: Hatching success was determined by counting hatched larvae at 22, 24, 26, 36, 38 and 40 hours after the incubation began. After 40 hours the final percentage of hatched embryos were calculated and hatching patterns over time were compared. The final mean hatching rates with blue light having a 69.5% $\pm$ 3.25% hatch rate, white light control having a 49.5% $\pm$ 3.11% hatch rate, red light having a 15.4% $\pm$2.2% hatch rate and dark control having a 3% $\pm$ 1.4% hatch rate. This confirms that higher energy wavelengths in the visible spectrum are more effective at inducing the hatching of dormant (B. calyciflorus) embryos. This result is similar to published findings for crustacean zooplankton. The ability of chemicals to disrupt this response to light will be presented.

## Stretchy Seaweed? Material Properties, Intracellular pH of Desmarestia sp. under Temperature Stress

*Lucy Hensley, Katie Dobkowski, Stephanie Crofts*

As Salish Sea kelp forest ecosystems change due to decreasing canopy coverage, understanding the physiology of understory seaweeds is vital in determining how these nearshore habitats function. We performed materials testing and intracellular pH analysis on Desmarestia sp. (blade morphology) under temperature conditions based on historical data and future climate projections to assess how environmental changes will affect this sub-canopy species. We set up three experimental temperature treatments: past (average 9.85 °C), present (average 13.1 °C), and future (average 15.08 °C) to mimic climate change progression, as well as two exposure times: short-term (4 days) and long-term (14 days). Material properties comparison between treatments revealed the stress (force/area) needed to fracture the tissue significantly decreases, and the strain the tissue can experience before fracture increases, with physiological stressor severity. Exposure comparison showed a significant increase in tissue toughness between short- and long-term exposure during the past treatment. Intracellular pH analysis revealed that intracellular pH increased significantly within stressed treatments suggesting acid expulsion into its environment. Exposure analysis exhibited a compounding stress effect where intracellular pH was significantly higher between short and long-term timeframes. These results indicate that ongoing environmental changes may affect the physiology of Desmarestia sp.. In combination with observations of altered grazing techniques and preference for stressed Desmarestia sp. by urchins, these changes may affect interactions within kelp-dominated habitats.

## A paralog switch rejects the Ortholog Conjecture in ostracod bioluminescence

*Nicholai Hensley, Emily Lau, Jessica Goodheart, Todd Oakley*

Researchers using non-model taxa often rely on similarity methods to assign gene function from more well-characterized species to their focal system. These methods implicitly assume genes related through direct descent during speciation (orthologs) will be more similar in function than copies within species produce via duplication (paralogs), termed the Ortholog Conjecture. Testing candidate bioluminescent proteins (c-luciferases) responsible for light production in the behaviors of Luminine ostracods, we find that orthology does not always predict gene function, refuting this assumption. In at least one species, an in-paralog outperforms the ortholog in producing light during in vitro assays. Many other lineage-specific duplicates are also highly expressed in the relevant tissues of closely related species, but their evolutionary distances do not predict such changes in expression. Although previous research measuring functions like gene expression or conservation of substitution rates support the Ortholog Conjecture, our results caution these interpretaions, and instead bolster recommendations to use all homologs for functional prediction, not just orthologs. Because orthology alone may not predict gene function, assuming the locus of evolution may be less predictable a priori.

## Trade-off between structural coloration and patterned plumage in estrildid and viduid finches

*Katherine Henson, Maria Creighton, Miranda Sinnott-Armstrong, Sonke Johnsen, Steve Nowicki*

Feathers are highly specialized structures that display a wide range of colors and patterns commonly used in avian communication. Two complex types of feather coloration are melanin-based patterns (such as spots and stripes) and structural colors (such as blue or glossy black). Both types of coloration require precise coordination of keratin and melanin production not only within each feather, but also across feathers within a plumage region. We hypothesized that patterned plumage and structural coloration independently signal similar information about a bird's individual quality via alternative mechanisms and are therefore unlikely to co-occur within species. To test this hypothesis, we examined plumage traits across Estrildidae and Viduidae, two closely related passerine families with highly diverse plumage colors and patterns. We scored for the presence or absence of melanin-based patterning and structural color from over 200 museum specimens across both families. We reconstructed ancestral states for each trait and used phylogenetic mixed modeling to test for correlated evolution of color traits. Consistent with our hypothesis, we found a negative association between patterned plumage and structural coloration. To our knowledge, this study is the first to assess the relationship between structural color and plumage patterns across a group of closely related birds.

## Effects of urbanization on parasitemia and immunophysiology in Cardueline finch species

*Xue Her, Joel Slade*

Urbanization is a rapidly expanding global phenomenon that significantly changes natural habitats, often forming novel ecosystems characterized by various urban features. This environmental change impacts a variety of birds, including Cardueline finches, such as lesser goldfinches (Spinus psaltria), house finches (Haemorhous mexicanus), and pine siskins (Spinus pinus), which are widely distributed across California and frequently found near bird feeders. In urban environments, these birds are exposed to a variety of stressors such as elevated noise levels, increased light pollution, chemical pollution and increased human activity. Additionally, landscape features in urban areas can also influence the distribution of disease vectors. To test whether urban stressors result in elevated stress response, we measured the heterophil/lymphocyte (H/L) ratios of Cardueline finches from various urban and rural habitats. In vertebrates, H/L ratios are an indicator of stress and can reflect aspects of the immune function. We hypothesize that urban-dwelling Cardueline finches will exhibit a higher H/L ratio, reflecting a stress response due to the high prevalence of stressors in urban environments. To control for H/L ratios, we quantified the presence of haemospordians and other pathogens, as acute infections are expected to elevate these ratios. Additionally, we predict that finches in rural areas will be exposed to a more diverse range of pathogens, as they are more likely to encounter vectors that can serve as reservoirs.

## Bioinspired surface structures in suction discs improve shear adhesion

*Alyssa Hernandez, Jessica Sandoval, Michelle Yuen, Robert Wood*

Multiple fish species utilize suction-based organs to maintain adhesion in unpredictable aquatic environments. These adhesive discs often include a softer disc margin that hosts surface protrusions called papillae, which stabilize and seal on variable substrates. The size, arrangement, and density of these papillae are quite diverse among different species. Considering papillae arrangements in multiple fish species, we fabricated physical disc models that tested three surface pattern parameters under shear loading. These parameters included the area of individual protrusions, the channel spacing between adjacent features, and the percent coverage of protrusions relative to the total disc area. To create our models, a soft silicone was added to a stiff circular suction cup, which was then "stamped" using a laser-etched and thermoformed mold base to create desired surface patterning. Discs were tested using a robotic arm equipped with a force sensor, which sheared them across smooth and rough surfaces at a fixed speed and distance. The arm also varied the initial compression, testing performance under different preloads. For our designs, patterns with smaller papillae-like protrusions and channel spacing often outperformed larger features. However, protrusions of intermediate size and channel spacing withstood the highest shear load, potentially highlighting a balance between pad area and fluid channeling. Additionally, discs with texturing often outperformed smooth control discs on multiple surfaces, but performance was highly dependent on preload.

## Characterization of Ras homolog enriched in brain (Rheb) among decapod crustaceans

*Ashley Hernandez, Talia Head, David Durica, Lars Tomanek, Donald Mykles*

Molting is regulated by steroid molting hormones (ecdysteroids), produced by paired molting glands, or Y-organs (YOs). YO ecdysteroidogenesis involves the molt-inhibiting hormone (MIH) signaling control of mechanistic Target of Rapamycin Complex 1 (mTORC1)-dependent protein synthesis, as rapamycin inhibits ecdysteroid synthesis and secretion. Ras homolog enriched in brain (Rheb) is a GTP-binding protein that activates mTORC1. As Rheb is up-regulated during premolt, its expression can be used as a proxy to determine the effects of molting on mTORC1 activity in the YO and other tissues. The CrusTome database was used to characterize 82 Rheb sequences across all major crustacean taxa. Phylogenetic analysis and multiple sequence alignments indicated that Rheb is highly conserved across metazoa. Alignment of protein sequence between decapods and humans revealed nearly 100% conservation of functional motifs, including GTP-binding sites and the Guanine Nucleotide Exchange Factor (GEF) and Guanine Nucleotide Dissociation Inhibitor (GDI) interaction sites. Differential expression of Rheb across eleven tissues was analyzed through PCR and gel electrophoresis for Gecarcinus lateralis and Carcinus maenas. Rheb protein was identified using liquid chromatography/tandem mass spectrometry in the YOs of both G. lateralis and C. maenas. Effects of molting on Rheb expression in the YO will be reported. This data emphasizes the importance of Rheb in the endocrine regulation of decapod molting. Supported by NSF grants to DM (IOS-1922701), DD (IOS-1922755), and LT (IOS-1922718 & IOS-23221487).

## Evaluating pyrethroid resistance in the invasive mosquito *Aedes aegypti* in Madera, CA

*Matthew Hernandez, Abraham Velazquez, Brian Tsukimura*

The invasive mosquito Aedes aegypti was first detected in Madera, California in 2013 and has since established itself across the state. A. aegypti poses significant public health risks in urban environments due to its preference for blood-feeding on humans and its capacity to transmit dengue. Currently, there are no vaccines available for this disease. Mitigating transmission primarily relies on adulticidal control of this mosquito species. This study aimed to evaluate the resistance of wild-caught A. aegypti from Madera, CA compared to the lab susceptible A. aegypti strain ROCK, focusing on selected pyrethroids. The CDC bottle bioassay consisting of one control and four replicates was employed to assess resistance in both groups using CDC standard concentrations of pyrethrum (15 µg/ml) and lambda-cyhalothrin (10µg/ml) in each bottle. Each bottle contained 25 mosquitoes and resistance was measured using time-mortality over a period of two hours with mortality being assessed at 15-minute intervals as set by the CDC. Two trials resulted in both wild-caught and ROCK mosquitoes reaching 100% mortality within 15 minutes for both pyrethroids, indicating no difference in susceptibility. Our findings suggest that the Madera population of A. aegypti remains susceptible to these pyrethroids, indicating their effectiveness in controlling this mosquito. This research provides valuable insights for guiding mosquito control efforts across regions where this invasive species has been detected.

## Don't let vertebrate bias claud(in) your vision: exploring *claudin* gene functions in *Ciona robusta*

*Sabrina Hernandez, Sydney Popsuj, Christina Cota, Alberto Stolfi, Bita Jadali, Reagan Hicks, Caroline Nawrocki, Joshua Kavaler, Olivia Lucia, Ella Dauskardt, Olchey Tchavyntchak, Katarzyna Pierkarz*

In vertebrates, claudins are membrane proteins and essential components of tight junctions between neighboring cells. Claudins are known to regulate the passage of ions and small molecules between both epithelial and endothelial cell types and are required for the integrity and function of the blood-brain barrier and intestinal lining. When claudins are dysregulated in vertebrates, they are implicated in numerous diseases including cancers and inflammatory bowel disease. Until recently, it has been thought that claudins are a vertebrate-specific innovation and that invertebrates lack true tight junctions. Here, we report that the tunicate Ciona robusta, a non-vertebrate chordate, possesses 11 claudin genes with wide-ranging and dynamic expression patterns. Using a combination of single-cell RNA sequencing analysis, in situ Hybridization Chain Reaction (HCR), cis-regulatory fluorescent reporters, and CRISPR-Cas9 mediated knockouts, we aim to identify the functions of these claudins in the context of Ciona development.

## Comparison of hydric and thermal landscapes in closed-canopy vs. open-canopy Hispaniolan anoles

*Isabela Hernandez Rodriguez, Nathalie Alomar, Brooke Bodensteiner, Martha Muñoz*

As climatic change intensifies, altering temperature and water availability, understanding how physiological diversity evolves is imperative. This study investigates the relationships between thermal and hydric physiology and the environmental factors that influence them, in Hispaniolan anole lizards. Hispaniolan anoles are part of a well-studied adaptive radiation in the Caribbean, distinguished not only by their distinct ecomorphology but also by their high ecophysiological diversity. Of key relevance to their ecophysiological diversity is that anoles vary in their use of forest types: whereas some species are specialized to forest edges/open habitats, others are restricted to closed-canopy forests (like cloud forests). Here, we compared the thermal and hydric diversity of ten species of Hispaniolan anole lizards, including representatives from both closed canopy habitats and open/edge habitats. We predict that closed-canopy anoles will be less heat tolerant and less desiccation tolerant than their open/edge-habitat counterparts. By contrast, we predict that cold tolerance will be dictated by minimum environmental temperatures, rather than by thermal habitat use. Our study provides deeper insights into how environmental and habitat features shape physiological traits in a classic case of adaptive radiation.

## Functional development of motor and sensory circuits for cardiac feedback control

*Luis Hernandez-Nunez, Joana Avrami, Areni Markarian, Keyue Shi*

Autonomic control of cardiac function is essential for survival, yet the functional diversity of the autonomic sensory and motor circuits of the heart remains poorly understood. Here we take a multidisciplinary approach, combining systems neuroscience techniques, genetics, and control theory to study the role of autonomic sensory and motor circuits in larval zebrafish. While larval zebrafish's optic and genetic accessibility has made it a popular choice for studying how the brain processes environmental cues to modulate behavior, it has not yet been used to study organ control or the autonomic nervous system (ANS) from a systems neuroscience perspective. Thus, we use calcium imaging, optogenetics, pharmacology, and electron microscopy to map the developmental time course of anatomical and functional innervation of the heart. We identify the emergence of parasympathetic and sympathetic control of the heart, as well as the anatomically defined neural populations needed for heart modulation. We also show the onset of cardiac sensing and cardiac state feedback to the brain. Our study provides a timeline of developmental landmarks of the autonomic circuits for heart control and sets the stage for future mechanistic studies of neurocardiac circuits.

## Effects of environmental indicators on shrimp-like metachronal swimming

*Adrian Herrera-Amaya, Zhipeng Lou, Nils Tack, Chengyu Li, Monica Wilhelmus*

Metachronal rowing is a widespread swimming strategy among crustaceans inhabiting the transitional flow regime in which both viscous and inertial effects are important. It is common for shrimp-like organisms to experience temperature changes in the order of 20°C due to migrations and/or seasonal changes. Such fluctuations can easily lead to 40% differences in viscosity, potentially affecting their propulsion dynamics. Not only does the inertial-viscous force balance change, but temperature fluctuations will also affect their muscle activity. Such a wide temperature range suggests that metachronal propulsion is resilient to changing water properties. Here, we investigate marsh grass shrimp (Palaemon vulgaris) as a model organism to explore the combined physical and physiological effects on their locomotion at natural seasonal temperature extremes (6° – 20°C). Experimentally, we manipulated temperature and viscosity independently to isolate physiological and physical effects. We then used the gait kinematics data to inform a computational fluid dynamics model to perform a parametric study varying viscosity and beat frequencies through naturally occurring extremes. The results show that shrimp can maintain their swimming efficiency when exposed to cold water due to the increased viscosity of the fluid, not from modifying their swimming gait. The simplicity of this hydromechanical mechanism is evidence of the ecological success of shrimp-like organisms in all climates, from the Tropics to Arctic Ocean waters and inland freshwater.

## Does the "plant pathogen landscape" change with fragmentation?

*Michelle Hersh, Cathy Collins*

Fungal pathogens that impact early life stage plants are important in maintaining plant diversity. Are these critical interactions impacted by landscape fragmentation? Fragmentation has a suite of biotic and abiotic impacts that can alter interactions between plants and their pathogens. Simultaneously, the process of fragmentation may change the distribution of pathogens across the landscape. We conducted a landscape-scale seed burial study across an experimentally fragmented landscape in Lawrence, KS. We buried over 2,400 seeds of seven plant species in small patches, large patch edges, large patch interiors, and the matrix between patches. Seeds were unearthed after one year; fungi were cultured from buried seeds and identified using DNA barcoding. Fungal community composition was predictably structured by host species, but also by landscape location, indicating that fragmentation altered the structure of seed-associated fungal communities. Further, both soil temperature and volumetric water content were associated with changes in fungal community structure. Pathogenicity of ten of the most common fungal species cultured was confirmed by experimental inoculation. All fungi tested were associated with seeds of multiple plant species, but pathogenicity was not simply predictable by host association alone. This work demonstrates that landscape fragmentation alters the community structure of seed-associated pathogens, with implications for plant diversity maintenance in anthropogenically disturbed landscapes.

## Titin underpins residual force enhancement, depression, and the stretch-shortening cycle effect

*Anthony Hessel, Devin Nissen, Michel Kuehn, Thomas Irving, Wolfgang Linke*

Skeletal muscle active tension is dependent on its history. When activated isometrically, tension can be predicted based on the sarcomeric length-tension relationship, where force is proportional to the overlap of the myosin-containing thick filaments and actin-containing thin filaments. Contrary to expectations, an active stretch-hold leads to increased tension (residual force enhancement), active shorten-hold leads to less tension (residual force depression), and an active stretch-shorten-hold leads to less tension but not at the level of a pure shortening-hold (stretch-shortening cycle effect). The I-band titin spring is thought to be the primary driver of these history-dependent effects, hypothesized to be through a change in titin-based stiffness upon activation. Using small angle X-ray diffraction in combination with a novel mouse model that specifically cleaves 50% of I-band titin, we evaluated the relationship between titin-based force, history-dependent properties, and sarcomere protein order and orientation. Our results demonstrate that cleaving 50% of I-band titin reduces the history-dependent tension effects towards those expected under purely isometric conditions. Furthermore, each of the isometric or length-change conditions had unique structural signatures that help to explain differences in tension, which seem to be more related to changes in titin-based tension on the sarcomere and force transmission, and less dependent on changes to cross-bridge kinetics. An activation-dependent change in titin-based stiffness seems plausible but the mechanism that accounts for this remains to be deduced.

## Flicker fusion frequency of *Calliphora vicina* compound eyes and ocelli

*Grace Hickey, Marisa McDonald, Daniel Chappell, Martin (Ric) Wehling*

Many flying insects possess three simple eyes, known as ocelli, in addition to their two compound eyes. The ocelli are thought to play a wide range of functions depending on the needs of each species, from increasing light sensitivity to increasing the processing speed of visual stimuli. Understanding the retinal properties of an insect's ocelli can help us determine their function in specific species and how factors such as artificial lighting may affect insect behavior. In diurnal flying insects, such as the blowfly Calliphora vicina, the ocelli are thought to contribute to flight stability and have to respond quickly during rapid flight movements. We expect the flicker fusion frequency of C. vicina ocelli to be in the hundreds of hertz range, compared to the slower human flicker fusion frequency of 60-80 Hz. Using electroretinography, we examined the temporal resolution of the compound eye and ocelli in C. vicina in dark and light adapted states. Preliminary results suggest that both have high flicker fusion frequencies, with the maximum critical flicker fusion frequency (CFFmax) around 200 Hz for the compound eye and 240 Hz for the ocelli. These values generally agree with the CFFmax values found for other Dipteran species.

## Establishing *Molgula citrina* as a model to study life history strategy evolution in tunicates

*Elizabeth Hiebert, Christina Cota, Sydney Popsuj, Dave Angelini*

Tunicates, a non-vertebrate chordate and closest extant sibling taxa to vertebrates, are an ideal model organism for studying body plan evolution and life history strategy. Tunicates, in general, display a biphasic lifestyle where individuals spend part of their lives as motile swimming larvae that eventually metamorphose into a sessile organism. Solitary tunicates typically spawn eggs and sperm to fertilize and develop in ocean currents. Exceptions to both of these rules lie within the Molgula genus, where many species have undergone parallel evolutionary losses of the larval body plan. Some Mogula species, including Molgula citrina, have evolved a brooding reproductive strategy whereby they spawn fully developed larvae. Here, we report our efforts to establish M. citrina as an emerging model organism. We will present preliminary results on a working genome as well as methods of antibody staining and dechorionation and electroporation. As we establish this emerging model organism, we aim to better understand the mechanisms by which different lifestyle strategies have evolved within tunicates.

## Bird nests made from anti-bird spikes

*Auke-Florian Hiemstra, Cornelis Moeliker, Barbara Gravendeel, Menno Schilthuizen*

The use of man-made, even sharp materials for nest building in birds is well known. But here we report the first well-documented study on nests of carrion crow Corvus corone and Eurasian magpie Pica pica that almost entirely consist of material that is meant to deter birds: anti-bird spikes. Carrion crows in Rotterdam (The Netherlands) and Eurasian magpies in Enschede (The Netherlands), Antwerp (Belgium), and Glasgow (Scotland) tear entire strips with sharp metal pins off buildings and use them as nesting material. Two anti-bird spike nests, now in the collections of Natural History Museum Rotterdam (crow) and Naturalis Biodiversity Center (magpie), were analyzed for composition and structure. Magpies may use the anti-bird spikes not just as ordinary nest material, but specific placement in the dome, overarching the nest, hints at functional use: to ward off (other) birds. Crows, for example, are known to prey on magpie eggs and offspring and the specific choice of this sharp material could benefit nest defense, for which magpies may normally rely on thorny branches. In the Anthropocene, now that living biomass is outweighed by anthropogenic mass, alternative nesting materials are increasingly being adopted by urban birds. With birds even using bird deterring materials like anti-bird spikes as nesting material, anything may become part of a bird's nest.

## Furling, morphing, or both? Feather muscle structure in bird wings using contrast-enhanced microCT

*Tobin Hieronymus, Jasmin Wong, Margaret Kilbane, Ishani Pandit, Shane Windsor*

Avian feather follicles are linked by bundles of dermal smooth muscle that control feather posture. Feather muscle bundles in the wings have unique attachments to skeletal elements, both through adjacent skeletal muscle tendons and by direct attachments to bone, suggestive of variable linkages between limb posture and overall wing shape. The three-dimensional structure of feather muscles in relation to feather follicles in the wing is poorly resolved, hindering hypothesis generation for experimental tests of function. In this study, we used contrast-enhanced microCT of Coturnix, Gallus, Falco, and Taeniopygia to resolve relationships between flight feather follicles and feather muscles. Special attention was given to attachment of m. expansor secondariorum to proximal secondary feathers and attachment of oblique interremigial muscles among distal primary feathers. In contrast to prior functional hypotheses, the paired heads of m. expansor secondariorum are positioned to depress the proximal secondaries—depression would furl the secondaries against the body in a closed wing, and/or increase root-to-tip washout in an open wing. Oblique interremigial muscles are positioned to hold primaries against each other in a furled wing, and/or support supination of primary feathers during upstroke in an open wing. These additional details of potential actions at different wing positions support design of in vivo loss-of-function experiments to assess feather muscle function at rest and in flight. NSF IOS EAGER 1838688; SOAR/BISCCIT.

## Bugs in the blood: exploring *Trypanosoma* dynamics in Mexican free-tailed bats

*Mackenzie Hightower, Meagan Allira, Kristin Dyer, Bret Demory, Lauren Lock, Amanda Vicente-Santos, Daniel Becker*

Nearly all mammals are susceptible to infection with trypanosomes, a genus of vector-borne protozoan parasites, with Trypanosoma cruzi posing significant human health risks among endemic countries within the Western Hemisphere. While T. cruzi infections among mammals have recently been documented in Oklahoma, research concerning sylvatic transmission in the state is limited. Mexican free-tailed bats (Tadarida brasiliensis) encounter areas endemic to T. cruzi during their yearly migration from Mexico through the southwestern United States, where they form large congregations at maternity and bachelor roosts in the summer. These behaviors, along with their long lifespans and shared coevolutionary history with the parasite, implicate the bats as playing a key role in parasite transmission. During monthly sampling trips from 2022-2024, we collected blood and morphometric data from over 400 Mexican free-tailed bats at two roosts in northwestern Oklahoma. PCR targeting the ssrRNA gene shared across mammalian trypanosomes confirmed Trypanosoma spp. infection in at least 8% of bats. We further tested how infection risk varied by reproductive status, age, sex, year, and sampling month using generalized additive models. Positive samples were sequenced to confirm infection, identifying at least Trypanosoma dionisii, which shares a close evolutionary relationship with T. cruzi. Evaluating the drivers and diversity of trypanosome infection among these migratory bats will provide insight into host–parasite dynamics and the endemicity of the parasite within the southwestern United States.

## Using museum specimens to document historical contamination

*Sarah Hileman, Jason Belden*

Natural history museums are an important wealth of data and opportunities for research with specimens offering snapshots in time while minimizing animal collecting; thus, reducing animal use. Oklahoma State University and other institutions have a variety of mammal specimens collected from regions of notable environmental contamination, including the Tar Creek Superfund Site. Tar Creek and surrounding Ottawa County are designated National Priority List Sites in Northeastern Oklahoma. This area sourced most of the lead and zinc ore mined for both World Wars. Habitat and landscape destruction from years of mining practices caused the displacement of generations of people from the region, and created environmental contamination still being remediated today. While studies in the area tend to focus on aquatic wildlife and surrounding landscape toxicity, fewer studies have examined metal distribution amongst mammal populations across broader taxa. This study focuses on select metal distribution in bone tissues in a comparison of both ground dwelling and flying mammals from the Superfund and surrounding locations. Findings show disproportionate levels of select metals in mammals in the Superfund Site as compared to reference specimens indicating broader implications for underlying physiological abnormalities. This type of study is important to further the knowledge of how large-scale environmental contamination can affect non-static populations without the necessity of additional on-site collecting.

## Two pathways to red carotenoid ornaments in birds: implications for honest signaling

*Geoffrey Hill, Rebecca Koch, Chidambaram Ramanathan, Cristy Truong, Hannah Reeb, Brooke Joski, Yufeng Zhang, Matthew Toomey*

It was recently discovered that many bird species use the enzymes CYP2J19 and BDH1L to metabolize yellow dietary carotenoids to red carotenoids displayed as ornamentation. In parallel investigations, production of red carotenoids was linked to mitochondrial function. These observations led to speculation that CYP2J19 was localized to the mitochondrion, with most evidence coming from studies of the House Finch. However, we present data that the House Finch does not utilize CYP2J19 to produce red feather pigments and that both CYP2J19 and BDH1L localize not to the mitochondrion but to the endoplasmic reticulum. The enzymes that enable House Finches to produce red carotenoids remain unknown, but we can now compare and contrast characteristics of ornamental red coloration that is produced via CYP2J19/BDH1L versus red coloration arising from the unknown House Finch pathway. These new discoveries hold large implications for understanding how plumage coloration serves as a signal of condition.

## Using environmental DNA to detect invasive rainbow trout in southeast Idaho tributaries

*Natalia Hincks, Emily Lancaster*

Rainbow trout, Oncorhynchus mykiss (Om), in the South Fork Snake River (SFSR) of Idaho has been under management of the Idaho Department of Fish and Game (IDFG) to prevent introgression with the native Yellowstone cutthroat trout, Oncorhynchus clarkii bouvieri. The SFSR and its four main tributaries all have suppression efforts to prevent Om from furthering detriment among established indigenous habitat. Two main suppression efforts is manual sorting of fish at weirs and during electroshocking by boat on the SFSR, based on visual species characteristics, which, with known hybridization, is prone to error. If these efforts are executed perfectly, Om will not appear above weirs in SFSR tributaries nor in any of the drainages of Palisades reservoir. We collected environmental DNA (eDNA) samples at 33 sites from drainages of the SFSR and Palisades reservoir and processed them using a species specific PCR assay for Om which also detects hybrid fish. Om were not detected in eDNA samples from Palisades Reservoir. Below the weirs on the SFSR tributaries, eDNA of Om was detected, but above the weirs, no full Om was detected. These results show that suppression efforts are successful in preventing Om from establishing upstream of SFSR tributaries weirs. As Om continue to be removed, eDNA and visual monitoring should continue basin-wide to ensure the absence of Om in this region.

## Playing for Both Teams: Molecular Mechanisms of Sex Change in the Bluebanded Goby

*Anthony Hinders, Grace Cain, Katrina White, Heather Ray, Devaleena Pradhan*

Sex change is present in at least 34 families of teleost fish with variable directionality for initial sex and final sex based on numerous environmental factors. For example, social environment, size, and/or age may trigger a cascade of mechanisms that regulate sexual plasticity across the entire body axis. This process has been well documented from a macro perspective, with morphological and behavioral data collected for a number of species, including the bluebanded goby Lythrpynus dalli, a bidirectional sex changing fish. Molecular level observations, however, remain unclear in how potentially multiple genes across endocrine and developmental mechanisms interact. Here, we targeted genes that play a role in sexual development and differentiation in L. dalli, including cyp19a1 (aromatase) and double-sex and mab-3 related transcription factor 1 (dmrt1), to illuminate the process of sex change on the transcriptional level. We generated all female social groups (n=12) to induce protogynous (female to male) sex change, with transitioning individuals sacrificed at 5 or 10 days and collected brain, gonadal, and muscle tissues. Stable males (n=6) and females (n=6) were also collected to serve as control ‘endpoints’. Transcriptional data from individuals at these time points will be combined with behaviors regarding aggression and parenting as well as morphological data to paint an integrative picture of protogynous sex change.

## From Wounded to Regeneration – Mechanisms of Whole-Body Regeneration in Sea Stars

*Veronica Hinman, Jon Lee Andrade*

Regeneration is a fascinating process through which animals can reform lost tissues following traumatic injury. Some animals, like sea stars, are exceptional regenerators and can fully regenerate their bodies after being cut in half. This process involves many poorly understood phenomena, including how the remaining cells detect tissue loss and reprogram to form the missing tissues and organ systems. Our recent work aims to understand how sea star larvae can regenerate their anterior body, including their nervous system, after being bisected. We will demonstrate how evolutionarily conserved wounding processes establish the reprogramming of cell lineages, re-establish the anterior-posterior pattern, and then recapitulate embryogenesis. Additionally, we will present a single-cell transcriptomic analysis that reveals how unique cell types contribute to regeneration and are regulated by wounding processes. These findings will be explored within an evolutionary framework to highlight similarities and differences in animal regeneration processes.

## Novel Strategies for Tick Control: Targeting Cuticular Expansion in Ixodes scapularis

*Isaac Hinne, Won Yim, Monika Gulia-Nuss*

In the last decade, the number of tickborne diseases (TBDs) has increased steadily and now accounts for 75% of all reported vector-borne diseases in the United States annually. Ixodes scapularis alone transmits seven of 20 pathogens transmitted to humans through tick bites including Borrelia burgdorferi which causes about 500,000 cases of Lyme disease annually in the US. Current tick control methods, such as the use of acaricides, have proven insufficient, highlighting the need for more effective strategies. The development and use of vaccines against ticks are known to be a more efficient, cost-effective, and environmentally sound way to control TBDs. However, a major obstacle to anti-tick vaccine development is the crucial task of identifying and characterizing novel tick antigen candidates. The success rate of pathogens transmitted by ticks is influenced by the long-lasting blood-feeding unique to ticks. Adult female ticks increase in size by approximately 100-fold during their seven to 10-day feeding period before dropping off the host. To accommodate this huge blood meal, the cuticle expands through synthesis and remodeling. This remarkable increase in size is a trait that is conspicuously understudied in ticks but could be explored to identify new targets for tick control. We are using a multi-omics approach to understand cuticular expansion in tick and combining with reverse vaccinology to identify new targets for tick control.

## Family matters: environment influences butterfly abundance and behavior but in lineage-specific ways

*Grace Hirzel, Ashlyn Anderson, Erica Westerman*

Understanding and being able to predict pollinator behavior is critical for maintaining pollination services for crops and biodiversity. However, pollinators are a diverse functional group, spanning temporal niches, ecological zones, and phyla. This diversity may be advantageous for the plants pollinators visit, while challenging for scientists interested in developing predictive models of pollinator abundance and behavior. Here, we use a broad strokes approach to identify predictors of abundance and behavior among different lineages of one group of pollinators: butterflies. We conducted monthly and biweekly surveys of butterfly abundance and family in central US tallgrass prairies in 2017-2021 and 2018-2020 respectively. We also collected behavioral data for butterflies during our biweekly surveys. We then assessed the predictive power of changes in temperature, precipitation, ambient light, and relative UV light on butterfly abundance and behavior, for the whole butterfly community, and individual taxonomic families. We found that temperature and ambient light were generally predictive of butterfly abundance, but that precipitation had a family specific effect, influencing Lycaenidae and Pieridae. In addition, while the butterfly community increased thermoregulatory behavior as precipitation increased and light levels decreased, this was driven by a large response in nymphalids. Our findings show that butterflies exhibit diverse responses to environmental stimuli, and that we may be able to use these diverse responses to predict family-specific changes in abundance and behavior over time.

## Bridging animal sociality and cognition with computational methods

*Elizabeth Hobson*

In many social species, individuals create their social worlds through interaction decisions and are then subject to and constrained by these social constructs, which can affect an individual's future actions. Understanding how much individuals "know" about their social worlds is critical in understanding these potential feedbacks. However, it is difficult to determine how much information individuals have about the social structures in which they live. In this talk, I summarize several ways my group is addressing these questions by combining empirical experiments with computational approaches to provide insight into cognition through social decisions. I highlight new work on aggression and dominance hierarchies, social learning and foraging, and mate choice copying and sexual selection to illustrate these approaches. These approaches, and a taxonomically broad perspective, provide new opportunities to investigate the effect of social information on individual behavior within conflict, learning in social contexts, and mate choice preferences and has the potential to provide rigorous evidence for the evolutionary patterns underlying social cognition.

## Shifting axes of phenotypic diversity across the evolutionary history of fishes

*Jennifer Hodge, Samantha Price*

Understanding how complex, multivariate phenotypes evolve across scales is crucial for deciphering the adaptive landscape of life. This study investigates how the major axes of phenotypic diversity shift across phylogenetic scales within teleost fishes, a group renowned for its extensive morphological variation. Using a morphometric dataset of eight traits that describe general body size and shape for over 6,500 fish species, we estimate the primary axes of phenotypic variation most aligned with, and independent of, the phylogeny. We quantify the extent to which the direction and magnitude of phenotypic diversification along these axes align or diverge across phylogenetic scales, and explore whether traits are consistently aligned with phylogenetic signal within and between scales. Preliminary analyses indicate that the major axes of variation shift significantly when analysed at different taxonomic ranks, reflecting the influence of lineage-specific evolutionary pressures and historical contingencies. This research offers new insights into the dynamic nature of phenotypic evolution and underscores the previously unrecognized importance of phylogenetic scale when interpreting patterns of morphological diversity.

## Uncoupling of mass loss, energy intake, and energy expenditure in a small passerine

*Brett Hodinka, Lewis Halsey, Tony Williams*

It is widely accepted that birds can adaptively regulate body mass in different ecological contexts, but little is known about how birds monitor and interpret their mass or the mechanisms that allow for rapid mass changes. Using captive zebra finches (Taeniopygia guttata), we increased perceived mass via attachment of weighted backpacks and provided birds with either an ad libitum mixed-seed diet or supplementary high-fat diet to investigate (a) how birds assess their body mass and (b) the physiological and/or behavioral mechanisms birds may employ to rapidly adjust body mass. In both experiments, and independent of diet treatment, birds with weighted backpacks rapidly lost mass within two days of backpack attachment while reducing overall activity and maintaining food intake. Our data suggest birds interpret body mass via a physical mechanosensory pathway rather than a physiological pathway: rapid loss of mass was not linked to changes in plasma metabolites (glycerol or triglyceride concentrations). We found no evidence that mass loss resulted from stress associated with attachment of weighted backpacks, based on plasma corticosterone measures. Our results suggest the processes of energy balance and mass regulation involve a greater array of mechanisms than simply matching energy in through the amount of food consumed to energy out, dictated by activity: zebra finches were able to decrease body mass through other, unidentified, mechanisms while maintaining dietary intake and reducing overall activity.

## On the multi-functional sexually selected characters across the avian speciation continuum

*Zackary Hodur, Derek Eddo, Silu Wang*

The evolution of sexually selected characters often provides strong premating and/or postmating isolation during speciation. These characters often harbor naturally selected functionality as well. The tempo and directionality of sexual versus natural selection on the same trait could render complex consequences at the species boundaries. With decades of studies on a diverse array of avian mating systems across the speciation continuum, it is an exciting time to synthesize the regularity and uniqueness in different clades of avian radiation. Here we synthesized the evidence of dual functional sexually selected characters targeting different sensory modalities: visual, acoustic, and olfactory, in various stages of avian speciation to understand the mode of synergy and antagonism of divergent sexual and natural selections behind avian radiation. This rich synthesis reveals the evolutionary trajectories during character divergence. We further highlight the major knowledge gaps and exciting future directions in this growing area of research. This melodious, colorful, and energetic review sheds light on the remaining mysteries in the radiation of feathered dinosaurs around us.

## Locomotor rest-activity patterns over ontogeny and between sexes in Lake Malawi cichlid hybrid cross

*Chloe Hoff, Niah Holtz, Evan Lloyd, Alex Keene, Craig Albertson*

The partitioning of ecological niches is key to the maintenance of biodiversity, especially in complex species assemblages. While circadian rhythm differentiation is one way in which species may partition their habitat, several questions remain with respect to this behavior, including how locomotor activity patterns change over ontogeny, differ between sexes, as well as their genetic basis. To address these questions, we examined locomotor activity in a large F2 hybrid population derived from crossing a diurnal cichlid species (Astatotilapia calliptera) with a nocturnal species (Tropheops sp. “red cheek”). Locomotor activity was tracked over a 24 hour light:dark cycle in individuals at early juvenile and adult stages. Notably, we found that juvenile activity was not predictive of adult activity. In fact, nocturnality was conspicuously absent among juvenile individuals, while 25% of adult F2 exhibited nocturnal patterns of activity, suggesting that the genetic architecture of this behavior changes ontogeny. We noted further that locomotor activity was not associated with sex, standard length, eye size, or melanin levels (used as a proxy for dominance), which suggests that it is not a secondary consequence of another trait (e.g., dominance). These data set the stage for genetic mapping studies to unravel the genetic mechanisms and evolution of circadian rhythm differentiation.

## Exploring the influence of female mate choice genetics on male mate preferences in a butterfly

*Wendy Hoffert, Kiana Kasmaii, Erica Westerman*

Mate preferences often appear differently across species and sexes, and this preference variation may be associated with genetic variation. For preferences that are genetically determined, the region of the genome that determines mate preference in one sex may also impact the preference or behavior of the other sex. To assess the genetic relationship between female mate choice and male mate preferences, we used the butterfly Bicyclus anynana. Having developed a selection line bred for female preference for four dorsal forewing spotted males, instead of the wild-type (WT) female preference for two dorsal forewing spotted males, we set out to determine if male preferences are also shifted in this selection line. We assess WT and selection line male preference for WT versus selection line females, to determine if selecting for female preference for 4-spotted males has a pleiotropic effect on male preference for WT females. Subsequently, we test male preference for females with either two or four forewing spots to investigate if there is a genetic correlation between male and female spot preferences. Preliminary data suggest that both WT and selection line males may prefer WT females over selection line females. This finding suggests that either pleiotropic effects of the preference for 4-spot locus, or inbreeding, may be influencing female attractiveness in this species.

## Intraspecific interactions and maintenance of polymorphic signaling along an environmental gradient

*Elizabeth Hoffman, Leah Bakewell, Brandon Buitrago, John David Curlis, Catherine Grey, Yanileth Lopez, John Nguyen, Claire Williams, Kelly Wuthrich, W. Owen McMillan, Michael Logan, Christian Cox*

Animal signals are important for intra- and interspecific communication and can be polymorphic within populations. However, the relative roles of habitat structure, individual behavior, and their interaction in the maintenance of signal polymorphism are still poorly understood. We studied signaling dynamics in the Panamanian slender anole (Anolis apletophallus), where males possess a polymorphic dewlap that can be either solid orange (solid morph) or white with an orange spot in the center (bicolor morph). Previous work has found that in a single population in central Panama, morph frequencies follow a gradient of canopy cover, with the bicolor morph dominating in areas with a more closed canopy, while the solid morph is more common under open canopies. However, how these signals are deployed during intraspecific interactions is unknown. We used tethered introduction assays to test how both male and female lizards respond to either male or female intruders along the gradient in canopy cover. We found that anoles of both dewlap morphs responded to signals from either dewlap morph, but in a sex-specific way. The responses observed included signaling via dewlap extension, which was coupled with head bobs or pushups, as well as attacking or fleeing. Our results highlight the role of habitat in mediating intraspecific interactions through animal signals.

## Comparison of three methods for quantification of fecal contamination

*Kellan Hoffman, Veronica Back, Sarah Wigren, Mark Elliott, Julie Olson*

Alabama has over 200,000 kilometers of rivers and streams. Navigable reaches of these waterways are frequently used for recreational purposes, serving as a significant source of income for local businesses and state agencies. Unfortunately, site closures are becoming increasingly common due to elevated levels of fecal indicator bacteria and Escherichia coli, organisms which can potentially lead to adverse health outcomes for humans and the environment, and a corresponding loss of recreational income. For this study, the Olson lab worked alongside Riverkeeper organizations in the Black Warrior, Cahaba, and Coosa watersheds during peak recreation season (June-August) to compare one emerging (Bacteroides 16S rRNA gene concentrations measured via droplet digital PCR, converted to cell count per 100ml) and two established (IDEXX Colilert and R-Cards enumerating E. coli, reported in CFU per 100ml) methods for estimating fecal contamination. Initial analyses of the dataset revealed a strongly positive correlation between E. coli counts reported by IDEXX Colilert and R-Cards over the entire study period (R=0.978, 0.887, 0.964). Correlations between ddPCR derived Bacteroides cell counts and E. coli counts from IDEXX Colilert or R-Card methods were strongly positive in June (R=0.959, 0.994) but decreased significantly in July (R=0.425, 0.685) and displayed very weak negative correlations in August (R=-0.135, -0.158). To investigate these discrepancies, additional analyses will include ddPCR quantifying Bacteroides originating solely from human sources and examination of precipitation patterns.

## 3D Muscle architecture reveals the hydrostatic function of the pangolin tongue

*Casey Holliday, Lillian Porter, Christopher Zobek, Conner Verhulst, Eric Hostnik, Copper Aitken-Palmer*

The tongues of pangolins are among the more derived of other mammalian ant-eating specialists, extending nearly a body length to capture food. Anteaters, aardvarks and pangolins all pack portions of their hyolingual apparatus in their thoracoabdominal cavity through the use of oropharyngeal, cervical and xiphisternal structures. The xiphisternal bones of pangolins extend into an extracoelomic pouch in their right flank and serve as the skeletal attachment for muscles of the tongue. Using DiceCT and 3D muscle architectural modeling of a cadaveric Phataginus tricuspis (White-bellied pangolin), we show how the arrangement of muscle fascicles in a section of the abdominal portion of the pangolin tongue is likely a hydrostat. Coiled xiphisternal elements anchor the longitudinally-oriented fibers of m. sternoglossus, the primary tongue retractor muscle. Interconnecting m. xiphisternalis muscle fibers envelope m. sternoglossus. The coiled nature of the xiphisternal bones and attachments of tongue retractors suggest an elastic mechanism may help propel tongue extension. The tongues reside in a glossal tube, separated via a mucosal layer, then ensheathed by a layer of circular muscles and more superficially longitudinal muscles which modestly, helicially wind around the long axis of the tongue. The fiber organization of the superficial layers suggest they are responsible for powered tongue extension. Together, the orientations and layering of muscles of the pangolin tongue appear to meet the criteria of a musculature hydrostat.

## Bite force and head shape plasticity of Crotaphytus collaris (Eastern Collared Lizard) in Arkansas

*Jackson Holsted, Matthew Gifford*

Seasonal plasticity suggests that variation in specific phenotypes occurs seasonally in individuals responding to environmental changes and can impact their performance within a community. Bite force is a crucial performance trait that helps determine mating success, territory, and prey type. Head morphology is often measured and compared among individuals when looking at differences in bite force, and specific aspects of morphology influence bite force more than others. Crotaphytus collaris populations in Arkansas are ideal for studying seasonal plasticity. Common in the southwest desert prairie, the Ozark highlands of Arkansas represent their eastern range limit. Over time, overlogging and fire suppression increased invasive plant presence. In Arkansas, research has examined population demography and reintroductions, but none have considered variation in performance or phenotypic plasticity. As environments change due to global warming and human-induced actions, trait plasticity could be a key factor allowing population persistence. This study examined bite force and head morphology in male and female C. collaris during the breeding and non-breeding season to test for patterns of change between individuals and populations in different glade habitats. We hypothesize that bite force and head size will peak during the breeding season and decrease afterward, with males exhibiting more pronounced changes than females. Data collection will conclude in August, followed by immediate analysis.

## The evolution and ecological consequences of rest/activity patterns in Lake Malawi cichlids

*Niah Holtz, Chloe Hoff, Evan Lloyd, Andrew Conith, Alex Keene, Craig Albertson*

Amongst the swath of biological mysteries, a fundamental question remains: how diverse species assemblages are maintained in space and across evolutionary time? The division of environmental resources through altered behavioral patterning—niche partitioning—is one way biodiversity is maintained. Most often, niche partitioning is viewed through a spatial lens, but temporal partitioning can also be important. Lake Malawi cichlids are an excellent model to study such questions due to their complex species assemblages, rapid speciation, and unparalleled diversity. Previously, we demonstrated marked variation in day:night activity across several cichlid taxa, suggesting that temporal niche partitioning may be important in this group. Here we expand our phylogenetic scope and utilize machine learning tools, including Yolo v8 and SORT, to increase our spatio-temporal resolution of these behaviors. We document broad and continuous variation in day:night activity, including diurnal, nocturnal, and crepuscular species. We note further that tank space usage differs between day and night, and across species, with some species utilizing the entire tank, while others exhibit more limited movement. By rigorously quantifying these behaviors in a phylogenetic context, we hope to better understand the evolutionary potential of behavioral patterning and its role in maintaining biodiversity.

## Does innovation in morphology increase performance? a case study with misfit fish

*Roi Holzman, Matt McHenry, Dana Kruger*

A classic pursuit in biomechanics is understanding how evolutionary innovations in morphology affect the mechanics and performance of species. However, the effects of innovation have been difficult to generalize, by virtue of its uniqueness. Here, we focus on a case of sequential innovation in the muscleskeletal cranial system in misfit fish. This radiation includes seahorses and pipefishes that evolved a Latch-Mediated Spring-Actuated (LaMSA) system to drive their ultrafast feeding strikes. Interestingly, species within this radiation show a sequential transition between muscle-powered feeding, a LaMSA system based on one elastic element and a system based on two elements. Here, we measured suction feeding kinematics and hydrodynamics in species with one- and two- elastic elements and compare them with muscle-powered species. We find that LaMSA increased suction flow and head elevation speeds by an order of magnitude in species with one- and two- elastic element systems compared to muscle-powered species. Within LaMSA species, size had a dominant effect on suction flow and head elevation speeds, while the number of elastic elements had a minor effect. However, the timing of major kinematic and hydrodynamic events (e.g. the timing of peak flow speed) in one-elastic element species was similar to that observed in muscle-powered species rather than the two-element species. Our results demonstrate that innovative morphologies do not universally improve all aspects of performance.

## The present is the key to the past: simulating deformation to detect biological signal in fossils

*William Hooker, Andrew Orkney, Brandon Hedrick*

Separating meaningful biological signal from surrounding noise is essential for conducting robust comparative morphological analyses. This is especially true for fossils, whose original biological shapes have been taphonomically altered due to burial in rock over geological time scales. To understand the effect of taphonomy on organismal shape, we simulated taphonomic deformation on a large dataset ($n = 68$) of raccoon (Procyon lotor) crania using 3D geometric morphometrics. While biological signals are apparent in the undeformed raccoon crania, these trends are obscured following artificial deformation. These results were compared with an extensive sample ($n = 59$) of crania of Diictodon feliceps, a basal therapsid from the Late Permian Karoo Basin of South Africa. We categorized the D. feliceps crania into five taphomorphotypes – bilateral, dorsoventral, rostrocaudal, shear (left and right), and saddle-backed, which formed distinct clusters in morphospace. Like the artificially deformed raccoon crania, biological trends were not detected in the taphonomically deformed D. feliceps crania, suggesting that taphonomic overprinting is driving shape trends in D. feliceps. Through the lens of artificially deformed specimens that have known biological shape, we are able to better understand how fossil deformation may be impacting biological signal. Ultimately, distinguishing the real signals from taphonomic noise will enhance our understanding of macroevolutionary change over deep time.

## Morphology, mechanics, and ontogeny of oral jaws and dentition across diverse diets (Stichaeidae)

*Richard Hoover, Joseph Heras, Kassandra Ford, Karly Cohen, Cassandra Donatelli*

Pricklebacks (Stichaeidae) are a model for studying the evolution of omnivory and herbivory in fishes. Several species integrate increasing amounts of plant material into their diets as they grow, and this ontogenetic dietary shift is matched by genetic, enzymatic, and soft tissue adaptations (such as increases in gut length) to better process and assimilate plant material. Since the mechanical demands of eating plants vary considerably from the demands of a carnivorous diet, we hypothesized that oral jaw morphology, dental characteristics, and tooth biomechanics reflect ontogenetic dietary shifts in pricklebacks. To explore this relationship, we first captured the fine morphology of the oral jaws and dentitions using high resolution microCT across four species of prickleback. We then compared jaw and dental traits between species and quantified the scaling of these traits over ontogeny ($n=9$ per species). We use linear discriminant analyses to identify traits that drive differences between dietary groups and to predict the diets of other stichaeid species. Lastly, we quantify functional variation within dentitions using a functional homodonty model. Pricklebacks span jaw and tooth morphotypes from fast-moving jaws with many needle-like teeth, to powerful jaws with large, rounded teeth. While there is trait overlap between groups, we find several jaw and dental traits define dietary groups and exhibit allometry over ontogeny.

## Quantifying the Kinematics and Hydrodynamics of Prayiid Siphonophores

*Ruby Hope, John Costello, Kakani Katija, Joost Daniels, Sean Colin*

Siphonophores, multi-jetting colonial jellyfish, are found abundantly throughout the water column in open ocean ecosystems. Little is known about their swimming mechanics due to difficulty collecting and working with such delicate animals in the laboratory. Most siphonophores generate thrust using jet propulsion by several propulsive units called nectophores; however, siphonophores in the family Prayidae (termed Prayiids) have unique nectophore morphology and kinematics that are inconsistent with jet propulsion. Determining propulsive mode is important because it is known to be related to the feeding strategies of cnidarians. To determine propulsive mode, videos from the laboratory and field were analyzed to quantify the swimming kinematics and hydrodynamics of 4 Prayiid species, Desmophyes sp., Praya dubia, Craseoa sp., and Stephanophyes superba. Their swimming acceleration was estimated from a kinematic model assuming they only used jet propulsion and compared to their observed acceleration. For all the species, the observed thrust was significantly greater than the predicted thrust (from the jet model); therefore, it appears that Prayiid siphonophores do not rely solely on jet propulsion to swim. To determine what other types of propulsive mechanisms that Prayiid siphonophores utilize, in addition to jet thrust, we used particle image velocimetry (PIV) to quantify the hydrodynamics around swimming nectophores.

## Superoxide Dismutase 1 knockdown affects lifespan and healthspan in Drosophila melanogaster

*Denise Horner, Nicole Riddle*

Superoxide dismutase 1, SOD1, is a mitochondrial enzyme that removes toxic superoxide anion radicals generated through electron transport leakage by metabolizing them into hydrogen peroxide and oxygen. SOD1 dysfunction is associated with several disease conditions such as premature aging, amyotrophic lateral sclerosis (ALS), and cancer. SOD1 knockdown reduces lifespan, while SOD1 overexpression increases lifespan in mice, flies, and nematodes. Using Drosophila melanogaster, we investigate the sex-specific effects of SOD1 knockdown on lifespan and healthspan. We use the UAS-Gal4 system to remove SOD1. We find that ubiquitous SOD1 knockdown has a strong effect on lifespan and that this effect is sex-specific. Males lacking SOD1 show a much shorter lifespan than control animals and shorter than females lacking SOD1. Females lacking SOD1 also show a reduced medium lifespan, but their maximum lifespan is similar to that of controls. Males lacking SOD1 also show decreased activity levels, while in females lacking SOD1 activity levels were similar to those of control animals. These results suggest that males are more affected by the accumulated reactive oxygen species and ongoing experiments will explore the molecular mechanisms that might control these sex-specific effects of SOD1 knockdown.

## Poor-quality dietary protein reduces number of eggs but not egg lipid content in lubber grasshoppers

*Alicia Horton, Amaya Yip, Emma Kordek, John Hatle*

Dietary protein quantity influences evolutionary fitness trade-offs of animals. For example, on diets that are low in protein, animals tend to produce higher quality but fewer numbers of eggs. We tested whether dietary protein quality can induce trade-offs by feeding grasshoppers four different diets. The amino acid composition of the precursor of egg yolk (vitellogenin) was the high-quality dietary protein. The amino acid composition of the mid-quality protein diet was 50% matched to vitellogenin. These two diets were isocaloric and isonitrogenous. Ad libitum-lettuce (positive control) and a low-protein diet (negative control) were also tested. Previously we showed that the mid-quality diet reduced the total lifespan eggs by ~50% (P=0.057) in comparison to the high-quality diet. Here we report on egg size and lipid content (extracted with petroleum ether). The low-protein diet increased the size-corrected lipid content in eggs by ~68%, in comparison to the other three groups (ANOVA, $P < 0.05$; REGWQ post-test $P < 0.05$). For egg size, the low-protein diet group produced eggs ~16% smaller than the ad libitum-lettuce diet group (ANOVA, $P < 0.05$; Tukey's post-test P=0.0019). These data imply reduced protein content; further investigation will determine the protein content of these eggs. The isonitrogenous high-quality and mid-quality protein groups had similar egg sizes and lipid contents. Overall, poor quality protein (mid-quality group) led to fewer eggs but no change in egg quality.

## Neural serotonin receptor expression and social behavior in the polymorphic white-throated sparrow

*Brent Horton, Nate Wilson, Donna Maney*

Neural serotonin (HTR) activity has been shown to mediate social behavior in mammals, yet this extent to which this hypothesis applies to birds remains poorly understood. Indeed, serotonin activity in the avian brain is vastly understudied given the role that birds play as models for understanding social behavior. Here, we used in-situ hybridization to quantify neural serotonin mRNA expression in white-throated sparrows (Zonotrichia albicollis). These sparrows exhibit plumage and behavioral polymorphism linked to a chromosomal inversion that captures a suite of neuroendocrine genes, including those for two serotonin receptors (HTR1B and HTR1E). During the breeding season, the two color morphs, white-striped (WS) and tan-striped (TS), differ in aggression and parenting behaviors. Our study examines whether and how neural serotonin receptor 1B and 1E expression differs between morphs and correlates with behavior. This examination focuses on behaviorally relevant nuclei of the serotonergic system and the vertebrate social behavior network (SBN). In mammals (e.g., mice), high neural serotonin activity is associated with low aggression, and vice versa. More recent evidence suggests that serotonin activity may also be associated with parental behavior. We consider whether these relationships are seen in regards to serotonin receptor expression in white-throated sparrows studied for behavior in the wild.

## Variation in activity as a function of lunar phases in an intertidal fish

*Sameen Hossain, Riley Wood, Ryan Earley*

The Earth's moon Luna plays diverse roles in regulating natural cycles, ranging from its influence on tidal rhythms to behavioral and migratory patterns of diverse marine species. The Moon's gravitational pull and phases have an additional effect on the nocturnal activities of terrestrial animals, making it a key facilitator of general ecological balance. This study used mangrove rivulus fish to explore the potential association between lunar phases and activity levels. We hypothesized that activity will vary in accordance with lunar phases, possibly in a sex dependent fashion. Our research methodology involves a comprehensive analysis of 1,768 samplings of catch data between 2010 and 2024. This dataset enables the tracking of long-term trends in fish activity across sites and time, particularly in relation to varying lunar phases recorded by the US Naval Observatory. We are currently finalizing data collection and intend to uncover patterns to further our understanding of the Moon's influence on variation in activity. This research might provide clues about potential shifts in predator or prey communities associated with tidal peaks and troughs, as activity levels are expected to change in the face of danger or opportunity to secure resources. Lunar cycles could also induce physiological changes that mediate behavioral expression, and we intend to explore whether such changes might be sex specific, with hermaphrodites and males showing different moon-related patterns of activity.

## Quantifying variation in the CNS of *Lithobates heckscheri* tadpoles

*Megan Hostetter, Dominik Valdez, Christopher Heesy, John Phillips, Leigha Lynch*

Despite the increasing prevalence of amphibians as models for early embryological development, little is known regarding variation of central nervous system (CNS) morphology in most species. Our study fills this gap in knowledge by providing an anatomical description of the CNS and quantifying the variation in brain volume relative to body mass and snout-vent length (SVL) in Lithobates heckscheri tadpoles as compared to adult specimens. Twenty L. heckscheri tadpoles collected near Valdosta, Georgia were subjected to a diffusible iodine-based contrast-enhanced computed tomography (diceCT) protocol. Utilizing AVIZO software, the CNS was then segmented to generate 3D models of the brain, spinal cord, spinal and cranial nerves. Brain volume data was collected using the cranial surface of the fourth cervical vertebral body as a cutoff from the distal CNS. A strong allometric signal was observed between brain volume and body mass ($R2 = 0.96$; $p<0.001$) and between brain volume and SVL in tadpoles ($R2 = 0.89$; $p<0.01$). This relationship was markedly increased in the adult. The size and shape of the telencephalon and optic tectum varied among specimens, but points of origin and branching patterns of the cranial nerves were consistent. The models created in this study are a critical foundation for understanding CNS morphology in developing anurans, particularly in wild populations, and can be used to determine the influence of environmental variation on this developing morphology.

## The evolution of using shed snake skin in bird nests

*Jennifer Houtz, Vanya Rohwer, Robyn Bailey, Maren Vitousek, Eliot Miller*

Many species of birds use shed snake skin in nest construction, but this behavior remains poorly understood. We use comparative and experimental approaches to suggest that the evolution of this behavior is mediated by nest morphology and predator communities. First, we found that 78 species from 22 families have been reported to use shed snake skin in nest construction. All but one of these species are passerines and, using comparative analyses, we show that this behavior is disproportionately observed in cavity-nesting species. Second, we examined a subsample of North American species, all of which are reported to use snake skin in nest construction, to see if the proportion of nests with snake skin differs between cavity and open cup-nesting species. This analysis suggested that the proportion of nests with snake skin is 6.5 times higher in cavity than in open cup-nesting species. Finally, we used a series of experiments and comparisons to test four hypotheses whereby snake skin could award fitness benefits (nest predation, nest microbiotas, nest ectoparasites, social signaling) and found support for the predation hypothesis. Snake skin reduced nest predation in cavity, but not open cup, nests. These unequal fitness benefits highlight different ecological conditions between nest morphologies and likely explains why, across species, cavity-nesting birds show this behavior more frequently compared to open cup-nesting birds.

## Opsin-expressing cells identified within the skin of the summer flounder (*Paralichthys dentatus*)

*Maureen Howard, Russell Ward, Lorian Schweikert*

Extraocular photoreception, the capacity for light detection in tissues outside the retina, has been implicated in variety of animal behaviors, including dynamic background-matching camouflage. Gene expression studies across color-changing animals have suggested similarities in the mechanisms of photoreception between the eyes and skin, including the expression of opsins traditionally understood to support image-forming vision. One such animal is the summer flounder (Paralichthys dentatus), but the expression pattern of opsins in the skin and the function they might serve in dynamic color-change remains unknown. Here we used anti-opsin immunohistochemistry to characterize the expression patterns of three opsin classes over the dorsal (i.e., color-changing) and ventral surfaces of a bilaterally asymmetrical flatfish, the summer flounder (N=3). On the dorsal surface, SWS1 and LWS opsin expression occurred beneath the skin's color-changing cells (i.e., chromatophores), while on the ventral surface, only LWS was expressed and only within cells comprising the most superficial layer of the ventral epithelium. These differences in opsin expression pattern and spectral sensitivity may suggest two distinct functions of dermal photoreception in the summer flounder, with that of the dorsal and ventral surfaces conferring abilities to sense information about the state of skin color and the state of the substrate environment, respectively. These findings provide new insights into the cellular biology of dermal photoreception, suggesting opsin may have a functional significance in mediating dynamic color change.

## Ocean acidification causes bivalve shell deformation via intracellular $Ca^{2+}$ signaling dysregulation

*Chi Huang, Joseph Matt, Christopher Hollenbeck, Wei Xu*

The calcareous shells of bivalves provide crucial structural support and protect their soft bodies from multiple environmental stresses. Increased atmospheric CO2 leads to an acidified ocean environment, reducing calcification rates and shell deformities in shellfish by disrupting the saturation state of CaCO3. To understand the effects of ocean acidification on marine bivalve calcification, we used the primary cells cultured from the mantle epithelial cells of Eastern Oyster (Crassostrea virginica), which is an economic fishery bivalve species, as a model of this study. The intracellular Ca2+ flux is visualized using the Fluo-4 Ca2+ indicator under the CO2 exposure. The increase in intracellular Ca2+ concentrations correlated with the upregulation of calmodulin, the primary sensor of intracellular Ca2+ levels in eukaryotic cells. The expression levels of several conserved shell matrix proteins (SMPs) under a simulated acidification condition suggested that the elevated CO2 level may affect the arrangement of CaCO3-SMPs during oyster shell formation. The potential roles of Ca2+ and calmodulin in organizing the shell structure in bivalve species were identified using a calmodulin antagonist, W-7, to treat the mantle cells. Additionally, the in vivo study with larval oysters showed significantly different responses of calmodulin and SMPs to acidification conditions varied by developmental stages. The genetic regulatory pathway mediated by the Ca2+-calmodulin signaling is likely essential for understanding the impact of ocean acidification on marine animal calcifications during development.

## Deep history of the MAPK signaling network: Phylogenetic relationships and functional specialization

*EJ Huang, Jeeun Parksong, Amy Peterson, Sergi Regot, Gabriel Bever*

The mitogen-activated protein kinase (MAPK) signaling network forms a three-tier phosphorylation cascade that regulates diverse aspects of cellular physiology in Eukarya. Despite its ubiquitous presence, the functional diversity across lineages and the causative evolutionary history of the MAPK signaling network remains poorly characterized. In this study, we performed a comprehensive phylogenetic analysis of MAPK network components across Eukarya, focusing on orthologs of human paralogs and transformations along the human phylogenetic backbone. We identify two major pulses of coordinated network expansion: one predating the origin of Opisthokonta, and another on the stem of Animalia. Notably, our reconstructed trees show distinct evolutionary trajectories for the two families of MAP3Ks. The Sterile (STE) MAP3Ks represent the original components and function of the ancestral cascade, with similar functions shared by plants and animals among other eukaryotes. However, it is the tyrosine kinase-like (TKL) MAP3Ks whose expansion aligns phylogenetically and functionally in a top-down order with diversification of the downstream MAP2Ks and MAPKs. Along with reviews from the experimental literature, we show that these expansion events are associated with finetuning and increased specificity for downstream substrates, with potential implication to the origin of animal multicellularity and the adaptive immunity in vertebrates. By elucidating the evolutionary history of the MAPK network, we provide an evolutionary foundation for further hypothesis generation regarding the functional expansion of this critical network in Eukarya.

## Extreme heat leads to impoverished invertebrate communities at the Rio Bosque

*Wilfrid Hufton, Krysta Lehman, Asher Marvy, Enrique Garcia, Alina Spera, Vanessa Lougheed*

Created wetlands within arid regions, such as the Chihuahuan Desert, provide hotspots for biodiversity as well as the ability to purify effluent from wastewater treatment plants (WWTPs). Arid regions account for almost one-third of the Earth's terrestrial landscape, however, wetlands within these regions are critically understudied. The purpose of this project was to evaluate how the health of the Rio Bosque Wetlands Park (RB) in El Paso, Texas has changed since transitioning from an inconsistent to a nearly year-round water supply in 2016/17. The RB's previous and current primary sources of water input are effluent, groundwater, and irrigation runoff. Analysis of aquatic invertebrate communities and water quality data can be used as proxies to interpret the ecosystem's health. Aquatic invertebrates and water quality were collected from four subsites within the RB across an eight-week period in June & July 2024. Since data were last collected in 2017, the results show a significant change in aquatic invertebrate community composition and increases in temperature. Despite the consistent water supply over the past 8 years, and subsequent increase in vegetation cover, multiple metrics may indicate that the state of the RB could have declined. Further research should be conducted on the vegetation, invertebrate, and vertebrate communities within the RB to determine how they have been affected since 2016/2017.

## Multimodal predator recognition and defense behavior in a rove beetle

*Noelle Huget, Jessleen Kanwal, David Miller, Mina Yousefelahiyeh, Joseph Parker*

Survival in complex ecosystems relies on the ability of animals to rapidly detect and respond to potential threats. Such recognition requires the nervous system to seamlessly integrate sensory cues across multiple modalities. However, the mechanisms underlying multimodal cue integration for predator detection and evasion remain poorly understood. Here, we use the genetically and experimentally tractable rove beetle, Dalotia coriaria, to identify the contribution of tactile, visual, and volatile and contact chemical cues in predator avoidance and defense. In nature, Dalotia use an abdominal chemical defense gland to selectively target and deploy benzoquinone irritants toward predators such as ants. We reconstituted this chemical defense interaction in tethered beetles walking on a spherical treadmill. We find that Dalotia's anti-predator response is comprised of two separable components: an evasive reorientation flee response and a defensive abdominal flexion response. Using CRISPR/CAS9 genetic engineering and computational neuroethology techniques, our results demonstrate that 1) the flee response is mediated by volatile chemical cues detected through Dalotia's olfactory receptors and 2) the defensive abdominal flexion response is triggered by a synergistic combination of tactile and contact-chemical cues. Specifically, cuticular hydrocarbons covering the ant cuticle are the predominant chemical cue for threat recognition upon contact, followed by ant trail following pheromones (iridoids). Overall, our study reveals how multimodal heterospecific stimuli enable threat detection and defense in an ecological interaction between two animal species.

## Proteomic changes in response to anoxia in anoxia-tolerant killifish cells

*Chelsea Hughes, Jason Podrabsky, Meranda Corona, Dietmar Kueltz*

Embryos of the annual killifish Austrofundulus limnaeus have the greatest tolerance to anoxia of all vertebrates, which is supported by the ability of embryos to arrest development in diapause. WS40NE cells, a neuroepithelial cell line isolated from an embryonic A. limnaeus tissue explant, can survive anoxia for 49 days, while SH-SY5Y human neuroblastoma cells can survive anoxia for only approximately 1.3 days and mouse N2A cells can survive for just over 3 days. Killifish cells, therefore, are an important tool in identifying specific cellular mechanisms that support anoxia tolerance and recovery in vertebrate cells. Mass spectrometry based proteomics was used to quantify differential protein abundances in anoxic, anoxia-recovered, and normoxic WS40NE cells. Multiple KEGG pathways, such as metabolic and insulin resistance pathways, were significantly upregulated and may support anoxia tolerance and recovery. Additionally, multiple pathways were significantly downregulated, suggesting that these pathways are not necessary during anoxia or may even be detrimental. Lastly, we identified several unidentified proteins that are differentially expressed across these conditions that may represent new players in anoxia tolerance. Understanding how key biological pathways are regulated during anoxia will provide insight into how these cells support stress tolerance. This work is partly funded by NSF (2025832, 2209383).

## Overturning a century of thought: pupillary light responses in animals with "immobile pupils"

*Parker Hughes, R. Langerhans*

Teleost fishes, which comprise about half of all vertebrates, are thought to possess immobile pupils. This is surprising because pupillary light responses (PLRs) offer clear advantages for visual performance in dynamic light environments, and most other vertebrates possess the ability. Reviewing the literature, we uncovered a neglected past—ample evidence for PLRs and the required iris musculature has existed for diverse fishes for over 100 years. Experimentally testing well-studied "model" fish species believed to have immobile pupils, we found that PLRs are ubiquitous and variable in magnitude among taxa. We then revealed how divergent light regimes have shaped the evolution of PLRs in a post-Pleistocene radiation of Bahamas mosquitofish (Gambusia hubbsi) inhabiting blue holes. In the absence of predators, G. hubbsi utilize much more dynamic light environments, and have subsequently repeatedly evolved greater pupillary constriction abilities. In blue holes with higher turbidity, which reduces light availability, these fish have further evolved greater pupillary dilation abilities. Altogether, our results contradict the current consensus in science, and suggest that PLRs are ancestral to Eugnathostomata, much more widespread than previously assumed, and that ecological changes in light environments can drive their adaptive evolution.

## Toe tips and tricks: climbing kinematics and morphology of Aneides salamanders

*Jonathan Huie, R. Pyron, Sandy Kawano*

Climbing salamanders (Aneides spp.) are renowned for their abilities to scale rock faces and trees, but lack classic adaptations for climbing like claws or adhesive toe pads. Here, we compared climbing and non-climbing species to identify phenotypic traits that enable Aneides to climb. To reduce the risk of falling, we hypothesized that climbing Aneides keep their center of mass closer to the substrate when climbing and have modified feet that improve clinging performance. We compared 3D kinematics of two climbers (A. aeneus and A. lugubris) with that of the terrestrial A. hardii walking on flat surfaces at 0, 45, 80, and 90 degree inclines. We also compared foot size relative to body mass, surface microstructures of the toes, and toe bone shape across Aneides species. We found that all Aneides use similar kinematics on steeper inclines, such as reduced climbing speed and greater limb abduction to lower their center of mass. However, some A. hardii (80%) and A. lugubris (30%) would not climb vertically, whereas 100% A. aeneus did and were the fastest species on all inclines. Aneides toe tips are smooth, suggesting they have no specialized adhesive properties. Although, climbing species have proportionally larger feet that increase contact area and toe bones that are more mechanically advantageous than terrestrial species. Aneides use a novel suite of traits to overcome the physical challenges of climbing.

## Cnidarian-algal symbioses in a changing world

*Ryan Hulett, Natalie Swinhoe, Emily Meier, Victoria Brown, Phillip Cleves*

As animals, we live intimately associated with microbes and these interactions are a fundamental feature of our biology. An intriguing case of animal-microbe interactions as well as a remarkable example of extreme cell biology is the cnidarian-algal intracellular symbiosis. Several cnidarian lineages (e.g., anemones, corals, and jellyfish) have the ability to establish intracellular symbioses with dinoflagellate algae. The algae enter cnidarian host cells and reprogram host gene expression, leading to transcriptionally distinct cell-states that harbor photosynthetic algae, which provide cnidarian hosts with their needed nutrition. This intracellular symbiotic relationship also plays a foundational role in coral reef ecosystems threatened by climate change, yet the transcriptional basis for its formation remains poorly understood. Here, we investigate the transcriptional mechanisms of symbiosis formation using functional genomics in the anemone Exaiptasia diaphana (Aiptasia), a research model for cnidarian-algal symbiosis. We found genes associated with symbiosis and symbiotic cell-states using bulk and single-cell RNA sequencing, identifying transcriptional regulators of symbiosis. We functionally characterized one of these transcriptional regulators, investigated its evolution, and mechanism of controlling symbiotic cell fate formation. This work reveals the transcriptional mechanisms of symbiosis formation in a sea anemone model for coral biology and explores how intracellular algae reprogram host gene expression and cell fate decisions.

## Bioenergetics of self-regulation under temperature stressors in developing fish from different therm

*Ione Hunt von Herbing*

Over 97% of ray-finned fishes produce free-swimming larvae. With < 0.01% survival and radically different morphologies from adults, larvae play a central role in adaptation to environmental change and dispersal of fishes. In modern larvae, responses to changing climate can exert negative effects through stimulation of the hypothalamic-pituitary-interrenal (HPI) axis and autonomic nervous system (ANS) and physiological adaptation is necessary to re-establish physiological stability. After a century of investigation, a critical gap remains in identifying how larvae employ bioenergetic strategies for allostasis (stability through change or self-regulation). Metabolic experiments on yolk-sac larvae in species from different environments, 1) zebrafish (Danio rerio) (tropical, freshwater) and 2) Atlantic cod (Gadus morhua) (cold-temperate, marine), were raised under chronic high-temperature (31°C zebrafish; 10°C Atlantic cod) vs. controls (28°C zebrafish, 5°C Atlantic cod) and further exposed to acute changes of 3°C (zebrafish) and 5°C (Atlantic cod). Chronically raised larvae had greater allostatic loads (ALs) (energetic costs of exposure to stressful events) than acutely exposed larvae, experienced energy budget shifts, increased energy allocation to metabolic activities, and impressive phenotypic plasticity in the first week of larval life. Additional acute exposure led to maladaptive responses (dysregulation) in the face of limited energy resources (yolk). Thus, response mechanisms to stressors may be a vehicle for the evolution of novel more resilient, or adaptive physiological states in developing stages.

## The use of blood metabolites to examine the energetic state of an ectotherm (Elaphe bimaculata)

*Norman Hunter, Isabella Davis, Lori Neuman-Lee*

Traditional studies of metabolic rate typically use oxygen consumption to examine trends of energy metabolism throughout an acute period. While useful for measuring total energy usage, oxygen consumption neglects energetics at a molecular level. The use of energy metabolites to gauge body condition and energy usage are common in birds, but are scarce in non-avian reptiles, especially during energetically demanding events such as reproduction. To examine changes of energy use and allocation throughout an energetically demanding event, we collected blood from 26 adult Elaphe bimaculata (15 male, 11 female) over a 42-week period that encompassed pre-reproduction brumation and mating in both sexes and post-oviposition in females. All blood samples were analyzed to determine blood glucose levels. We found that glucose varied over the course of the reproductive period. Blood glucose levels decreased throughout the brumation process.These results indicate that the use of blood metabolites to study energy allocation is a potentially viable method to study the metabolic processes of snakes at a molecular level.

## Seasonal Homeostasis of Brown Bears (Ursus arctos horribilis): Plasma Osmolality varies with Creatin

*Andrea Huriega, Amelia Christian, Anthony Carnahan, Charles Robbins, Gabriella Ten Have, Jessie McCleary-Smith, John Thadden, Nicolaas Deutz, Perry Barboza*

Bears must maintain osmotic balance of blood when feeding in summer and fasting in winter. We hypothesized bears would vary proteins, electrolytes, urea and creatinine to maintain plasma osmolarity in each season. We sampled blood plasma from adult nonreproductive bears (5 females; 4 males) at 16 h post feeding over 33 d in summer (August to September) and over 90 d of winter dormancy (December to March). Bears maintained body mass in the summer period and lost 16% of body mass in dormancy. Body water turnover declined from 10.3 L·d-1 in summer to only 0.7 L·d-1 in winter, but plasma osmolality was maintained in a range of 26 mOsm around a mean value of 273 mOsm. Creatinine concentration was lower in summer (1.4 vs. 2.8 mg·dL-1) whereas urea concentration was lower in winter (16 vs.10 mg·dL-1). Plasma osmolality was not related to concentrations of electrolytes (Na, Cl, K) or proteins (albumin, globulin) in either season. Osmolality increased with creatinine concentration in both seasons. Osmolality declined as urea concentration rose in summer (13 mOsm over 13 mg·dL-1) but increased slowly as urea rose over winter (5 mOsm over 13 mg·dL-1). We know bears use urea to recycle N in winter, but urea may be an important osmolyte for homeostasis in both seasons.

## Present and future distribution modeling of the Olympia oyster (*Ostrea lurida*)

*Luis Hurtado, Kristin Privitera-Johnson, Christine Mantegna, Camille Gaynus, Tiara Moore*

The Olympia oyster (Ostrea lurida) is the only oyster native to Western North America, and can be found from Baja California, Mexico to British Columbia, Canada. This formerly abundant species was an important food source for Indigenous peoples, but unsustainable commercial harvest in the late 19th century severely depleted its populations. Interest in oyster recovery across Western North America has surged over the past two decades and many restoration projects have been implemented to reintroduce O. lurida to habitats where it was extirpated. Restoration efforts should consider the effects of changing climates on the long-term habitat suitability of selected sites. Thus, understanding how environmental variables (temperature, pH, salinity, chlorophyll, etc.) shape the potential distribution of O. lurida is critical. Using publicly available records of O. lurida occurrences and Bio-ORACLE v3.0 marine data layers, we modeled the present-day distribution of this species through a maximum entropy approach. After selecting the best performing model, we projected it for 2050 and 2090. Our projections indicate that O. lurida will undergo a significant northern range expansion and some southern range contraction. Overall, we project a net gain in potential habitat. Restoration projects and commercial aquaculture initiatives may benefit from using this model to inform site selection, ensuring these efforts target habitats that will remain suitable through at least the end of the century.

## Beyond patterns in integrative biology – testing explanations for sex differences

*Jerry Husak, Rhynn Paulsen, Simon Lailvaux*

Integrative biologists have a recognized history of conducting research that is both hypothesis driven and pattern finding. The latter type of investigation is often an essential precursor to the former, but at some point a discipline must move beyond repeatedly confirming a pattern and begin explicitly testing proximate and ultimate explanations for that pattern. We searched all issues of several integrative biology and comparative physiology journals in the last several years to see how and why integrative biologists have tested for sex differences in their study systems. Specifically, we searched for articles that tested for sex differences in traits. Beyond that, we further determined if the investigators proposed a proximate/ultimate explanation for the sex difference and whether they collected any relevant data to test that explanation. Our results suggest that many studies test for a sex difference, but frequently without an a priori or a posteriori reason. Of those studies that both found a sex difference and proposed an explanation, the vast majority had no data to support or refute that explanation. We use some similarly descriptive and non-mechanistic examples from our own research to make recommendations for how to better move from pattern to explanation.

## How difficult is it to be ICONIC? Challenges faced by BIPOC shark scientists in the Global South

*Ingrid Hyrycena, Meghana Binraj, Buddhi Maheshika Pathirana, Omolara Fola-Matthews, Lauren Simonitis, Jasmin Graham*

The longstanding lack of gender, ethnic, and racial diversity in shark and ray studies has been a concern. Additionally, “parachute” or “helicopter” science, where scientists from wealthier nations conduct research in developing countries without involving or informing local researchers, is pervasive. In response, researchers from countries in the Global South collaborated with peers from the Global North, leading to the establishment of an international joint project called ICONIC Oceans following Integrated, Coordinated, Open, Networked (ICON) principles. In partnership with artisanal fishers, morphometric data and biological samples collected from fishing landing sites were coupled with fisher interviews, citizen science, and active participation in fishing operations in Brazil, India, Nigeria, and Sri Lanka. Each country had its own Field Research Lead. Despite the sociocultural differences between Africa, Asia, and South America, we experienced similar challenges: sexism, risky working conditions, difficulties obtaining permits, and limited access to or complete lack of infrastructure. Furthermore, scientists with greater financial power often conduct their research in an unethical manner, displaying exploitative behaviors towards early career researchers and creating unfair competition. It is crucial to address these issues and discuss strategies and solutions to prevent this from persisting any longer. Even without solving the big issues (like lack of institutional power), research activities are possible at individual grassroot levels if the systemic problems are addressed.

## An ICONIC Ocean of opportunities: the overlooked cartilaginous fishes biodiversity in Brazil

*Ingrid Hyrycena, Patricia Charvet, Victoria Lebedeff, João Pedro Sader Teixeira, Paulo Santos dos Santos*

Brazil holds the seventh position globally in terms of species richness of sharks, rays, and chimaeras with a total of 211 marine and freshwater species. Despite the country’s ranking among the top 20 in the world for the capture, trade, and meat consumption of sharks and rays, there is still a significant knowledge gap about several species. Fishing offers an opportunity to obtain and study these organisms. Six species (Dasyatis hypostigma, Hypanus spp., Rhizoprionodon spp., Mustelus spp., Galeocerdo cuvier, Carcharhinus leucas) were chosen as targets of the ICONIC Oceans project efforts in Brazil. However, thanks to a strong partnership with artisanal fishers, we had access to more species than planned, totaling 30 species (18 sharks, 11 rays, and 1 chimaera). We combined biometric data and biological samples with information about commercial operation, type of gear, and location. We actively participated with fishers through beach seines, bottom-trawling and gillnet operations, fishing landings, and citizen science. Even for endangered species like Rhinoptera spp. and Aetobatus narinari where release was prioritized, we still were able to collect valuable data. Our records of A. narinari expand its geographic range to the southernmost region of Brazil, 5 specimens were seen and released by fishers in Balneário Camboriú city. Our initial results demonstrate that with proper funding, we can access a wide range of threatened species while collaborating with traditional communities.

## Addition of a peristaltic wave to a multilegged robot improves locomotion performance

*Massimiliano Iaschi, Baxi Zhong, Daniel Soto, Jianfeng Lin, Tianyu Wang, Daniel Goldman*

Soft robots demonstrate capabilities in navigating complex environments due to the mechanical intelligence inherent in their compliant components. However, such compliance also introduces challenges in precise actuation and control. Consequently, soft robots are often slow and prone to mechanical failure. Here, we propose a hybrid robot with rigid body and soft actuation, where rigid modules coupled with springs are actuated by cables. Specifically, we built a 95cm long five-segment crawler with non-actuated rigid "legs". Each segment has two DOFs: a cable-driven joint that moves planarly in the sagittal plane (vertical joint) and a cable-driven linear actuator for longitudinal contraction (peristaltic joint). Movements in vertical and peristaltic joints were prescribed by propagating a traveling superposition of two waves, referred to as vertical and peristaltic waves respectively. We show that on hard ground a phase of $\pi/4$ rad between waves leads to effective forward translation at $0.16 \pm 0.01$ BLC (body length per cycle) whereas phasing of $\pi$ rad can only self-transport at $0.09 \pm 0.01$ BLC. Preliminary experiments on complex terrains consisting of steps whose height was approximately 140% the robot height suggest that the inclusion of peristalsis substantially improves the overall locomotion performance by manipulating the head trajectory and avoiding jamming. Highlighting the importance of peristaltic waves, our robot experiments provide insights to model elongated limbless or multilegged animals, with the objective of complex environment traversing or burrowing applications.

## Effects of early-life exercise on tendon morphological and mechanical properties

*Apolo Ibanez Rincon, Dean Mayfield, Anthony Cobos, Tyler Whitacre, Angela Horner, Natalie Holt*

Exercise can increase tendon mechanical properties by yielding higher tendon stiffness and modulus. Since tendon tissue turnover slows after skeletal maturity, it has been suggested that early-life exercise may be beneficial. We exposed mice (N=48) to running wheels that were either locked in place (control; n=13), unloaded (low resistance; n=17), or loaded (high resistance; n=18) for 10 weeks post-weaning. Mice were tested either immediately after the growth period or after a 3-month washout. Mice were terminally anesthetized, an electrode placed on the sciatic nerve and the Achilles tendon exposed, marked at its proximal and distal ends and connected to a force and length transducer. Isometric tetanic contractions were performed to determine maximum active muscle force. Sine waves of sufficient amplitude to reach 70 - 80% of this force were applied, the tendon videoed at 60 Hz, and digitized to determine tendon stretch. Images of the tendon were taken, length and cross-sectional area were determined, and tendon strain, stiffness, and elastic modulus were determined. Preliminary results suggest that there is no effect of early-life exercise on tendon morphological or mechanical properties, even with higher wheel resistances. Future work is needed to see if there are any beneficial effects of early life exercise in aging tendons.

## Syrinx Anatomy and Vocal Production in New World Vultures (Aves: Accipitriformes: Cathartidae)

*Bradley Ibarra, Carmen Urban, Lucas Legendre, Julia Clarke*

New World vultures (Cathartidae) are the only birds proposed to lack a syrinx, the vocal organ of Aves. The few previous studies have yielded different results regarding the presence, absence, and structure of key tracheal and bronchial elements in Cathartidae (e.g. syringeal muscles/membranes and tracheal/bronchial rings). New World vultures have largely been described as incapable of producing vocalizations due to lacking a functional syrinx; however, there is a relatively diverse repertoire of sounds made by Cathartidae available in online sound libraries. This lack of consensus concerning the syrinx and vocal ability of Cathartidae prompted reinvestigation of cathartid airway anatomy to disentangle the variety of claims made in previous literature. Here we test for the presence of anatomical traits that match previous definitions of a functional syrinx in other avian clades. Through dissections, diffusible iodine-based contrast-enhanced computed tomography (diceCT), and histology of two species in Cathartidae, we find evidence that New World vultures have some of the key components critical to a functional sound-producing syrinx. These findings broaden our understanding of the essential components of a syrinx and clarify the evolution of syringeal structures in Cathartidae. This study highlights the need to think critically about our definition of the syrinx, which was historically defined primarily in reference to function, for future descriptions of other understudied bird clades in a functional and phylogenetic context.

## Influence of visitor numbers and noise levels on the behavior of captive meerkats

*Malak Ibrahim, Kelly Diamond*

It is crucial to understand how external factors impact the welfare of captive animals. For animals on exhibit, higher visitor numbers can increase stress in meerkats as indicated by elevated glucocorticoid concentrations. This research also explored how group size could influence the stress level of meerkats. Additional captive animal studies have shown that noise levels can also be considered an external stress factor. Our aim for this study was to quantify behavioral changes in meerkats in response to visitor number and noise level. We aimed to identify behaviors that have traditionally been associated with elevated stress levels to assess meerkat stress levels using non-invasive methods. We predicted that these external factors would increase stress, resulting in behavioral differences when larger and louder groups are observing meerkats compared to smaller, quieter groups. To investigate this, we observed a group of six captive meerkats at the Memphis Zoo, collecting data on visitor number, noise level, and meerkat behavior at regular intervals. None of our behaviors differed among the noise levels recorded. However, we found that more meerkats spent time resting when there were fewer visitors surrounding their exhibit. This study highlights the influence of human-caused external stressors on captive animal behavior and that, although they may not always change meerkat behavior, understanding subtle behavioral responses is crucial to enhancing the welfare meerkats in zoo environments.

## Leveraging mass citizen science data for insect color macroecology: a foundational AI approach

*Jacob Idec, Robert Guralnick*

The natural world is awash in functional colors, yet our understanding of color variation across the tree of life remains poorly understood. Citizen-science platforms where users upload images of organisms present an opportunity to obtain large-scale body color, especially for groups such as dragonflies where many colors fade to brown within months in museum specimens. However, these field images are often noisy, lacking standardized lighting, camera sensors, and camera post processing. Furthermore, the variation in viewing angle and background make accurate segmentation of organisms difficult, and filtering for heterogeneous life stages, dead organisms, and incomplete bodies necessary. Here we unveil a multistep pipeline for color extraction that starts with two foundational models - the groundingDINO zero-shot object detector and the SegmentAnything model - to automatically segment organisms from their backgrounds. Next a filtering step clusters these segments by pretrained ResNet-extracted features and allows the user to select unwanted clusters to drop. Having obtained normalized body segments, color traits can be recovered using color means & thresholds, color clustering, or species-discriminative feature extraction using BioEncoder. We showcase the utility of this approach via two case studies - North American dragonflies and beetles - where we visualize color trait evolution and test thermoregulatory and signaling hypotheses. We also discuss the challenges and complexities of using these data and strategies for pulling the best possible signal from noise.

## Stress changes DNA methylation over 8 hours in house sparrow (*Passer domesticus*)

*Oluremi Ige, Aaron Schrey, Kevin Kohl, Marty Martin*

House sparrows (Passer domesticus) thrive in a variety of environments after being introduced, having been successfully introduced across the globe. As such, house sparrows are an excellent model to investigate how individuals respond to novel environments. Epigenetic mechanisms, particularly DNA methylation, play an important role in the rapid response of house sparrows to introduced environments that is necessary for this success. There is greater variance in DNA methylation among introduced compared to native house sparrows. DNA methylation state is correlated to gene expression, and changes in DNA methylation are related to organismal response to stress. Here, we compare DNA methylation states before and after an injection of lipopolysaccharide (LPS), used to simulate the infection, among introduced and native house sparrows. Our objective was to determine how dynamic DNA methylation states were among individuals, among geographic locations, and between birds from introduced and native locations. We used epiRADseq to screen DNA methylation from blood samples from 0- and 8-hours post LPS injection from house sparrows that had been collected from introduced and native areas. We expect there to be greater variance in DNA methylation and more change over time in birds from introduced locations compared to birds from native locations.

## Thermal impacts on growth and metabolism in larval Tautog (*Tautoga onitis*)

*Emily Ignatoff, R. Chambers, Delan Boyce, Ehren Habeck*

As consumer demand for fish increases, it is critical that fisheries scientists consider means of captive rearing with minimal detriments to fish health and survival, and to the environment. The tautog (Tautoga onitis) is a wrasse (family Labridae) found in shelf and inshore habitats of the Western North Atlantic between Nova Scotia and South Carolina. It is popular among recreational fishers and a highly valued market fish. Nevertheless, efficient methods for rearing tautog in an aquaculture setting have yet to be established. This study sought to evaluate how water temperature affects larval tautog growth and metabolic rates in a laboratory setting. Data for this analysis were drawn from experiments conducted in 2023 and 2024 at the NOAA NMFS Sandy Hook Laboratory. In 2023, impacts of a wide range of constant temperatures (16 to 26°C) on larval size and metabolic rate were assessed at ∼35 days post-hatching– near the transition between tautog larval and juvenile life stages. In 2024, the same metrics were collected from an experiment that expanded sampling frequency for a more modest temperature range (18 to 22°C). Analyses of the 2023 data suggest larval growth and respiration rates increase with temperature, but these measures of performance may come at a price of reduced metabolic efficiency, increased feeding costs, and elevated risks of starvation, leading to higher total mortality despite greater growth.

## Forelimb muscle activity in alligators and the evolution of limb posture and powered flight

*Masaya Iijima, Christopher Mayerl, Victor Munteanu, Richard Blob*

The evolution of archosaurs provides an important context for understanding the mechanisms behind major functional transformations, such as shifts from sprawling to erect limb posture and the acquisition of powered flight. Reconstructing the evolution of motor control requires data from extant species, but the scarcity of electromyography (EMG) data from the crocodilian forelimb has hindered understanding of neuromuscular evolution in archosaurs. We recorded EMGs for nine forelimb muscles from American alligators during terrestrial locomotion, testing for variation in motor control across different limb postures and through tetrapod phylogeny. Among the muscles examined, m. pectoralis, the largest forelimb muscle and primary shoulder adductor, exhibited significantly smaller mean EMG amplitudes for steps in which the shoulder was more adducted (i.e., upright). This suggests that using a more adducted limb posture helps to reduce forelimb muscle force and work during stance, a factor that may contribute to relationships between evolutionary changes in limb posture and increases in body size. Comparisons of EMG burst phases among tetrapods revealed that birds and turtles, which have experienced major musculoskeletal transformations, displayed distinctive burst phases in comparison to those from alligators and varanid lizards. These results support the conclusion that major shifts in body plan and locomotor modes among sauropsid lineages, such as powered flight, were associated with significant changes in muscle activation patterns.

## Global Patterns of Species Richness and Phylogenetic Endemism in Chameleons

*Chukwudi Ikegwu, Josue Azevedo, Lotanna Nneji, Segun Oladipo*

Phylogenetic endemism and species richness patterns reflect how speciation, extinction, and dispersal have influenced current distributions of species. Understanding patterns of phylogenetic endemism and species richness can provide essential insights into variation in geographic patterns of community assemblages, and it is fundamental to biological conservation planning. Here, we investigated geographic richness patterns and phylogenetic endemism of Chameleons using over 26,000 geo-referenced records covering more than 200 chameleon species globally. We measured the phylogenetic endemism (PE) as the total phylogenetic branch length encompassed by taxa in the geographic region, where the phylogeny was modified such that each branch length was divided by the global range size of its descendent clade. Our results showed that most areas of high PE for Chameleons present a combination of both ancient and recently diverged diversity, which is distributed primarily in Madagascar, the Eastern Arc Mountains and the coastal forests of East Africa. Areas of weighted endemism and phylogenetic endemism are higher across Madagascar, resulting in more phylogenetically distinct PE centres. Our study highlights the importance of Madagascar and East African ecoregions to ancient and recent narrowly distributed Chameleon diversity, which has important implications for the conservation of the World's chameleons.

## Does incubation temperature influence host defenses in different eastern bluebird populations?

*Sila Inanoglu, Joyce Anastasia, Hannah Brewer, Olivia Hansing, Sandra Knutie, Carissa Leung, Jenna McKay, Bridget Sleath, Sarah Knutie*

Hosts have evolved and developed defenses, such as tolerance and resistance, against their parasites. Host defenses can vary across species or individuals within a population, especially when there are local adaptations to temperature, but few studies have examined this across different host. The goal of our study was to identify whether host populations vary in defense strategies against the same parasite taxa and how temperature influences defenses across these populations. Specifically, we examined resistance and tolerance strategies in three populations of eastern bluebirds (Sialia sialis) against their parasitic nest blow flies (Protocalliphora sialia). We then experimentally manipulated nest temperature (cold/heat/none) during egg incubation and measured changes in resistance. To identify defense strategies across three populations (Connecticut [CT, 42°N], Southern Minnesota [SMN, 45°N], and Northern Minnesota [NMN, 47°N]), we followed survival and measured hemoglobin levels (a proxy of blood loss, tolerance measurement) of nestlings and then quantified blowfly nest abundance and prevalence (resistance measurement). To identify whether temperature influences resistance across populations, we experimentally manipulated nest temperatures during the egg incubation stage and measured the resulting parasite abundance. Parasite prevalence was similar in NMN and SMN, but abundance was highest in NMN and CT, suggesting that SMN is resistant while NMN is tolerant. When heat stress was introduced, parasite abundance decreased in the NMN population, suggesting that the heat treatment increased resistance in the NMN population.

## Better predicting multi-trait evolution to climate change by incorporating predation and plasticity

*Miyauna Incarnato, DeAnthony Rothwell, Kyle Coblentz, John DeLong, Kristi Montooth*

Amid global climatic change, it is critically important to understand how multiple simultaneous selective forces interact with temperature to shape the evolutionary trajectories and ecological dynamics of populations. Using a model protist system Paramecium caudatum, we are investigating the interplay between climate change, predator-prey dynamics, and phenotypic evolution by evolving genetically diverse populations to warmer and more variable climates in the presence or absence of a copepod predator. We have shown that P. caudatum has significant genetic variation for multiple traits, including shape and movement, that interact to impact predation risk (Coblentz et al. 2024, Functional Ecology, https://doi.org/10.1111/1365-2435.14644). To build a predictive understanding of how climate change interacts with predation to drive prey trait evolution, we need to incorporate thermal plasticity of these same traits. We are investigating the potential for the unique genetics of P. caudatum, including two nuclei—a germline micronucleus and a highly reorganized macronucleus where gene expression occurs—to enhance trait plasticity in this system. We will present data using a quantitative genetic framework that tests whether the development of a new macronucleus, which is coupled to sexual reproduction, imparts greater potential for trait plasticity in response to the two thermal treatments experienced by our evolving populations.

## Individual Mechanisms of Balance Control: Modulating Lower Leg Stiffness in Humans

*Lauren Infantino, Manny Azizi*

Balance is a multi-level process influenced by factors such as age, physical activity, injury, and personal history. To stabilize the center of mass over the base of support, individuals employ a variety of stabilizing mechanisms at the joint level, influenced by personal physiological constraints or adaptations. At the ankle joint, individuals may modulate joint stiffness to maintain balance by coactivating antagonistic muscle pairs, creating equal and opposing torques around the joint effectively allowing the lower leg segment to remain vertically upright to support the mass. Understanding how and why individuals modulate ankle joint stiffness, and how this relates to overall balance control and correlates to individual characteristics, is crucial for a comprehensive understanding of human balance control mechanisms. To discern ankle joint stiffness and its relationship to balance, we collected Center of Pressure (COP) data to evaluate balance level and electromyography (EMG) from antagonistic muscle groups (Tibialis Anterior-Medial Gastrocnemius) to evaluate the level of simultaneous activation indicative of joint level stiffening (co-activation index). We predict that those who modulate towards a higher ankle joint stiffness will be associated with a higher level of balance. In addition, certain individual characteristics will be more closely associated with participants modulating towards a higher ankle stiffness to stabilize the body. Preliminary results demonstrate certain individuals stiffening the ankle joint significantly more than others to promote stabilization (68% vs 28%).

## Novel method for creating super high resolution species distribution models

*Aleida Iriarte, Jason Brown*

Species distribution models (SDM) help ecologists save time and resources by predicting high-suitability areas for target species. Unfortunately, SDMs are inferences and sometimes do not accurately reflect reality. This is especially true for SDMs of smaller organisms, like amphibians, that rely on specific microhabitats not distinguished by typical 1km resolution SDMs. In this project, we aim to increase the spatial resolution of SDMs by developing a novel method that allows data resolution of 30m to be incorporated into the models, resulting in greater accuracy. Using a unique algorithm developed by Dr. Jason Brown, we use microtopography layers to convert climate data in 1km resolutions into 30m resolutions. Once the high-resolution datasets are created, we combine them with rarified occurrence points and run an analysis that determines which variables are the best predictors for the species' distribution. The final model is a combination of multiple models with the best predictive variables. Using this novel method, I created species distribution models for two Peruvian poison dart frogs (Ranitomeya fantastica and R. summersi). The new models outperformed models made using 1km data resolution in three separate performance metrics; AUC, AIC, and OER. This suggests the creation of more precise SDMs that reflect the complexity of landscapes and microhabitats. These new high-resolution SDMs can be useful for locating elusive species that require specific microhabitats.

## Modeling the relationship between gape and bite force in primates

*Jose Iriarte-Diaz, Stephanie Canington, Janine Chalk-Wilayto, Jose de Oliveira, Igor de Souza, Carla Escabi-Ruiz, Megan Holmes, Cláudia Kanno, Michael Platt, Claire Terhune, Myra Laird*

Bite force and gape are two important performance metrics of the feeding system of animals, and these metrics, for a given muscle, are inversely related because of fundamental constraints in sarcomere length-tension relationships. This means that, without specific muscular adaptations, most animals cannot produce high bite forces at large gapes for a muscle of a given size. Despite the importance of these variables for feeding biomechanics and functional ecology, the paucity of experimental data on maximal bite forces in primates has led to bite forces largely being estimated through indirect methods, such as physiological cross-sectional areas of jaw adductor muscles as a proxy of their maximum tetanic force capacity. In this project, we quantify and compare in vivo bite forces and gapes with output from 3D and musculoskeletal models of jaw adductor muscles of different species of primates, including lemurs, capuchin monkeys, and macaques. Our results suggest that musculoskeletal models are better at predicting the shape of the gape-bite force relationships than at predicting the magnitude of maximal bite force. The combination of experimental and modeling data allows us to evaluate the relative importance of morphological and functional parameters used in musculoskeletal models such as muscle architecture parameters as well as the role of ecology and behavior in the estimation of bite force in primates.

## Studying the evolution of body shape and locomotion through the lens of 3D modelling

*Duncan Irschick*

Over the past decade, there has been tremendous innovation in 3D modelling techniques, both from a hardware and software perspective. These new innovations now allow scientists to reconstruct living animals in 3D with a high level of accuracy. When combined with new machine learning techniques, and innovations in rigging and animation, it is now possible to study questions in the evolution of body shape and locomotor kinematics using these methods. Here, I discuss several ongoing projects using these tehniques, including new efforts to study locomotor kinematics in terrestrial megafauna, as well as modelling efforts of marine megafauna, particularly sharks and marine mammals, and how 3D modelling has yielded new insights into the evolution of body shape in these animals. Finally, I discuss ongoing efforts to scan a wider range of animals for a wide range of scientific, educational and conservation uses.

## A novel form of phenotypic plasticity evolved via lineage-specific changes in gene expression

*Andrew Isdaner, Nicholas Levis, David Pfennig*

Novel forms of phenotypic plasticity may evolve by lineage-specific changes or by co-opting mechanisms from more general forms of plasticity. Here, we evaluated whether a novel resource polyphenism in New World spadefoot toads (genus Spea) evolved by co-opting mechanisms from an ancestral form of plasticity common in anurans: accelerating larval development rate in response to pond drying. We compared overlap in differentially expressed genes between alternative trophic morphs constituting the polyphenism in Spea versus those found between tadpoles of Old World spadefoot toads (genus Pelobates) when experiencing different pond-drying regimes. Specifically, we (1) generated a de novo transcriptome and conducted differential gene expression analysis in Spea multiplicata, (2) utilized existing gene expression data and a recently published transcriptome for Pelobates cultripes when exposed to different drying regimes, and (3) identified unique and overlapping differentially expressed transcripts. We found thousands of differentially expressed genes between S. multiplicata morphs that were involved in major developmental reorganization, but the vast majority of these were not differentially expressed in P. cultripes. Thus, S. multiplicata's novel polyphenism appears to have arisen primarily through lineage-specific changes in gene expression and not by co-opting existing patterns of gene expression involved in pond-drying plasticity. Therefore, although ancestral stress responses might jump-start evolutionary innovation, substantial lineage-specific modification might be needed to refine these responses into more complex forms of plasticity.

## Wild Eastern bluebirds are resilient to anthropogenic noise: insights from a novel cognition assay

*Sara Isgate, Caitlin Honus, Bailey Betcher, Gabriel Casanova, Julian Avery, Jason Keagy*

Problem-solving should shape breeding success in wild animals, and there is growing interest in biologically relevant assays of such cognitive abilities. In birds, previous research has shown decreased problem-solving proficiency when exposed to noise. However, it is unknown how the interplay between noise and cognition impacts fitness. Here we focus on cognitive performance and parental care in cavity-nesting birds with and without anthropogenic noise.

We developed a novel, low-cost operant conditioning device to observe problem-solving performance in wild Eastern bluebirds (Sialia sialis) exposed to playback of anthropogenic noise. During peak nestling provisioning, mated pairs were presented with the device, featuring an obstructive door and two levers, on the front of their nest box. Perching on the "active" lever allowed subjects to access nestlings within the box, while the box remained closed while perching on the "inactive" lever. We quantified personality traits (neophobia, activity, persistence), problem-solving performance, and eventual fledging success.

We found no significant effect of noise on problem-solving performance or reproductive success. However, problem-solving performance was significantly affected by personality, with neophobic birds being less likely to solve and highly active birds being more likely to solve. Problem-solving performance also significantly improved over time, consistent with learning. Operant conditioning devices like this, which capitalize on the evolutionary motivation to provision young, are therefore valuable for quantifying innovation potential in the face of anthropogenic change.

## Hop 'til You Drop: Impact of Limb Loss on Locomotion in Spotted Lanternflies (Lycorma delicatula)

*Ariba Islam, Anand Kanumuru, Pranav Krish, Jonathan Shadan, Kyle Dixson, Christine Lee, Ashley Choi, Gabby Guilhon, Michael Granatosky*

The spotted lanternfly (Lycorma delicatula), is an invasive planthopper rapidly spreading through the Northeastern United States. The current approach to eradication is through the "See it. Squish it" campaign. Despite these efforts, the lanternfly's leaping ability often allows it to evade capture, even with damaged or broken limbs. This study investigates whether such physical damage affects their locomotor performance. We studied how limb loss influences climbing speed, take-off speed, and acceleration in nymph-stage lanternflies and whether recovery occurs post-amputation. Eighty individual lanternflies were divided into four groups: control, foreleg amputation, midleg amputation, and hindleg amputation. Using high-speed cameras, we recorded their climbing and leaping performance before and after limb removal. Post-amputation, the lanternflies were monitored daily for a week to assess any changes. Our findings reveal that while foreleg amputation notably slowed climbing speed, it had minimal impact on leaping. In contrast, removing the hindlegs led to significant declines in both climbing and leaping speeds, as well as reduced acceleration during take-off. Midleg amputation showed only minor effects on leaping performance. No recovery signs were observed, indicating that limb loss consistently hampers locomotor abilities. Despite these impairments, lanternflies were still able to climb and leap when needed, raising questions about the ultimate impact of these performance limitations on their survival and fitness.

## The Living Sailor: Using iNaturalist and Zooniverse to Unlock a Mystery in High Seas Biogeography

*Tom Iwanicki, Rebecca Helm*

For thousands of years, humans have been delighted and surprised by strange blue jellies washing up on shore. These harmless animals, called by-the-wind sailors (or Velella velella), are normally found in the open ocean far from shore, but occasionally, when the wind blows just right, they drift ashore where they may be photographed by iNaturalist observers. Here we introduce The Living Sailor project on Zooniverse, where we leveraged 11,115 iNaturalist observations to answer a decades old question about by-the-wind sailors: does the direction of the fleshy sail guide by-the-wind sailors into different biogeographic regions? A total of 1,169 volunteers classified cumulatively 67,926 subjects to determine three variables: (1) count: the number of by-the-wind sailors, (2) condition: alive or dead, and (3) direction of sail: left or right. Using a super-majority threshold of agreement among six volunteers per subject, the volunteers were able to positively identify 6,377 by-the-wind sailors. Subjects that proved difficult for volunteers to reach consensus contained valuable information and we provide insight for the development of Zooniverse training materials and best practice for shore-based photography for iNaturalist Projects. We also highlight feedback and impressions from highly motivated volunteers for an "on-the-ground" perspective and as a resource for future community science efforts.

## Flying vinegar flies localize attention when responding to complex visual scenes

*Aaron Jackson, Steeve Pierre, Jamie Theobald*

Insects exist in a world full of movement, navigating through cluttered environments to seek resources while attempting to avoid dangers. Flies must use tiny brains to process sometimes staggeringly complex sensory input, and then produce coherent flight. It is an ongoing challenge to understand how insect brains successfully assign salience and attention to elements of a visual scene. To address this, we examined three aspects of attention: object tracking, anticipation during occlusion, and attentive acuity. To determine effective attention, we examined tethered, flapping flies while they viewed patches of coherently moving dots among general, incoherent motion. We then altered other visual aspects of the scene to mimic visual features of natural environments. Our results from white noise motion suggest that fruit flies focus their attention on solid objects that exist in their environment.

## Brockton Kids Lead the Way: A Sustainable Investment in Connecting Urban Kids to Nature

*Molly Jacobs, Anushree Bopardikar, Clare Cunningham*

Environmental stewardship arises when people feel connected to nature, when nature is part of their personal system of ethics, and when they feel empowered to make a difference. Children from urban, underserved communities may appear to have lower levels of environmental stewardship or affinity for nature, simply because their access to nature has been limited. Brockton Kids Lead the Way is a NOAA-funded partnership between Manomet Conservation Sciences and Wildlands Trust designed to sustainably invest in access to nature in Brockton, a diverse, urbanized, and economically disadvantaged environmental justice community in Massachusetts. Manomet and its partners work with participating schools to design, build, and co-teach in outdoor learning spaces on school properties, working with schools to build repeated exposure to outdoor learning time and nature-based curricular elements into teaching culture and practice. The outdoor learning spaces and associated lessons have been extremely well received by students and teachers at the schools; curriculum integration has been slower but is ongoing. Here, we will provide an interim assessment of the program including evaluation by a senior STEM education researcher from TERC. Overall, teachers wished to continue using their outdoor learning spaces, and the spaces and lessons were engaging for their students and supported their content understanding. We will also discuss ways academic scientists can make their education-based broader impacts work more effective and sustainable.

## Bridging the gap between biology and biomimicry: are biological principles useful for designers?

*Sarah Jacobson, Dimitri Smirnoff, Anita Schuchardt, Mary Guzowski, William Weber, Jessica Rossi-Mastracci, Alan Love, Ruth Shaw, Mike Travisano, Mark Borrello, Gillian Roehrig, Emilie Snell-Rood*

The biological world commonly serves as inspiration for design and other problem solving (e.g., engineering, architecture), a practice known as biomimetics or biomimicry. However, problem-solvers without a background in biology can struggle to tap into the wealth of biological knowledge. To address this gap in knowledge, sets of biological principles have been created by different organizations to distill the vastness of biology and make it accessible to professionals and students. However, the problem-solving utility of these principles is understudied. We surveyed problem solvers of various professions for their perception of problem-solving utility for two sets of biomimicry frameworks: "Life's Principles" and "Nature's Unifying Patterns". Respondents indicated their perceptions quantitatively using a six-point Likert scale followed by qualitative explanations of their thinking using open-ended responses. This poster builds on our quantitative study with an exploration of why survey participants assigned particular statements particular ratings. Here, we present preliminary themes of what made statements more or less useful for problem solving, identified through qualitative coding. Respondents expressed confusion with statement phrasing as well as relevance to their particular fields. They also identified why certain statements hold utility for them in their problem-solving process. Our analysis will help inform biologists what qualities of these statements problem solvers find applicable for biomimetics, and additionally, will aid in the creation of a common vocabulary amongst biologists and problem solvers.

## Effect of countermovement depth on jump performance in guinea fowl

*Cesar Daniel Jacques Ibarra, Brooke Christensen, Caitlin Bemis, Monica Daley, Ava Sirignano*

Ground dwelling birds use jumping as a primary mechanism of predator evasion in the wild. Maximal jump velocity and height are limited by the force and power produced by an animal's hindlimb muscles. Jump performance can be enhanced through a countermovement behavior, which increases the force and power output through muscle pre-stretch and elastic recoil. In our study, we investigate the role of the countermovement on maximal force and take-off velocity in jumping guinea fowl (Numida meleagris). Based on prior research, we hypothesize that variation in jump height will require shifts in kinematic timing of the pre-jump countermovement. To test these ideas, we collected high-speed video and ground force data as guinea fowl executed jumps from the force plate onto a horizontal bar incrementally adjusted to three vertical heights (30cm, 50cm, 70cm). We analyzed hindlimb joint kinematics from video data and double integrated the acceleration measured from ground reaction force to calculate changes in center of mass velocity and position over time. Preliminary results indicate a relationship between joint flexion, during the countermovement, and vertical jumping height. The data suggest that the higher the individual jumps the deeper countermovement performed and greater the joint flexion. NSF DBI-2319710.

## Automating bumble bee tracking to study sublethal impacts of pesticides on behavior

*Anupreksha Jain, James Crall*

The vast majority of flowering plants depend on insect pollination for successful reproduction, but many pollinator species are in decline due to anthropogenic stressors, with dire consequences for biodiversity conservation and food security. The intensive use of insecticides in conventional agriculture has been shown to adversely affect the physiology, behavior, and performance of non-target organisms at even trace but field-relavant concentrations. However, there are significant knowledge gaps in our understanding of simultaneous effects on different types of behaviors in a realistic plant community context. Here we used a combination of low-cost high-throughput computer vision and machine learning powered tools and individual tag tracking to investigate the sublethal effects of imidacloprid, a neonicotinoid, and flupyradifurone, a novel butanolide insecticide, on Bombus impatiens nesting, foraging activity, and flower visitation in a semi-field environment. By advancing our knowledge of the sublethal impacts of pesticides on bumble bee behavior, this work contributes to the development of informed strategies to safeguard pollinator populations and pollination services. Further, this protocol can be powerful and effective for comprehensively studying multi-modal effects of various stressors on bumble bee behavior, informing the development of sustainable agricultural practices and conservation strategies.

## Interactive effects of the social environment and habitat quality on maternal hormone allocation

*Anna James, Alexandra Bentz*

Mothers can communicate environmental conditions to developing offspring through hormones, potentially programming them to be better adapted (i.e., hormone-mediated maternal effects). While maternal effects are found across taxa, they are particularly well studied in birds. For example, in many species, females allocate higher levels of testosterone (T) to egg yolks in response to heightened social competition (e.g., greater breeding density), which can cause offspring to grow faster and be more aggressive. However, natural environments are becoming increasingly contaminated with pollutants, some of which are endocrine-disrupting chemicals that can alter hormonal processes. Exposure to these contaminants could impact a female's ability to communicate social information via yolk T to her offspring, disrupting an important source of inter-generational plasticity. Here, we used female red-winged blackbirds (Agelaius phoeniceus) to investigate how breeding in habitats that differ in potential contaminant exposure affect a female's ability to allocate yolk T in response to the social environment. We measured breeding density and collected eggs from habitats that vary in their exposure to urban stormwater runoff. Stormwater runoff from streets can contain pesticides, fertilizers, pharmaceuticals, and industrial chemicals, many of which could impact hormonal processes. We then quantified yolk T concentrations using enzyme-linked immunosorbent assays. Ultimately, these data will help us understand the factors that can disrupt a female's ability to communicate the social environment across generations, potentially leading to maladaptive effects.

## An experimental heat challenge uncovers individual variation in heat dissipation behaviors

*Emmy James, Rees Many, Kimberly Rosvall, Elizabeth Derryberry*

Heat waves are increasing in severity and frequency worldwide, posing new selection pressures on organisms. Behavior can shield organisms from this change, with strategies like shuttling or panting to avoid overheating. Despite behavior's potential role in setting the pace of evolutionary response to heat, relatively little is known about the scope of individual differences in heat dissipation strategies. This gap is particularly wide for endotherms and their altricial young, for whom heat may be inescapable. Using an experimental heat challenge, we quantified variation in heat dissipation behaviors of individually marked tree swallow (Tachycineta bicolor) nestlings. We elevated the ambient temperature of nestboxes by 4°C and scored the behaviors of twelve-day-old chicks, such as panting and proximity to cool air from the nestbox hole. Consistent with prior studies, heat-exposed broods perform more heat dissipation behaviors. And yet, within these broods, we uncover substantial individual differences in behavioral strategies; when confronted with the same heat challenge, some nestlings pant almost constantly while their siblings hardly pant at all. This suggests that some individuals may be more equipped to mount a behavioral shield against heat than others. Our future research will explore the underlying causes of this variation – and its consequences – to understand how behavior may alter the pace of adaptation to heat.

## Feeling the heat: thermal plasticity changes competitive ability across a salamander hybrid zone

*Emmy James, Martha Muñoz*

Temperature mediates performance in ectotherms, affecting their ability to grow, survive, and reproduce. Aggression and evasion are key examples of thermally dependent behaviors that can impact fitness. However, we know little about how the thermal sensitivity of such behaviors varies among close relatives and impacts competitive outcomes. Woodland salamanders (Genus: Plethodon) from the Appalachian Mountains are distributed across wide thermal gradients. These lungless salamanders compete for space and develop hybrid zones where territories overlap among species. Plethodontids tend to exhibit increased aggression at warmer temperatures, suggesting that as temperatures rise, behavioral interactions may be altered in ways that impact hybrid zone dynamics. It is thus far unclear, however, how salamander hybrids, which may encroach on their parent populations and drive competitive exclusion, respond behaviorally to warming. Here, we used staged bouts to examine the effects of temperature on aggression and evasion in the Plethodon shermani and Plethodon teyahalee hybrid system from the southern Appalachians. The behavior of salamanders from parent populations, particularly Plethodon shermani, appears to be more sensitive to thermal changes than that of hybrid individuals. Our results suggest that rising temperatures may increase competition for preferable microhabitats, but the effects on behavior among parental and hybrid salamanders will be asymmetric. Temperature may therefore alter the outcomes of competition, determining which populations can persist under rapid warming.

## What affects honeybee (Apis mellifera) recruitment to pollen sources?

*Madeline James, Peculiar Emmanuel-King, Erian Stewart, Morgan Carr-Markell*

The unique foraging strategy of honey bees involves a communication behavior called the waggle dance. This dance includes repeated signals, called waggle runs, that each convey distance and direction. Honey bees collect nectar as their main source of carbohydrates, but pollen provides most other nutrients. Different plant species provide pollen with different nutritional compositions. For nectar sources, the net energy gained per trip has a major effect on the intensity of recruitment (number of waggle runs per dance). However, we know far less about what influences the intensity of recruitment to pollen sources. We hypothesized that two factors would influence recruitment intensity for pollen: distance to the pollen source and what plant species the pollen was collected from. To test these hypotheses, we placed two honey bee colonies in observation hives with access to the outside. We recorded 100 dances advertising pollen sources (each was paint marked to prevent resampling) and extracted a sample of the pollen from each dance. To estimate the distance to the pollen source, we took the mean of the duration of four waggle runs, and pollen loads were identified using DNA barcoding. Preliminary results show great variability in the intensity of recruitment from 1- 298 waggle runs per dance. We discuss the effects of distance and plant species in this observational study and future directions for field experiments.

## Visual ecology of two tidal creek crabs, *Petrolisthes armatus* and *Panopeus herbstii*

*Madison Janakis, Daniel Speiser, Daniel Chappell*

Tidal creeks can be challenging for vision because they can be spectrally narrow and have high levels of caustic flicker, which respectively lower chromatic and achromatic visual contrast. To enhance visual contrast, tidal creek inhabitants can use the angle of linear polarization (AoLP) of light, color vision, or increased sensitivity. We asked how crabs in tidal creeks enhance visual contrast by investigating AoLP sensitivity, spectral responses, and relative sensitivity in the porcelain crab, Petrolisthes armatus, and the mud crab, Panopeus herbstii. We found both species have visual spatial acuities between 4 and 10°, but while mud crabs are sensitive to AoLP under bright broad-spectrum light, porcelain crabs are not. Additionally, mud crabs can distinguish AoLP under narrow-spectrum blue and green light when the light is bright enough. We used electroretinography to compare the relative sensitivities, maximum temporal sampling rates, and spectral responses of the species' compound eyes. We found mud crab appositional eyes are less sensitive to light than the reflecting superposition eyes of porcelain crabs. Further, P. herbstii has a slower maximum temporal sampling rate, 50Hz, than the 80Hz maximum rate of P. armatus. By fitting visual pigment templates to spectral response curves, we predict that P. herbstii has two visual pigments while P. armatus has three. We conclude mud crabs and porcelain crabs may enhance visual contrast within tidal creeks using different strategies.

## Olfactory mechanisms underlying mosquito foraging on sources of plant sugar

*Sandeep Jandu, Jeff Riffell*

The mosquito's acute olfactory system has been extensively studied for its role in host-seeking. However, little is known about the olfactory mechanisms underlying nectar foraging, a crucial behavior supporting mosquito survival and providing nutrients and energy needed for effective host-seeking. Given mosquitoes' strong drive to feed from sources of plant sugar, the mechanisms underlying this behavior represent an evolutionarily conserved and essential system that can be exploited to develop effective interventions. Here, we utilized DNA barcoding and Gas Chromatography-Mass Spectrometry (GC-MS) to identify nectar sources consumed by mosquitoes and analyze the volatile organic compounds (VOCs) they emit. DNA was extracted from mosquitoes collected from field sites throughout Florida – a process which also resulted the extraction of DNA from any nectar material remaining in the mosquitoes' digestive tract. To identify the sources of nectar from which the mosquitoes fed, barcoding PCR was performed using plant-specific markers, and the resultant samples were sequenced. Concurrently, mosquito-attractive plants were collected from field sites and nurseries in Florida, and the bouquet of VOCs emitted by those plants was captured via dynamic headspace collection. The chemical composition of these samples was analyzed using GC-MS. These results show that mosquito-attractive plants share certain features in their volatile chemical composition. Subsequent experiments will include electrophysiological characterization of associated mosquito olfactory receptors, and behavioral assays that perturb the ratio of key plant VOCs.

## Expression of myoneurin and type 3 deiodinase in the green anole lizard (*Anolis carolinensis*)

*Madisyn Jarvey, Rachel Cohen*

The green anole lizard (Anolis carolinensis) is seasonally breeding such that this lizard displays distinct physiological, morphological, and behavioral changes between the breeding and non-breeding seasons. During the non-breeding season, lizards have smaller gonads, lower sex hormone levels, and a decrease in reproductive behaviors compared to breeding lizards. In this study, we are examining myoneurin (MYNN) and type 3 deiodinase (dio3) mRNA expression to determine whether these genes are involved in mediating seasonal changes in the green anole lizard. MYNN is known to regulate gene expression by functioning as a transcription repressor and dio3 is known to convert thyroid hormone to an inactive form. We predicted that both genes will be more highlighly expressed in the non-breeding season. We designed primer sets that amplify the anole MYNN and dio3 genes and ran polymerase chain reactions, gel electrophoresis and DNA sequencing to validate our primers. We then isolated mRNA from the hypothalamus of breeding and non-breeding male and female lizards (n=6), performed cDNA synthesis, and set up standard curves. We have performed a full run on our control gene, beta actin, and we found no differences between sex and season ($p>0.377$). Future research will involve analyzing a full run for our two genes. This work will help us determine if MYNN and dio3 are involved in regulating seasonal changes in the brain that correspond to reproduction.

## Small carnivores of the Siwaliks: indicators of gradual change or sentinels of environmental change

*Steven Jasinski, Sayyed Abbas, Khalid Mahmood, Muhammad Babar, Muhammad Khan*

The Siwaliks/Siwalik Group are an important stratigraphic section of rocks deposited from the Miocene through Pleistocene epochs (18 to 1 Ma). Well-known for their fossil mammals, carnivores are an important, albeit somewhat understudied, portion of their fauna. Mammalian carnivores are vital parts of food webs. While apex predators are often considered paramount in these systems, it is the small carnivores ($\leq$21.5 kg) that may be more informative of changing conditions. Their more intermediate trophic positions mean they are more directly affected by changes to the base of food webs. Carnivoran biodiversity in the Siwaliks underwent distinct changes through time where groups with smaller carnivorans, such as felids and mustelids, increased in biodiversity over time, while others with larger carnivores, such as nimravids, amphicyonids, and hyaenodontids decreased over time. Hyaenids are an exception to this as they increased over time. Although the membership of some of these groups show significant temporal changes, newly collected body mass size data shows a gradual but distinctly smaller change over time. Therefore, while the species change, the niches do not. For the Siwaliks, the small carnivores instead suggest gradual change over time, rather than significant changes to the environment or the relevant ecosystems. A lack of changes to the body size regimes in mammalian carnivores, instead, suggests more consistent environmental conditions with competition likely leading to biodiversity changes through time.

## Resolving feeding dynamics of marine predators using a multi-sensor biologging approach

*Amenya Jean, Seth Cones, Laura McDonnell, Camrin Braun*

Foraging- an organism's process of hunting, capturing, and consuming food- provides essential nutrients and energy needed for survival. Predator-prey interactions are key in structuring a trophic hierarchy in ocean biomes. Since quantifying the foraging process in free-ranging animals remains challenging, developing a biologging technique that measures feeding in free-ranging marine predators could greatly advance our knowledge of trophic dynamics and ecosystem structure. While the methodological, analytical, and technological limitations to quantifying predator-prey interactions in the ocean are daunting, the physical act of a predator attempting and successfully foraging on a prey item can be readily measured in jaw movements. In this study, we developed a biologging approach that combines accelerometer and magnetometer sensors to measure feeding events. A magnet was affixed to the dorsal surface near the upper mandible, and the magnetic field strength could be used as a robust proxy for jaw angle. We conducted a series of multi-day trials on captive smooth dogfish (Mustelus canis) and collected (n=60) feeding events, along with a field test on two wild animals. This approach successfully resolved distinct feeding events and facilitated analysis of fine-scale kinetic variations, such as jaw angle, prey-handling, recovery time, and bite frequency. This research represents a crucial step toward accurately identifying and quantifying feeding events in wild marine predators, enhancing our understanding of predator-prey dynamics and feeding hotspots in marine ecosystems.

## The effects of heat stress on honey bee (Apis mellifera) physiology and microbiome

*Sarah Jendresky, Adrian Fisher*

The honey bee (Apis mellifera) is an economically and environmentally vital pollinator that is regularly exposed to a variety of stressors. As environmental stressors continue to transform with a changing climate, understanding the repercussions becomes imperative to species' welfare. During the winter, cold temperatures and a reduction in forage availability largely contribute to high colony mortality rates. While overwintering mortality is well-documented, comparable mortality rates are occurring during summer months, suggesting heat stress may negatively affect colony maintenance and worker physiology. To assess the effects of developmental and post-eclosion heat stress on honey bee physiology and behavior, sets of worker brood and newly emerged workers were maintained at an optimal rearing temperature or a temperature regime simulating a heat wave. Gut microbial symbiont composition was compared between differing rearing temperature treatments. Worker pollen consumption rates, hypopharyngeal gland size, and vitellogenin concentration were also evaluated in response to rearing temperature. It is expected that the heat stress will negatively impact honey bee workers, indicating the mechanisms by which climatic warming induces colony mortality.

## Defining simple characterizations of complex structures in canid nasal passages

*Redah Jessani, Ella Kim, Nichole Wheeler, Eusabeia Silfanus, Mia Pham, Vivian Nguyen, Nicholas Hebdon, Lindsay Waldrop*

The internal structure of mammalian nasal passages are incredibly complex. This complexity stems from sets of delicate, high tortuosity passages known as turbinates. These structures are incredibly important to consider when trying to quantify biomechanical processes that occur within the nasal passages such as airflow and olfaction. However, these delicate structures can be very difficult to capture even in µCT, particularly in animals like canids which have numerous densely packed turbinates compared to fewer more robust features like in humans. This is made even harder in situations where soft tissue isn't present, such as in fossil taxa or museum specimens. However, given the complexity of these structures and their semi-random configuration within the nasal passage they are still exceedingly difficult to quantify even if they are fully captured. Here we present our approach to simplifying and abstracting these structures through a novel application of geometric morphometrics and Rstudio to analyze µCT slices allowing for easier characterization. This approach allows us to preserve simple and repeatable representations of the structural complexity that can be useful for both comparative and biomechanical analysis at greatly reduced costs in both user time and computational power.

## Oxidative stress as an indicator of hybrid breakdown in rice and corn strains of fall armyworm moths

*Bennett Jetmundsen, Natalie Harris, Brian Counterman, Geoffrey Hill, Wendy Hood*

When the genetic architecture of interbreeding populations diverges, differences in survival or reproductive performance of the hybrid offspring relative to their parental population can result in barriers that could lead to reproductive isolation and ultimately the origin of new species. One likely source of genetic divergence is in the compatibility of interacting mitochondrial and nuclear gene products. Mitonuclear incompatibilities have the potential to alter the efficiency of oxidative phosphorylation and the production of mitochondrial-derived reactive oxygen species. Fall army worm moths (Spodoptera frugiperda) have two different strains, corn and rice strains, that display differences in behavior and fecundity. We hypothesized that mitonuclear incompatibility between populations may contribute to the divergence of these populations. Rice and corn strains of fall armyworm moths were collected and mated to create hybrids of the two strains. Citrate synthase (CS) activity was measured as an indicator of mitochondrial volume and 4-hydroxynonenal and protein carbonyl were measured as indicators of relative lipid peroxidation and protein oxidation, respectively. Our results indicate that the hybrid offspring display greater CS activity ($P=0.03$), and thus higher mitochondrial volume than the parental strains. A companion study indicated that mitochondrial respiratory performance was reduced in the hybrids. An increase in mitochondrial volume is a common mechanism of compensating for poor mitochondrial performance. Results for the oxidative damage markers will be presented.

## Interactions between trophoblasts and natural killer cells in the North American deer mouse placenta

*Kylie Jewett, Kathryn Wilsterman, Megan Hemmerlein, Ashley Larson, Ellery Myers, Kendall Foreman*

Placental development is deterministic for reproductive outcomes in mammals. Our lab has identified the placenta as a major site of adaptation to high elevation in the North American deer mouse (Peromyscus maniculatus). However, placental development is only well-described in a handful of model species. To support further investigation into the developmental mechanisms by which the placenta contributes to differential reproductive outcomes in our system, our lab has generated a species-specific atlas of placental development in deer mice. Maternal natural killer (NK) cells and fetal trophoblasts play complementary roles in remodeling maternal arteries and establishing the implantation site. I investigated the interactions between NK cells and trophoblast cells using immunohistochemistry to label NK cells (perforin) and trophoblasts (cytokeratin) in serial cryosections of the placenta across gestation. I observed extensive interactions between these cell types throughout gestation. The number of NK cells increased until embryonic day 17.5, after which their abundance stabilized. Trophoblasts followed a similar pattern with a gradual increase in number before plateauing near embryonic day 18. These results define a deer mouse-specific timeline for trophoblast and NK cell dynamics across gestation and offer insight into how placental interactions may vary across species. The analysis of placental development will elucidate how cellular mechanisms influence reproductive success across mammals and environments.

## Earwax deters insects

*Thomas Jeyakumar, Joseph Nehme-Haily, David Ancalle, David Hu*

Earwax coats the ears of all terrestrial mammals, but its role remains a mystery. This study is motivated by medical studies showing insects invading and becoming trapped in people's ears. We observe fire ants walking on earwax coated walls and in an earwax tunnel. Earwax slows ant speed by a factor of 2 when walking over it. Ants that walk through earwax are coated in it, and subsequently groom more and walk 6 times slower. We hypothesize that earwax impairs the locomotion of fire ants, through its viscoelastic and adhesive properties, and characterize the adhesive ability of earwax using SEM scans and micro-indentation measurements. This sheds light on the defensive systems of the ear canal, which itself lacks any inherent mechanical defense, but depends on earwax for protection.

## Bluegill sunfish maximize axial muscle power for suction feeding, not swimming

*Yordano Jimenez, Elizabeth Brainerd, Eric Tytell, Ariel Camp*

Nearly all fish perform axially powered swimming and suction feeding behaviors, but it is still often assumed that the axial muscles are specialized for their ancestral locomotor function. Recent studies challenged this paradigm by demonstrating that multiple fish species can reach the theoretical power limits of muscle during their strongest suction strikes, raising the question: are the trunk muscles in some fish specialized for suction feeding? Here we integrate data on muscle behavior (EMG and sonomicrometry), skeletal kinematics (XROMM), and fluid flow (PIV) from independent studies on bluegill sunfish (Lepomis macrochirus) to understand the functional versatility of fish axial muscle. Axial muscle produced very similar ranges and maxima of instantaneous mass-specific power for suction strikes (13 – 444 WKg-1) and C-starts (41 – 462 KWg-1). These results indicate that peak total muscle power during suction feeding is double that of the strongest C-starts, as axial muscle contractions are primarily unilateral for locomotion and bilateral for feeding. Our findings show that bluegill sunfish possess a versatile axial system capable of peak performance across mechanically distinct behaviors.

## Effect of anthropogenic masking noise on signal detection in otophysan fishes

*Alexandra Johnson, Brooke Vetter*

Effect of anthropogenic masking noise on signal detection in otophysan fishes Alexandra Johnson, Brooke Vetter Department of Biology, University of St. Thomas In the underwater environment, fish are exposed to human-generated sound or "anthropogenic noise" (e.g., motorboat traffic). This study investigated the impact of boat motor sound on the behavior and physiology of common carp (Cyprinus carpio) and yellow bullhead catfish (Ameiurus natalis). We conditioned monospecific schools (N = 3 – 4 individuals) to associate a 405 Hz sound stimulus (136 dB re: 1 uPa) with food rewards. If conditioning was successful, we then applied increasing levels of masking boat noise (0.06 – 10 kHz) to evaluate if fish still exhibited the conditioned response. We also used the auditory evoked potential electrophysiology method to evaluate the impact of masking boat noise (136 dB re: 1 uPa and 146 dB re: 1 uPa) on fish hearing thresholds. Auditory threshold tuning curves showed that both species' lowest thresholds were between 400 and 800 Hz. Across the range of frequencies evaluated (100 Hz – 3 kHz), we found moderate threshold shifts (0 – 6 dB) for both species exposed to the 136 dB re: 1 uPa masking noise. The greatest threshold shifts occurred in common carp exposed to the 146 dB re: 1 uPa masking noise, especially from 400 Hz-1 kHz in (16.2 – 12.6 dB increase), which were significantly ($p < 0.05$) higher than baseline thresholds.

## Thermal performance curves for grounded running in two congeneric sea stars of differing flexibility

*Amy Johnson, Cara Fields, Jolie Ganzell, Abby Steinwachs, Olaf Ellers*

Sea stars achieve their maximum speeds during an oscillatory gait driven by the coordinated movement of tens to hundreds of hydraulically-driven feet (podia). This gait is kinematically similar to grounded running. Because sea stars are marine ectotherms, the kinematic characteristics – frequency and maximum speed - of that oscillatory gait should be a function of temperature and could be species-specific. We characterize thermal performance curves (TPC) for oscillatory gait kinematics for two congeneric sea stars, Asterias forbesi and A. rubens, which differ in their north-south distribution in the Atlantic. The shape of the TPC for maximum speed and frequency did not differ between species, however, at the optimal and lower temperatures the maximum speed and oscillation frequency of A. rubens was greater than that of A. forbesi. Morphometric comparisons revealed no weight-specific differences in arm length, arm width, area of central disk, total body area, or total podial area, however, the faster species of sea star had a lower body density and more flexible arms. This result is consistent with the hypothesis that most podial force in sea star locomotion acts to overcome body weight and with literature showing that increased weight causes more podia to be used per oscillation and maximum speed to be slowed. Thus, the interaction of podial biomechanics with sea star underwater weight likely determines locomotor performance in sea stars.

## The seasonality of energy balance strategies in Anna's hummingbird (*Calypte anna*)

*Chelsea Johnson, Sam Sandoval, Jesus Ovalle, Derrick Groom*

Major life history events, such as reproduction, molt, and migration, can have vastly different energy demands. To meet these changing energy needs, various strategies can be employed to maintain energy balance, with each having inherent fitness costs and benefits. On one hand, animals can modulate energy intake by modifying foraging intensity. On the other, animals can regulate energy expenditure via activity and metabolism. However, our knowledge of how energy balance strategies vary across the annual cycle remains poor. The objective of our project is to characterize patterns of energy balance in captive Anna's hummingbirds (Calypte anna) under different photoperiods. Hummingbirds have among the highest metabolic rates of any vertebrate, yet their precious nectar resources fluctuate seasonally, all while they undergo energetically demanding annual life history events. We hypothesize that, cued by photoperiodic changes, hummingbirds will adjust their physiology and behavior in accordance with the annual cycle. Birds experienced four weeks each of three different photoperiods: long days, fall equinox, and short days. Body mass, condition, molt status, and basal metabolic rates were measured weekly. Torpor frequency was estimated using thermal cameras. Feeding intake and activity were measured daily. As environmental conditions continue to shift drastically in the face of climate change, studying these patterns can help shed light on energy balance strategies and resource requirements across the year.

## Social interactions and sensory cue use in embryonic fathead minnows (*Pimephales promelas*)

*Jewel Johnson, Matthew Hasenjager, Jessica Ward*

Oviparous organisms are highly vulnerable to various threats during the egg stage, including predation, parasitism, disease, and adverse environmental conditions. Consequently, mortality rates during embryonic development are often high. A growing body of evidence indicates that embryos can detect external cues indicative of such threats, and respond appropriately to the situation with various behaviors. However, in addition to direct exposure to environmental cues, embryos may gain information about local conditions from social cues from nearby conspecifics. How aquatic embryos use social cues to learn about the postnatal environment remains largely unexplored. Here, I use experimental assays and network-based diffusion analysis to detect social transmission of a localized predator threat through clutches of a common oviparous freshwater fish, fathead minnow (Pimephales promelas), and identify the sensory modalities involved in embryo-to-embryo information transfer (visual and/or mechanosensory). Preliminary results suggest that embryos perceive and respond to changes in the locomotor activity of neighboring siblings and that both mechanosensory and visual cues may play a role in facilitating the spread of information through a clutch.

## Do alternative male reproductive tactics, age, and sex influence physiology?

*Sean Johnson, Troy Baird, Christopher Goodchild*

Sexual selection has resulted in the evolution of two alternative reproductive tactics in mature male Collared Lizards (Crotaphytus collaris); defense of breeding territories (T-males) and stealthy non-territorial social tactics (NT-males). T-males routinely obtain more mates and sire more offspring than NT-males, but potential physiological costs of increased advertisement and agonistic behavior required for territory defense have not been examined. Using blood samples collected during the 2021–2023 breeding seasons (April-June), we are examining immune function, oxidative stress, and hematological indices in T- and NT- males, as well as NT-female Collared Lizards occupying the Arcadia Lake Dam flood control spillways (Edmond, OK, USA). We are measuring packed cell volume (PCV), hemoglobin, mean corpuscular hemoglobin concentration (MCHC), and are counting types of white blood cells (i.e., heterophils, lymphocytes, monocytes, eosinophils, basophils) in whole-blood smears. We are also assessing oxidative stress by quantifying reactive oxygen metabolites (ROMs) in blood plasma. Results to date suggest that T-males have lower heterophil, but higher lymphocyte counts than NT-males. Hematocrit and hemoglobin were higher in males versus females, but neither MCHC nor white blood cell counts appear to differ in males and females. Thus far our data suggest different physiological profiles in T- versus NT-males which we are continuing to test by expanding our sampling efforts.

## Proposed mechanism for head shaking behavior in Spiny Dogfish Sharks (Squalus acanthias)

*Nicolas Johnston, Bradley Wood*

Head shaking behaviors in Spiny Dogfish Sharks (Squalus acanthias) are an effective means of food processing. Although much is known about the mechanics and physiology of biting behaviors during head shaking, the potential muscles involved in moving the head side-to-side are less well known. We have identified a previously unspecified, yet well defined, hypaxial muscle that has the ideal orientation, position, and attachments to generate the necessary forces for lateral head shaking motions. This muscle arises caudally from the scapulocoracoid cartilage and from the cranial-most pre-caudal vertebrae, and inserts cranially onto the caudolateral processes of the chondrocranium. Its pennate muscle fibers share a common tendon of insertion onto the caudolateral angle of the chondrocranium. These tendon fibers then continue along a cartilaginous bar to terminate onto the outer angle of the chondrocranium. Since this muscle lies in the horizontal plane, deep to the horizontal skeletogenous septum and superficial to the branchial region, its contraction would generate the moment necessary to turn the head ipsilaterally. Furthermore, the pennate morphology of this muscle enables the ideal orientation of muscle fibers as the head sweeps laterally. By traveling along a cartilaginous bar, the tendon of insertion avoids compressing the emerging vagus (X) and lateral line nerves. We propose to name this muscle the Musculus paraspinalis.

## Impacts of air pollution on the auditory physiology of house sparrows (*Passer domesticus*)

*Shae Johnston, Chisom Okogbue, John Wenderski, Liam Hanlon, Natalia Gonzalez-Pech, Kelly Ronald*

Urbanization has drastically increased in the past several decades; with this there has been a matching increase in air pollution. Air pollution consists of several compounds of varying sizes, but the smallest and arguably most dangerous particle is the nanoparticle. Nanoparticles are able to bypass the blood-gas barrier and the blood-brain barrier, with one potential mechanism for this being through sensory nerves. Nonetheless, it is currently unknown whether exposure to nanoparticles alters hearing sensitivity directly. Songbirds are particularly unique because they have thin blood-gas barriers and are particularly sensitive to airborne contaminants. The aim of this project was to determine the impact of chronic iron oxide nanoparticle (IONP) exposure on the auditory processing ability of the house sparrow (Passer domesticus). Birds were captured from locations around Holland, MI, USA. Pre-exposure auditory brainstem response (ABR) tests were performed, and then exposure to aerosolized IONPs consisted of 50 hours of exposure over 10 days. Following exposure, hearing was assessed again in a pre vs post-test design. We predicted that exposure to iron oxide nanoparticles would reduce hearing sensitivity. Changes in the ABR have the potential to disrupt the comprehension of auditory signals during communication, which may interfere with appropriate mating and antipredator behaviors. In particular, this communication and behavior disruption could impact the survival and fitness of urban birds.

## Using marker-assisted selection to introgress RKN resistance into Virginia-type peanut backgrounds

*Erica Jones*

The North Carolina State University Peanut Breeding Program is the primary supplier of Virginia-type peanut (Arachis hypogaea) cultivars for the Virginia-Carolina (VC) region. Root-knot nematode (RKN, Meloidogyne spp.) can tremendously impact peanut production fields, with reported reductions in yield of up to 50%. Although RKN incidence in the VC region is rare, no Virginia-type cultivars are available with known RKN resistance if incidences increase in the future. Therefore, this study aims to identify and transfer resistance from donor peanut germplasm into elite, Virginia-type backgrounds for cultivar development. GP-NC WS 06, developed from the wild peanut species Arachis cardenasii, demonstrates resistance to peanut root-knot nematode. Recent whole-genome sequencing revealed a 4Mb A. cardenasii introgression on Chr. A09, closely resembling known RKN resistance gene regions. Testing confirmed GP-NC WS 06 and the industry standard for RKN resistance, TifNV H/O, both possessing A. cardenasii introgressions (4Mb and 112 Mb, respectively), significantly outperformed the susceptible check Bailey II when exposed to Meloidogyne arenaria. Our trial population was created by crossing GP-NC WS 06 with Bailey II to incorporate the smaller, 4Mb introgression block. A marker-assisted selection program selected 111 F5 plants based on markers spanning the 4Mb region and other markers across the genome for traits critical to the peanut breeding program. We identified five single recombinants and one double recombinant within the Chr. A09 introgression during marker-assisted selection. Current efforts involve phenotyping and whole-genome sequencing recombinants to refine the Chr. A09 introgression size and pinpoint the specific mechanism responsible for RKN resistance.

## Effects of environment on the morphology of the vestibular system in North American river otter

*Hansan Jones, Erika Tanquilut, Celeste Delap, Heather Smith, Leigha Lynch*

Environmental variation is often a primary driver of phenotypic variation among populations and has been quantified within many morphological systems. Yet variation in the vestibular system in relation to environmental variation is virtually unknown among species, despite its correlation with behavior. To fill this gap, we generated 3D models of the vestibular systems of Lontra canadensis using micro CT scans of skulls from differing environments. Our samples included skulls collected from the following locations: Alaska (5), Washington (5), Tennessee (6), Florida (4), and Arkansas (4), for a total of 23 specimens. We quantified morphological variation using 3D geometric morphometric landmarks: 11 landmarks and 109 semi-landmarks. A Procrustes ANOVA indicated that there was a significant difference in the morphology of the vestibular systems between populations. This was further confirmed by PERMANOVA statistical analysis performed on the PC scores that accounted for 95% of the variation. This variation is predominantly in the orientation of the lateral semicircular canal. We hypothesize this variation may be correlated with water turbidity (as the vestibular system is important in orienting the otter as it swims), and prey capture. Future research will allow us to better understand the mechanism that leads to the variation that we observed.

## Timing Matters: Bacterial Colonization Order Impacts Tadpole Microbiome Composition

*Korin Jones, Lisa Belden, Myra Hughey*

Dispersal is understood to have an essential role in the assembly of ecological communities, including communities of bacteria associated with host organisms. Priority effects, resulting from differences in dispersal timing, have seldom been investigated in host-associated bacterial communities, however. We experimentally inoculated treefrog embryos to understand how priority effects might impact the tadpole microbiome. On the first day embryos were given a standardized inoculum composed of one bacterium isolated from the skin of wild-caught adult frogs. On the second day, the initial inoculum was removed, and embryos were inoculated with a different, single isolate inoculum or a community inoculum. Additionally, we explored how these outcomes might differ between host and non-host environments through co-culture experiments that mimicked our in vivo experimental design. Through 16S rRNA gene amplicon sequencing, we observed that priority effects altered the community composition of our newly emerged tadpoles, supporting increases in the relative abundances of initial isolates, however these benefits were not universal to all bacterial taxa. Comparisons between our in vivo and in vitro experiments revealed that patterns were broadly similar across experiments, though we did observe some notable differences. Our experiments provide evidence of the importance of priority effects during the assembly of bacterial communities in a vertebrate host, provide empirical support for understudied ecological theory and may ultimately serve to improve the viability of probiotics in amphibian conservation.

## Exploring inter-habitat variation in anuran evolutionary regimes

*Menna Jones*

The clade Anura constitutes a unique study system in ecomorphological evolution: despite members sharing the same highly conserved bauplan, there is a striking breadth of functional, morphological, and ecological diversity. This diversity is often simplified into habitat-specific groupings, which assume the same broad set of physiological and behavioural requirements of species inhabiting them. However, from an evolutionary perspective, the question of how taxa evolved in response to or in concert with habitat requirements remains understudied. Phylogenetic comparative methods provide a valuable tool for exploring this question. Importantly, exploring the fit of different evolutionary models to morphological traits on a per-habitat basis will further understanding of the mechanics underlying the habitat-specific groupings.

I will use phylogenetic comparative methods to evaluate inter-specific variation in anuran evolutionary regimes, focusing on morphological traits that correlate strongly with behaviour, and explore potential links to habitat transition frequency. This work will distinguish between bounded yet random evolution (i.e., bounded Brownian motion), and directional evolution toward an optimum (i.e., Ornstein-Uhlenbeck), something that is often lacking in similar studies. Such distinction is crucial as these two evolutionary regimes risk conflation at the inter-habitat scale, despite representing fundamentally different biological and evolutionary processes. Moreover, I expect size-related traits to evolve randomly between bounds, whereas traits dictating locomotion will be pulled towards optima, as the latter link most strongly to species fitness within a habitat.

## Lay date and egg size in a long-term dataset: intersections of behavior and physiology

*Patricia Jones, Robert Mauck*

Reproductive success in wild animals is influenced by factors including physiology, body condition, climatic conditions, and pair coordination. Long-term datasets provide a unique opportunity to examine how these factors interact in natural populations. Egg volume and lay date are quantifiable reproductive parameters, making them ideal for understanding these questions. We used a long-term dataset that tracked individuals over an 18-year period to investigate patterns in egg volume and breeding phenology in a population Leach's storm-petrels, Hydrobates leucorhous, a long-lived procellariiform seabird. We found that lay date is strongly affected by pair-bond duration, with pairs that mated together in the previous year laying earlier than pairs that did not, and lay date continuing to move earlier over longer pair bond durations. Eggs laid earlier in the season had larger volumes than eggs laid later in the breeding season, but egg volume was not affected by pair-bond duration when controlling for lay-date. Egg volume was not affected by female breeding experience. Egg volume was affected by female morphology and spring sea-surface temperature, a critical time period when females are building resources for egg production. The strongest predictor of hatch success is whether birds remated with the same mate as the previous year. We propose that variation in reproductive success of Leach's storm-petrels is driven predominantly by increasing pair coordination over time.

## How do physiology, competition and micro-habitat drive abundance patterns of tropical montane birds?

*Samuel Jones, Steven Portugal*

Restricted elevational ranges are common across tropical montane species, but mechanisms generating and maintaining these elevational range patterns remain poorly resolved. We test evidence for three long-standing hypotheses – (i) habitat specialism, (ii) interspecific competition and (iii) thermal physiology– in determining patterns of abundance across elevation of four Mesoamerican cloud forest songbirds with differing range patterns. We predicted point level abundance against habitat variables and experimentally informed covariates specific to testing contrasting hypotheses. Contrary to physiological hypothesis (iii), we found no evidence to suggest that thermoregulatory costs impose constraints on species distributions, and that the entire elevational range was comfortably within sustainable physiological limits for each species. We found mixed support for the biotic factors we tested, however. For two species, habitat preference was most important in setting the elevational ranges of the lower elevation species, and competitive exclusion was more important in setting the elevational range of the higher elevation species. For the remaining two species – we found no evidence for our other hypotheses on elevational range occupation. Collectively, this suggests that while biotic factors may be more important in setting the elevational distributions of species, the exact mechanisms are complex, species-specific and that different hypotheses are not mutually exclusive. Our findings also concur with recent literature; that thermal physiology is an inadequate explanation for setting elevational range limits of tropical species.

## Wax "tails" enable planthopper nymphs to self-right midair and land on their feet

*Thomas Jones, Christina McDonald, Sheryl Yap, Gerwin Alcalde, Ruby Ana Laude, Saad Bhamla*

Planthoppers are small insects known for their remarkable jumping abilities, as their name suggests. During nymphal stages, they secrete posterior waxy filaments, oftentimes resembling an extravagant tail. While speculated as protection against predators and pathogens, the waxy filament's potential non-defensive uses remain largely underexplored. This research delves into the filament's role in planthopper nymphs' aerial dynamics.

We examined planthopper motion under two conditions: with wax intact and wax removed, using species collected during field work in the Philippines. The motion was captured via high-speed videography. Those with wax intact exhibited swift aerial righting (a strategy used by animals to achieve a favorable body position mid-air and subsequently during landing), whereas wax-removed nymphs often tumbled during jumps. Moreover, wax-intact planthoppers achieved significantly higher landing success, as opposed to wax-removed ones that rotated mid-flight, often failing to land on their feet. This study unveils a previously overlooked biomechanical function of insect wax structures.

## Genome based identification of putative predatory bacteria: discovery of a novel species from the family *Micavibrionaceae*

*Victoria Jones, Hugo Doré, Emily Junkins, Lizzy Wilbanks*

Bacterial predation, where bacteria hunt and consume other bacteria, plays a critical role in microbial ecology. Yet, the specific mechanisms enabling this behavior remain poorly understood, as our knowledge is limited to a few well defined model species. Isolation and culture-based methods often fail for studying predatory bacteria, as they rely on specific prey for survival. Thus, the ability to identify putative novel predators by their distinct genomic features is crucial for expanding our knowledge of these organisms. In microbial aggregates known as “pink berries”, we discovered a putative novel bacterial predator (LS7A1) from the family *Micavibrionaceae*. This study identifies genetic mechanisms of predatory behavior within LS7A1’s genome to determine whether this novel organism is a predator. Some key predatory traits targeted are receptors for chemotactic prey hunting, pilus structures for attachment, and secretion systems that deliver toxins to lyse prey cell walls. Preliminary findings include individual components of primary secretion systems types I & II, and secondary secretion systems SEC & TAT. We also searched for the absence of certain metabolic capabilities, such as amino acid biosynthesis, which indicates the need to obtain nutrients from prey. Contrary to our expectations, most amino acid pathways were present and complete within LS7A1’s genome. The results of this study will enhance our ability to identify and characterize putative novel bacterial predators from their genomes, which is crucial for expanding our knowledge of these key ecological players.

## Investigation of population resistance to cold-induced oxidative damage in a lizard

*Nicole Joseph, Benjamin Haussmann, Tiffany Hegdahl, Travis Robbins, Mark Haussmann*

In ectotherms, metabolic rate positively scales with environmental temperature. We previously demonstrated that when exposed to cold temperatures (18°C), southern prairie lizards (Sceloporus consobrinus) showed an expected decrease in metabolic rate. However, these lizards exhibited a statistically significant increase in oxidative damage to DNA, a harmful metabolic byproduct measured as 8-hydroxy-2’-deoxyguanosine (8-OHdG). Interestingly, cold-induced DNA damage differed by population; lizards from the northern-most population, that experience colder annual temperatures, exhibited no increase in 8-OHdG levels. Oxidative damage following cold exposure in southern populations may be due to the cold exposure itself, or to rapid warming up after the exposure. The purpose of this study is to investigate what specifically underlies the cold-induced increase in 8-OHdG. Adult lizards from the northern and southern populations were exposed to a day-long cold temperature challenge (18°C) in the lab. We measured body temperatures for each lizard immediately following the treatment. Blood samples were taken to measure 8-OHdG in either a cold glove, to determine if the day-long cold exposure affected 8-OHdG levels, or after a brief period in a warm incubator, to isolate the effects of rewarming on 8-OHdG. Finally, we measured 8-OHdG levels two days after the temperature challenge to examine the DNA repair capabilities of each population. As the climate becomes increasingly unpredictable, understanding how ectotherms physiologically respond to temperature changes is essential for predicting their survival.

## Staggering stink bugs: autotomy affects stability and locomotor performance in *Halyomorpha halys*

*Lilian Jubb, Brandon Jackson*

Autotomy, the voluntary loss of a limb, is a common predator evasion strategy in arthropods. Most research surrounding autotomy has focused on arachnids, which have developed morphological compensations to manage the stability challenges posed by limb loss, as explained by the extra leg hypothesis. However, studies on insects are scarce, creating a significant knowledge gap. In hexapods, their double-tripod gait means that losing any one limb disrupts one of the tripod stances; it is unclear how insects compensate for the resulting loss of stability and potential performance effects. We hypothesize that insects exhibit neural plasticity, allowing them to adjust their gait patterns to enhance stability, improve performance, and mitigate the fitness costs of autotomy. To test this, we analyzed the gait patterns of 12 adult brown marmorated stink bugs (Halyomorpha halys) before and after autotomy. We recorded gait trials on a flat, plexiglass surface using 2-3 high-speed cameras (Edgertronic, 100 fps) and tracked eight body points and four points per leg with Deeplabcut. Detailed 3D reconstructions were performed using Anipose. Preliminary results indicate that prior to autotomy, most insects walked in stable configurations 100% of the time, dropping to 70-90% afterward. Despite this, there was limited impact on most measures of locomotor performance, at least on flat, smooth surfaces. Ongoing analysis is focused on gait variation and stability.

## Adaption of maternal investment strategies to high altitude in deer mice

*Makenna Juergens, Kathryn Wilsterman*

Elevational gradients are associated with changes in life history traits. For example, birds exhibit a well-established tradeoff between parental care and fecundity such that species usually decrease clutch size with increasing elevation. The degree to which elevational gradients have shaped mammalian life history traits is comparatively poorly understood. Unlike in birds, at least some mammals do not seem to follow the same patterns are birds: litter size increases with increasing elevation in the North American deer mouse (Peromyscus maniculatus). Previous research also shows that deer mice from high elevations provide less care (i.e. invest less energy) to pups in early development. However, these initial studies did not consider flexibility in maternal investment associated with pup age, parity, and paternal presence. We hypothesize that the challenges of high-altitude environments have led to greater relative investment in the first parity and increased importance of paternal presence across development. To test this hypothesis, we are comparing maternal behavior and pup developmental milestones across the duration of lactation between highland and lowland-derived dams. These data will provide further insight into how evolution of maternal care strategies contribute to greater individual fitness within challenging elevational gradients.

## Alloparental Feeding in Violet-green Swallows (*Tachycineta thalassina*)

*Galen June, Christine Mantegna, Camille Gaynus, Tiara Moore*

Parental allofeeding is an avian behavior in which the parents feed their young or newborns. This behavior is mostly performed in species that are born heavily dependent on their parents for care. Allofeeding in violet-green swallows (Tachycineta thalassina) is an understudied field. Most notably, not much is known about the factors that affect allofeeding. Since the allofeeding stage of a bird's life is when both the allofeeder and the nestling are extremely vulnerable, we wanted to identify environmental and behavioral patterns associated with allofeeding. In this study, three nesting sites with 18 violet-green swallows (6 allofeeders and 12 nestlings) were recorded for 24 hours in one-hour intervals over 7 days. Tidal and temporal variations were recorded onsite and corroborated using national databases from NOAA. The footage was analyzed to measure the time of allofeeding at each nest site with both the environmental and behavioral data yielding significant results. Most notably, allofeeding rates between nest sites, across time of day, and at both high and low tidal heights were significant. These findings mean that location, predation, and food abundance could be major factors that contribute to the rate of allofeeding in violet-green swallows. Violet-green swallow populations in the Pacific Northwest are declining, and further understanding of the factors that affect the rates of alloparental feeding in violet-green swallows could prove useful in conservation efforts.

## Barcoding reef cryptobiota of Guam: phylum Nemertea

*Parker Jung, Svetlana Maslakova, Robert Lasley*

The island of Guam harbors the most biodiverse coral reefs in US waters, and these are under threat from the global climate change and other human impacts. As vast numbers of species remain undiscovered and unnamed, biodiversity assessments are urgently needed to establish baseline for monitoring changes. Nemertean worms, with some 1350 described species, are part of the reef cryptobiota, important as predators and producers of diverse toxins, but one of the lesser known phyla of marine invertebrates. During a recent biodiversity survey on Guam, focussing on reef-associated invertebrates, we triple-documented 46 species of nemerteans with photographs, morphological vouchers, and DNA-barcodes. Another three morphologically distinct species were not barcoded. We did not encounter four species reported by others. This brings the total known species-level diversity of nemerteans on Guam to 53 species, up from 10 previously reported, 30 representing species new to science. Remarkably, 89% are undescribed, and 78% are not known outside Guam. Our study adds 43 new species, six new genera, two new families, and one new order record for Guam. The large fraction of unnamed species mirrors that found in other recent studies of nemertean diversity worldwide, and reflects the global state of marine biodiversity knowledge. This highlights the urgent need for supporting research in taxonomy and systematics, and the use of turbotaxonomic approaches to rapidly document species.

## How foxes dive into snow

*Sunghwan Jung, Jisoo Yuk, Anupam Pandey, Leena Park, Willy Bemis*

Certain fox species, such as red and arctic foxes, use a hunting technique called mousing, where they plunge-dive into snow to catch prey like rodents. These foxes can jump and dive into snow at speeds of 2 to 4 m/s with their slim & narrow facial structure. This study examines how foxes efficiently dive into snow by analyzing the role of skull morphology on impact forces. Using 3D-printed fox skulls, we replicated mousing behavior in the lab by dropping them into fresh snow to measure dynamic impact forces. The impact force is modeled using hydrodynamic added mass during the initial impact phase, considering the added mass effect in granular media at high Reynolds numbers and the properties of snow as a granular medium. Our findings indicate that the curvature of the snout significantly influences the impact force, with a sharper snout resulting in lower average impact forces. Additionally, by having its center of mass placed close to the chest location of the fox, the fox exhibits minimal angular rotation. This adaptation allows foxes to dive head-first into snow with minimal tissue damage.

## Guinea fowl (*N. meleagris*) bone shape undergoes unexpected changes to altered loads during growth

*Derek Jurestovsky, America Campillo, Kavya Katugam-Dechene, Talayah Johnson, Jonas Rubenson, Stephen Piazza, Timothy Ryan*

The musculoskeletal system is complex and the plastic response to external stresses, particularly during the growth stage, is difficult to assess and poorly understood. The objective of this study is to assess changes in external limb shape in response to differential loading of the limbs. We hypothesize the loaded limb will experience morphometric changes in the epiphyses. We used ten two-week-old guinea fowl (N. meleagris) to test this hypothesis by adding a 4.5% distal limb mass on the tarsometatarsus of the right limb leaving the left limb as a control with no added mass. These animals maintained this added limb mass (frequently adjusted to maintain 4.5% body mass) until they were euthanized at 16 weeks of age. Subsequently, both limbs were CT scanned. We placed 17 (semi)landmarks on the tarsometatarsus using Viewbox software and performed a Procrustes-based geometric morphometric analysis of shape using the R package Morpho. Contrary to our hypothesis, we found the proximal epiphysis and diaphysis generally were narrower in the loaded limb compared to the control limb. Furthermore, we found that the proximal epiphysis was mediolaterally broader in the control limb compared to the loaded limb ($p<0.05$). These results suggest that alterations in distal limb increased distal limb mass led to significant changes in the morphology of the tarsometatarsus. This study highlights the complex and unexpected ways the musculoskeletal system adapts to external stimuli.

## The control of shape during laterally confined locomotion of Araneae, Hogna carolinensis

*Heiko Kabutz, Katrina Arbogast, Kimberly Fung, Kendall Webster, Kaushik Jayaram*

Spiders exhibit exceptional walking and climbing skills with their eight legs; allowing them to navigate over, around, and through various obstacles. A deeper understanding of tradeoffs associated with the positioning of legs and gait selection in spiders within restricted environments, particularly when lateral movement is constrained, can provide bioinspired principles for limb placement and coordination enhancing the maneuverability of small-scale legged robotic systems. Towards this goal, our research examined the gait patterns of Hogna carolinensis wolf spiders as they navigated a laterally constrained course (100+,80, 60, and 40% relative to their nominal leg span) designed to restrict leg movements. By employing high-speed video recording, we quantified the locomotion kinematics as a function of the constraint level and used a random decision forests method to rank the measured features (such as speed, stride frequency, stride length, lateral oscillations, joint angle ranges, etc.) by their relative importance. Joint angle analysis revealed distinctive responses of spider limbs that are strongly correlated with the magnitude of the constraint. We used principal component analysis to identify the major template body-appendage shapes and analyzed their variation with increasing lateral constraint. These findings contribute new insights into natural movement dynamics of arachnid locomotion in cluttered and confined environments with implications for biomechanics and robotics.

## Evaluating the role of the tongue in the coordination of sucking and breathing in infant feeding

*Elska Kaczmarek, Shanique Yazzie, Dylan Anderson, Maressa Kennedy, Ani Smith, Hannah Shideler, Skyler Wallace, Thomas Stroud, Holly Sabato, Harlow Smith, Emily Volpe, Christopher Mayerl*

Infant mammals must coordinate feeding with breathing to limit the frequency of aspiration and maintain adequate blood oxygen saturation. Prior research has evaluated swallow-breath coordination, because milk is most likely to enter the airway during swallowing, and suck-swallow coordination, because suck characteristics influence swallow characteristics and by extension swallow-breath coordination. In contrast, suck-breath coordination has not been investigated. This coordination is likely important because tongue muscles are known to increase airflow during inspiration by opening the upper airway, and tongue movements during sucking may similarly support or impede inspiration. We investigated whether breathing is coordinated with sucking and whether tongue and suprahyoid muscle activity supports both behaviors. Furthermore, we tested whether coordination is reduced in preterm compared to full-term infants. We implanted radiopaque beads in infant pigs and recorded synchronous biplane X-ray video, intraoral pressure, electromyography, and plethysmography during feeding. Respiration amplitude and rhythmicity was more variable in preterm than full-term infants, limiting coordination with suckling. In full-term infants, inspiration spanned multiple sucks, while expiration occurred more quickly during a single suck. In some individuals, inspiratory rib expansion was faster near the start of a suck (when the tongue is positioned anteriorly and the airway appears the most open), however, this pattern was not seen in all individuals. These results highlight the importance of evaluating how physiologically disparate processes are coordinated to facilitate organismal function.

## Sick Bees at SICB: The Effects of Supplemental Feeding on Viral Burden in the Western honey bee

*Josiah Kaderis*

Supplemental feeding of wildlife happens in three different contexts: management, recreation, or accidental. The effects of feeding wildlife on pathogen load has been well documented in vertebrate organisms such as deer, song bids, and even stingrays. Previous studies have indicated that feeding can bring animals closer to each other than they would naturally be in the wild. This aggregation of animals can exacerbate transmission of diseases as pathogens tend to favor group living, leading to higher viral loads and pathogen persistence and maintenance in wild populations. The effects of feeding on viral load has been well studied, but the effects of supplemental feeding on invertebrates, specifically pollinators, is limited. Here I propose to investigate the effects of supplemental feeding (i.e pollen patties) on viral burden in Apis mellifera (Western honey bee). A. mellifera pollination services are valued montearily in the billions for US agriculture and are the most managed pollinator worldwide, but A. mellifera colonies are exposed to a wide variety of parasites and pathogens that can cause colony collapse disorder (i.e Deformed wing virus, varroa mites, Bee paralaysis virus, tracheal mite infestation, small hive beetle infestation, American foulbrood, and Nosema). This poster presents preliminary results investigating the effects of ad libitum feeding on honey bee viral loads. Expected outcomes are two-fold. (1) Colonies fed pollen patties treated with Chlorantraniliprole (a bee-safe insecticide) will have significantly reduce viral and parasite load in A. melliferia colonies. (2) Colonies fed untreated pollen patties will exhibit a higher viral and parasite load compared to those fed treated pollen.

## Evolution of diverse reproductive strategies and sperm morphology in tropical frogs

*Ariel Kahrl*

Fertilization environment is a major driver of sperm evolution across the animal tree of life. Traditionally, fertilization modes have primarily been broken into internal fertilizers and external fertilizers. In anurans, external fertilization can take many forms, from more well-known aquatic fertilization to aquatic or terrestrial foam nests, to fertilization on land, arboreal fertilization on leaves, and many other diverse and understudied environments. Using ancestral character reconstruction, we show that these diverse fertilization environments have evolved multiple times in frogs, particularly in tropical species. This diversity in external fertilization has also led to a rapid diversification of sperm length across externally fertilizing frogs. The rapid evolution of terrestrial fertilizing amphibian sperm is likely due to the species-specific nature of the biophysical/biochemical properties of the fertilization environment. Additionally, the morphology of amphibian sperm exhibits unique structures, such as an undulating membrane along the flagellum, and high variation in the shape of the sperm head. We explore and discuss how these structures evolved and how fertilization environments shape these structures.

## What Good Are Soldiers During Peacetime? Foraging Efficiency of Fire Ant Soldiers

*Darmon Kahvazadeh, Kaushik Rahman, Dal Hyung Kim, Clint Penick*

Division-of-labor is a hallmark of eusociality. In addition to the division between the reproductive and non-reproductive castes, numerous species have evolved further divisions within the non-reproductive caste, such as distinct soldier and minor worker castes. However, the function of the soldier caste is not always clear, especially in species that display continuous polymorphism rather than clearly distinct worker and soldier morphs. Here we test whether larger workers contribute to colony success by (1) foraging faster, and/or (2) carrying weight more efficiently. We ran 190 fire ant workers (Solenopsis invicta) that varied 24-fold in mass on an untethered automatic tracking system for a total of 12 minutes each. Larger workers travelled at a higher velocity than small workers, but their velocity was proportionally slower relative to their body size. Regarding transport of weight, larger workers travelled with a higher momentum, both absolutely and in proportion to their body size. We then tested whether the increased momentum of larger workers provided an advantage when carrying weight by measuring velocity and momentum of 142 workers carrying brood. Larger workers carrying brood ran at the same velocity as smaller workers but had a four-fold increase in momentum. Ant soldiers may thus be more efficient at transporting large food items and brood, which could explain how they contribute to colony success outside of defensive roles in the colony.

## Mosaic coloration of blue shark skin: nano-architecture features and interplay of its components

*Viktoriia Kamska, Clementine Ferrari, Chiara Micheletti, Michael Blumer, Venkata Surapaneni, Luca Bertinetti, Mason Dean*

Shark skin is armored with tooth-like dermal denticles, whose fluid dynamic properties have been exhaustively explored. In contrast, the coloration mechanisms of sharks' skin remain unexplored despite their exhibiting sophisticated camouflage patterns and occasionally even bright colors. We investigate the characteristic color patterns of blue sharks (Prionace glauca), having a distinctive blue on their back, transitioning through silver-grey laterally to brilliant white on the abdomen. Unlike other vertebrates, where chromatophores reside in the dermis, blue shark color is localized inside the denticle pulp cavity, even in excised denticles. The pulp cavities are comparatively enormous relative to other investigated species'; FIB- and environmental SEM revealed that the pulp cavity lining, which somewhat looked like a shimmering mosaic in light microscopy, consists of guanine-like shards (2 µm long, 50 nm thick) underlain by dark-brown ellipsoid bodies (∼500 nm), likely melanosomes. The blue color is unstable (but somewhat reversible with humidity changes) and visible through the apical side of the transparent and prismatic denticle's crown. Additionally, the branched micro-canals within the denticle wall accumulate melanosome-like organelles within the dentine of the denticle's neck, heightening the dark underlying background. Our observations suggest that blue shark skin color is likely structural, relying on the interaction of nano-scale structures boosted by denticle wall features.

## No evidence of sexual dimorphism in tidepool sculpin pectoral fin morphology

*Emily Kane, Shubham Vijay Kumar Yadav, Emalie Abshire, Andrew Moura, Austin Garner*

Intertidal sculpins possess adaptations such as incised, thickened, and prehensile ventral pectoral fin rays that assist in maintaining position on the substrate in wave-swept waters. In several species, anal fins also display these traits, but their use is primarily for grasping females during copulation and traits are only apparent in males. Although tidepool sculpin (Oligocottus maculosus) males possess enlarged anal fin rays following this trend, the rays are not prehensile, thus males primarily use their pectoral fins to clutch females. Given this additional functional role of pectoral fins, we examined whether morphological traits of the pectoral fins differ between sexes in this species. We photographed the flattened pectoral fins of freshly euthanized specimens ($n = 19$ females and 20 males) in July 2024 and quantified morphometric traits previously associated with station-holding performance, which could be co-opted for grasping during mating behaviors. We did not find evidence of sexual dimorphism in any trait. Exaggerated, dimorphic traits may be reduced outside of the winter breeding season, but the permanence of exaggerated anal fin morphology in males suggests that dimorphic fin traits may not be plastic. Instead, we hypothesize that grasping function during station-holding may be a significant constraint on pectoral fin morphology, leading to exaggerated traits that are similarly apparent in both sexes but that can be co-opted during copulation in males.

## Juvenile tarantulas rapidly recover locomotor function following leg loss

*Suzanne Kane, Xuanyi Wu, Brooke Quinn, Sarah Xi, S. Tonia Hsieh*

Many animals can voluntarily lose a limb or other appendage (autotomize) during antagonistic encounters; some also can regenerate functional replacements for lost limbs. We studied the time course over which spiders, which frequently experience leg autotomy, adopt compensatory strategies in response to the resulting locomotor challenges. Juvenile tarantulas (Davus pentaloris) with no experience of autotomy were filmed running before and after losing one diagonally-opposed foreleg and hindleg. After limb regeneration, an additional set of controls were recorded, the same legs removed, and the subsequent locomotion recorded. Video analysis was used to determine the timing of running performance and gait changes for each treatment. Intact spiders have been found to locomote using an alternating tetrapod gait, but after losing these two legs they often switch to an alternating tripod gait to reestablish stability. We hypothesized that autotomized spiders would initially evince impaired locomotion and require time to adapt to a new gait. Instead, the specimens adopted the alternating tripod gait within a few minutes of the first autotomy and moved with the same path tortuosity as before leg loss. While spiders ran at 40-69% of their intact speed immediately after leg loss, they recovered to full speed after a day. They also resumed their original speed and gait upon leg regrowth. These findings indicate that spiders are robust to the locomotor perturbations caused by leg loss.

## From genes to environment: understanding the drivers of sensory trait variation in bluefin killifish

*Ratna Karatgi, Rebecca Fuller*

Sensory environments can strongly influence selection on many organismal traits and affect the evolution of signaling modalities and sense organs. Organisms frequently optimize signal modalities and perception mechanisms to the sensory background; however, this can be challenging when there is variation in the sensory environments. Aquatic lighting environments are exceptionally heterogeneous because of the filtering effects of depth and dissolved organic substances. Consequently, aquatic species must navigate a complex sensory landscape, where their visual perception and signaling strategies must readily respond to environmental changes.

To elucidate the genetic and environmental contributions to variation in traits involved in signaling and signal perception, I study the bluefin killifish, which inhabits springs and swamps with variable lighting environments, exhibiting fin color polymorphism and plasticity, visual system variation. Using bulk RNA sequencing, I investigate the gene expression differences underlying variation in fin coloration and the visual system in fish originating from a spring and a swamp river. To examine potential limiting factors to putatively adaptive plasticity in fin coloration, I explore the effects of microhabitat variation during development on the extent of plasticity in adult fin coloration. By examining the contributions of genetic and environmental factors to trait variation, this study will shed light on the evolutionary forces shaping phenotypic diversity in complex, non-model system organisms.

## Modified granular glands are a source of sexually dimorphic biofluorescence in a lungless salamander

*Michael Kardos, Sarah Woodley*

Biofluorescence has recently been discovered in many amphibian families. Biofluorescent cutaneous glands are abundant in lungless salamanders (family Plethodontidae), though little is known about the morphology and function of these glands. In this study, we used various microscopy and histological techniques to better understand the structure and function of biofluorescent skin glands in the Red-legged Salamander (Plethodon shermani). We were able to verify that one particular type of skin gland (modified granular glands) is the primary source of biofluorescence in this species. Modified granular glands fluoresced green when excited with blue wavelengths of light. These glands often, but not always, have a golden-yellow tint under white light. Biofluorescent glands are largest and most numerous in the ventral surface of both sexes, especially in the ventral tail. We also report sexual dimorphism in gland size but not density, with males possessing larger glands than females but at roughly equal densities in both sexes. Biofluorescent glands produce a carbohydrate-rich secretory product and possess a robust myoepithelial sheath around their secretory cells, suggesting that their secretion is episodic rather than continuous. Together, these results demonstrate that modified granular glands are the primary source of biofluorescence in P. shermani and that biofluorescent gland size is a male-biased sexually dimorphic trait. Further study is warranted to determine the chemical and/or visual functions of this glandular system.

## Hold Tight: The Impact of Limb Loss on Spotted Lanternfly (Lycorma delicatula) Grasping Strength

*Anand Kanumuru, Ariba Islam, Pranav G.R. Krish, Kyle Ray Dixson, Jonathan Shadan, Ashley Choi, Christine Lee, Gabby Guilhon, Michael C. Granatosky*

The spotted lanternfly (Lycorma delicatula) is an invasive insect native to Asia that has rapidly spread across the Northeastern USA. To combat its spread, the “See it. Squish it.” campaign has been promoted. However, these insects often escape by leaping away even if they sustain damaged limbs in the process. It is not yet understood how such limb damage may aFect their future ability to avoid capture. This study analyzes the eFects of limb loss on grasping strength in third- and fourth-instar nymph-stage spotted lanternflies. Since these nymphs spend much of their time on thin branches, their ability to resist being pulled oF by predators is a crucial biomechanical performance measure. Forty nymphs were divided into four groups: control, forelimb amputation, midlimb amputation, and hindlimb amputation. A small string was glued to the back of each nymph, and they were placed on an instrumented pole and slowly pulled until they could no longer hold on. After a round of initial trials, a limb was removed based on their group assignment. Our findings revealed that limb loss significantly reduced the maximum force a nymph could resist. Foreleg amputation had the greatest impact on grasping ability. Overall, the lanternflies could still resist forces greater than their body weight to maintain grip on the substrate, making it unclear if limb amputation significantly aFects their overall survival and fitness.

## Seasonal fluctuations and variability in thermogenic capacity in a high-elevation migratory songbird

*Jessica Karr, Ryan Wilgenkamp, Thomas Hahn, Jessica Malisch, Jamie Cornelius*

Individuals with greater metabolic flexibility are expected to exhibit higher survival during challenging weather conditions. Many migrant birds overwinter in relatively mild climates before arriving at high-elevation breeding locations that are characterized by more variable spring weather. However, researchers have yet to fully explore if such migrants invest in thermogenic capacity and how thermogenic capacity changes as migrants transition to breeding concurrent with less variable weather conditions. Here we describe the metabolic physiology of mountain white-crowned sparrows (MWCS) in the Sierra Nevada from migratory arrival to breeding. Eighteen male MWCS were captured from May to July 2024 at Tioga Pass, CA and baseline blood samples, body condition, and body mass were collected. Thermogenic capacity was measured as summit metabolic rate (Msum) within one hour of capture. Eight individuals were recaptured at least 14 days later and resampled. Our findings suggest that there is high individual variation in early season MWCS Msum and that Msum declines by an average of 14% from May to July. These results indicate that MWCS invest in thermogenic capacity that may help them cope with extreme conditions and then reallocate resources during the breeding season. Future research relating variation in thermogenic investment to fitness - especially across years of variable spring weather - will allow us to understand the defenses birds have against extreme weather and the consequences for fitness.

## FathomVerse: gaming for ocean exploration

*Kakani Katija, Lilli Carlsen, Emily Clark, Giovanna Sainz, Joost Daniels, Kevin Barnard, Ellemieke Berings, Meggy Pepelanova, Gaf van Baalen*

In order to fully explore our ocean and effectively steward the life that lives there, we need to increase our capacity for biological observations; massive disparities in effort between visual data collection and annotation make it prohibitively challenging to process this information. State-of-the-art approaches in machine learning cannot solve this problem alone, and building an integrated community of educators, scientists, and enthusiasts is key to enabling effective collaboration between humans and AI. FathomVerse, a mobile game designed to inspire a new wave of ocean explorers, teaches casual gamers about ocean life while improving machine learning models and expanding annotated datasets. Of the three billion gamers worldwide, up to 70% say they care about the environment, and FathomVerse taps into this community with innovative gameplay and rich graphics that draw players into the captivating world of underwater imagery and cutting-edge ocean science. In less than one month after launch in May 2024, 8k players from 100 different countries generated >3M annotations that are used to generate consensus labels and retrain machine learning models. Here we share our process of designing FathomVerse, discuss early successes from the initial launch and future plans, and touch on ways for educators to integrate the game into their curriculum. Through FathomVerse, we hope to engage global audiences (high school and up), increasing public awareness and inspiring empathy for ocean life.

## Transcriptional differences in nectar volume between bee and hummingbird pollinated Penstemon

*Amanda Katzer, Lena Hileman*

Reproductive isolation can maintain species boundaries through isolating mechanisms in premating, postmating and prezygotic, or postmating and postzygotic, or some combination of these. Plants are non-mobile and commonly have prezygotic reproductive barriers such as differential pollinator attraction. To attract a specific biotic pollinator, plants can present pollinator attraction/reward traits, such as flower color and nectar volume. The genetic basis of these traits is better understood for flower color, but the genetic basis of nectar volume is currently not fully understood. We use the model system Penstemon to compare a bee pollinated species to a closely related hummingbird pollinated species to understand nectar volume differences at a transcriptomic level, including testing for allele specific expression. Previous QTL work on the two species found one locus of large effect for nectar volume, and GWAS data points to a relatively few number of outlier diagnostic SNPs between the two species. We used this previous data to filter our transcriptomic data to candidate genes that fell under the QTL and contained outlier diagnostic SNPs which resulted in three main candidate genes. One of these candidate genes we found to be a putative LIPID TRANSFER PROTEIN. The gene had no clear pattern of cis regulation in the F1 hybrid between the two species, pointing to amino acid changes causing differences.

## Predation and multifunctionality in the macroevolution of ant mandibles

*Julian Katzke, Evan Economo*

The ants have evolved a broad trophic spectrum, they perform vastly different behaviors, universally exhibit a social lifestyle. Across ants, the range of mandible morphologies is highly disparate, and they are the primary tools that ants use in social, environmental, and dietary interactions. Here, we use a comparative approach to show how ecological parameters relate to shape diversity and we investigate functional consequences of differently shaped mandibles. Using over 600 mandibles as 3D models, we quantify shapes with geometric morphometrics for more than 250 genera. Variations on a ground plan are prevalent in all larger clades involved in any kind of lifestyle. Derived forms evolve convergently and are often associated with specialized predatory functions and occur in most lineages but by modifying different subregions of the mandible and thus increasing the overall diversity of mandible shapes. More restrictedly and mainly associated with polymorphism, ants advance into a region of morphological space where the mandible is shortened to possibly increase bite strength. However, most ants retain the ground plan, but this shape configuration seems unique compared to other wasps and even fossil stem ants. We test the functional consequences of 'the ant mandible' with simulations of movement inferred from morphology. With this, we investigate the hypothesis that this configuration optimizes for both biting and carrying, two crucial functions in the central-place foraging and colony-maintaining ants.

## The role individual social experiences play in shaping maternal hormone allocation

*Jasmeen Kaur, Ryan Paitz, Golnaz Habibi, Eli Bridge, Alexandra Bentz*

Females communicate non-genetic information about the environment to their developing offspring to generate potentially adaptive phenotypic plasticity. For example, birds allocate hormones, like testosterone (T), to their egg yolks in response to heightened social competition, causing faster growth and increased aggression in offspring. Yet not all studies show a positive effect of competition on yolk T transfer, making its adaptive value unclear. One reason for this could be that past work assumes that competitive environments have a uniform effect on females, which overlooks individual social experiences (e.g., aggression received vs initiated, affiliative bonds, etc.). Here, we used captive house sparrows (Passer domesticus) to record a female's unique social experiences within her environment and relate this to yolk hormone allocation. During the breeding season, we video recorded enclosures and calculated the aggressive and affiliative behaviors initiated and received by females while yolking eggs. Eggs were collected on the day laid to quantify the concentration of T and other yolk hormones using liquid chromatography with tandem mass spectrometry (LC/MS/MS). We explored how social behaviors predict yolk hormone allocation and used LC/MS/MS to determine how multiple hormones interact in response to a female's social experiences. This approach offers a more holistic understanding of the social environment's role in maternal effects and helps clarify how these hormonal responses might shape future generations.

## Dental alveoli as possible drivers of crown shape across ontogeny in Alligator and Crocodylus

*David Kay, Haley O'Brien, Paul Gignac*

In some thecodont vertebrates, such as rodents, alveoli and tooth cusps are related such that buccolingual alveolar constraint mechanically produces tooth cusp offset. We have shown previously that alveoli and tooth crown shapes in Alligator, which is likewise thecodont, are also significantly related, suggesting this kind of mechanism may extend to crocodylians. Uniquely, crocodylians form their sockets iteratively during ontogeny, implicating a means to generate heterodont or homodont dentitions over their lifetimes. We hypothesize that such physical constraint would take the form of robust alveolar walls surrounding molariform teeth and thinner walls surrounding caniniform teeth. We quantify alveolar growth in heterodont (Alligator mississippiensis) and homodont (Crocodylus acutus) crocodylians to investigate potential differences between alveolar growth as a possible driver of crown shape. We digitally reconstructed μCT data of jaws from hatchlings, yearlings, juveniles, and adults, measuring the buccolingual thickness of alveoli, thickness of alveolar septa, and number of complete alveolar septa. Linear regression and non-parametric ANCOVAs show that Alligator has robust buccolingual alveolar thickness and grows thin alveolar septa late in ontogeny relative to Crocodylus. The results are consistent with a model of alveolar constraint driving tooth shape: iteratively grown alveolar septa provide a physical, mesiodistal constraint helping to shape developing crowns. This work reveals a novel facet of dental variation in crocodylians and sets up potentially common mechanisms shaping tooth crowns across thecodonts.

## Variation in disruptive camouflage patterning in the European cuttlefish (*Sepia officinalis*)

*Audrey Kaye, Kendra Buresch, Charles Chubb, Nina Bresciani, Roger Hanlon*

Cuttlefish conceal themselves in complex environments by rapidly changing their skin's color, pattern, and 3D texture based on keen visual input. Their camouflage is categorized roughly into three basic pattern designs—uniform, mottle, and disruptive—with some variation in expression. The disruptive pattern is unique because it hinders initial detection through background matching but also prevents recognition by predators. It allows cuttlefish to obscure their characteristic body outline by independently expressing up to 11 large, high-contrast skin components of light and dark. Two unanswered questions were addressed: How consistent is the disruptive pattern that cuttlefish produce when repeatedly exposed to the same visual backgrounds; and do different cuttlefish all show the same pattern on a given background? We tested eight cuttlefish four times on three substrates, including a black and white checkerboard, an image of black rocks with white shells, and a natural sand and shell substrate. We photographed them and used an image processing algorithm to extract statistics reflecting the contrast, granularity, and papillae structure of their disruptive patterns. Results showed that disruptive pattern expression was more consistent within than between individuals. Amidst inter-individual variation, the white square and white head bar were the most consistently expressed components across cuttlefish and substrates. Understanding the constant and variable aspects of this versatile camouflage pattern can inform human-engineered camouflage for natural and artificial environments.

## Multisensory information processing in the premotor area in the *Manduca sexta* moth

*Pramod KC, Jeff Riffell*

Foraging species need to respond to their surroundings by acquiring and processing sensory information in a timely manner to elicit behavior. The behavioral response depends on the available sensory cues. Manduca sexta, a crepuscular moth, visits various innately attractive night-blooming flowers that often exhibit different phenotypes. How the multisensory information from the flowers – such as odor, visual, and gustatory cues – is encoded in the moth brain as a single percept is unclear. Here, we use the neural ensemble recordings in the lateral accessory lobe, a premotor area, and a putative multisensory integration center, to examine how combinations of floral signals are encoded in this brain loci. We presented the moth with different sensory information, such as floral scents, floral color, and sugar solutions, and stimuli were carefully scaled to those simulating real flowers. We found that most neural units respond to different colors of flowers of the same size. We also observed that some units were responsive to floral scents – these units were different from those tuned to the floral color, indicating compartmentalization in the lateral accessory lobe. Gustatory stimuli also modulated neural ensemble responses. This result will help us understand the neural processes of how behavioral decisions emerge from the distributed circuits in these brain areas.

## Does larval dietary stress affect adult butterfly wing color?

*Chloe Keck, Daniel Speiser, Carol Boggs*

Resource allocation, the process by which consumed nutrients are directed toward growth and reproduction, is key to understanding an organism's life history. Organisms acquire set amounts of nutrients throughout their lifespan, so allocating those nutrients to effectively increase fitness is necessary. Resource allocation strategies balance the distribution of these nutrients, resulting in trade-offs. Holometabolous insects, such as butterflies, allocate larval-derived nutrients during the pupal stage of development toward various adult traits, such as the pigments that give their wings color. In many species, wing appearance is involved in mate choice and recognition. In the butterfly Speyeria mormonia (Lepidoptera: Nymphalidae), male adults preferentially approach females with more orange wings. Therefore, wing color is a key component in individual reproductive fitness. Here, I examine the effects of decreased larval food resources on adult S. mormonia wing color and pigment. I performed a larval dietary restriction experiment in which there were two experimental groups. The control group received Viola larval hostplant ad libitum, and the treatment group received half the quantity of hostplant as the control group during the last half of the last larval instar, when nutrient acquisition is fastest. After pupation, adult wing color was measured using reflectance spectroscopy and pigment quantity was measured using thin-layer chromatography. Results suggest that larval dietary stress affects wing color, such that reflectance measurements of adult wings differ between treatments.

## Comparative skeletogenesis of Ranidae frogs in central Appalachia

*Stephanie Keer*

Anura, the clade that includes frogs and toads, is the most numerous and diverse group of amphibians on Earth. Anuran locomotion is tied highly to the unique suite of skeletal morphologies they possess, including the urostyle, radioulna, tibiofibula, astragalus and calcaneum. These bones of the post-cranial skeleton facilitate both the classic anuran saltation (jumping) and all other forms of locomotion anurans engage in, including swimming, walking, climbing, and burrowing. Significant work has been done to characterize how these bones facilitate locomotion biomechanistically and characterizing their shape as part of geometric morphometrics in a phylogenetic context. However, this work has been done primarily in adult frogs and fails to trace the developmental heterochronic and morphometric changes within these bones that allow anurans to transition between aquatic tadpoles and adult morphology and locomotive styles. As a result, we do not yet understand when and what kind of morphometric differences to promote locomotive diversity. Therefore, here we present the skeletogenesis of four semiaquatic Ranidae species to demonstrate how skeletal ontogeny and morphology intersect to facilitate specific forms of locomotion at specific life stages.

## Do the migratory parrots pack light for their domestic flights?

*Aubrey Keirnan, Vera Weisbecker, Andrew Iwaniuk*

In birds, the evolution of migratory behaviour is associated with changes to physical traits, including differences in the brain. More specifically, migratory species tend to have relatively smaller brains and cerebral hemispheres, both of which are linked to reduced adaptability to environmental changes and the energetic expense of migration. Most of what is known about migratory behaviour and brain morphology in birds is based on songbirds, but songbirds are not the only bird species that migrate. Amongst parrots, the sister taxa to songbirds, three Australian species are migratory: Swift (Lathamus discolor), Orange-bellied (Neophema chrysogaster), and Blue-winged (Neophema chrysostoma) parrots. Here, we test if these migratory parrot species have undergone changes in relative brain and brain region sizes using μCT-scanned skulls to create digital endocasts. In contrast to songbirds, these three parrot species did not differ in relative brain size or brain region sizes from their non-migratory relatives. The distances that migratory parrots fly are relatively short compared to most migratory songbirds, so this difference could be due to shorter distances. While we cannot rule out neuroanatomical differences not visible in endocasts, we conclude that the migratory parrots likely retain similar cognitive abilities to other parrots and do not follow the general pattern observed in songbirds.

## Carryover effects influence the physiology and energetics of Florida framework corals

*Elise Keister, Will Ryan, Shelby Gantt, Samantha Jerry, William Fitt, Dustin Kemp*

The loss of coral cover varies across the Florida Keys Reef Tract, with greater declines in cover on offshore forereefs than nearshore reef habitats. We investigate how corals' physiological characteristics influence cross-shelf reef decline. We studied three common coral species that are found in both offshore and nearshore reefs, during two winter and summer time periods from 2019 to 2022. Our findings not only revealed initial divergent physiological differences within coral species across these reef habitats, but also show similar responses to a thermal stress event during the summer of 2020. Specifically, shifts in symbiotic dinoflagellate communities, symbiont densities, and coral energy reserves in colonies were observed across species for both reefs. Our results reveal lasting impacts of thermal stress events via negative carryover effects within the offshore corals, with faster recovery of nearshore corals resulting in positive carryover effects for increased resilience. These findings highlight the need to evaluate population-level carryover effects to manage Florida's coral reef ecosystems effectively and aid coral restoration by selecting genotypes better adapted to local habitats and changes influenced by a changing climate.

## Comparative depth perception in arboreal lizards

*Amanda Kellerhals, Savannah Swisher, Trevor Brewington, Victor Munteanu, Richard Blob*

Many arboreal (tree-dwelling) animals use vision to investigate their habitats and perceive hazards, such as drop-offs, in efforts to limit the risk of falling. In this study, we observed the willingness of three species of arboreal lizards with different body proportions to navigate a drop in environmental height: Chamaeleo calyptratus (tall-bodied), Gastropholis prasina (low-bodied, long tail), and Anolis equestris (low-bodied, shorter tail). We placed lizards in a custom-built apparatus with a ledge that simulated a natural drop of 15 cm. We filmed trials from side and aerial views, and timed how long it took for the lizards to navigate over the drop.

Overall, we found that the lizards spent more time traversing across the platform when there was a 15 cm drop compared to the control (0 cm drop). The traversal direction in the control arena configuration was more frequently through the middle of the arena, whereas traversal for the 15 cm drop configuration was more frequently along the edges of the arena. The difference in time taken to explore the arena is consistent with lizards taking additional time to assess their risk of falling when there was a drop was present in their environment.

## A comparison of the flexural strength of *Parasteatoda tepidariorum* and *Argiope aurantia* spider silks

*Ella Kellner, Sarah Stellwagen*

Spider webs are made from several types of silk, a few of which are some of the strongest biomaterials known. These silks withstand forces in many directions in order to capture prey, for example, the cobweb weaver Parasteatoda tepidariorum uses gumfoot lines as a spring-loaded trap to capture ambulatory prey. Conversely, Argiope aurantia, an orb weaver, uses capture spiral silk to snag flying prey. The tensile strength, or the parallel forces generated when a silk strand is pulled from both ends, has been tested and well-characterized for these silks. However, flexural strength, or the force that results when a silk is pushed or deformed perpendicularly, has not been investigated. As silks in nature are warped and distorted from many directions depending on use, it is important to understand the contrasting functional characteristics when alternately stressed. We have begun examining the flexural strength of spider capture silk and found cobweb gumfoot lines sustain higher flexural forces at faster speeds. Different species of spider capture prey based on the habitats in which they reside, resulting in distinctive prey capture strategies. Comparing these strategies and the resulting differences in silk biomechanics can give key insights into how these spider silks evolve.

## Neural circuitry of peer group affiliation in male and female spiny mice

*Aubrey Kelly*

Despite the prevalence of large group-living across the animal kingdom, few studies have examined the neural mechanisms that make group living possible. Spiny mice, Acomys dimidiatus, evolved to live in large groups and exhibit a preference to affiliate with large over small groups. We determined neural circuitry that facilitates the drive to affiliate with large groups. We first identified an anterior cingulate cortex (ACC) to the lateral septum (LS) circuit that is more responsive to large than small groups of novel, same-sex peers. Using chemogenetics, we then demonstrated that this circuit is necessary for both male and female group investigation preferences, but only males' preference to affiliate with larger peer groups. Thus, the ACC-LS circuit may have evolved to promote social investigation in both sexes and was subsequently co-opted in males to also drive affiliation preferences. Furthermore, downstream from the LS, the lateral hypothalamus (LH), which is involved in defensive behavior in other rodents, was more responsive to large peer groups in female, but not male, spiny mice. Chemogenetic inhibition of the LH increased female affiliation with novel peer groups, showing that this brain region suppresses affiliative behavior. Thus, greater responsivity of the LH in females may reflect the sex difference in spiny mice that females exhibit more same-sex aggression than males. Together, these findings reveal circuitry for sex-specific regulation of mammalian peer group affiliation.

## Genomic and transcriptomic sequencing to identify genetic mechanisms of thermal adaptation

*Morgan Kelly*

Thermal tolerance traits govern the abundance and distribution of organisms across environments and shape organismal responses to climate change. However, mechanisms determining variation in thermal tolerance are poorly understood for most species. The splash pool copepod Tigriopus californicus exhibits divergent thermal tolerance traits across populations, and is easily crossed and reared in the lab. As a result, it is an excellent model for examining mechanisms of temperature adaptation. I compare transcriptomic and whole genome re-sequencing data for five populations of Tigriopus distributed along a latitudinal temperature gradient. Results of this project will provide a comprehensive map of the genetic and physiological bases of temperature adaptation in this species, and shed light on key questions, including the role of gene regulation vs. protein coding changes in physiological divergence among populations, and the proportion of the genome involved in temperature adaptation.

## Unraveling the neuromotor responses to dynamic variation in milk flow rate during infant pig feeding

*Maressa Kennedy, Ani Smith, Thomas Stroud, Emily Volpe, Dylan Anderson, Harlow Smith, Skyler Wallace, Hannah Shideler, Shanique Yazzie, Holly Sabato, Elska Kaczmarek, Christopher Mayerl*

The ability to respond to variation in the environment is a critical component of performance in both locomotor and feeding biomechanics. In feeding, these environmental parameters can include differences in texture, temperature, or volume. For infants, one relevant variable is milk flow rate. While we know that performance outcomes (e.g. aspiration) vary depending on milk flow rate, we have limited insight into the neurophysiologic responses (e.g. kinematics and muscle activity) that drive this performance. We utilized a computer-controlled bottle nipple to instantaneously adjust flow rate through changes in duct diameter while feeding infant pigs to evaluate how the motor system controlling feeding responds when the pig senses an acute change in a single variable. We collected biplanar videofluoroscopic data synchronized with fine-wire electromyography and intraoral pressure recording. We found that when flow rate decreased, pigs increased intraoral suction generation, genioglossus activity, and changed how they moved their tongue to acquire milk. In contrast, when flow rate increased, pigs responded by swallowing at a faster rate and swallowing larger boluses. These results give us insight into the sensorimotor system controlling infant feeding and detail the motor changes that occur when a change flow rate is sensed in real time. Future work will leverage these principles to better understand feeding function, as well as test what other variables infants are capable of responding to.

## Modeling growth and anchoring of plant root-like structures in dry granular media

*Deniz Kerimoglu, Nicholas Naclerio, Aradhya Rajanala, Elliot Hawkes, Daniel Goldman*

Plants anchor themselves in soil and sand by elongating their primary roots and growing lateral extensions (root hairs). To discover principles of anchoring (upward resistance forces which exceed elongation intrusion forces), we developed a soft robot that achieves tip growth via a pressurized thin-walled tube, initially inverted back inside itself; the model also includes hair-like protrusions, emanating sequentially down the robot during elongation. The robophysical model reveals that the incorporation of hairs increases peak pullout forces by a factor of two. To understand the robot's dynamics and generate hypotheses for root hair function in anchoring in biological systems, we developed an experimentally validated numerical simulation of an elongating root-like structure with growing hair protrusions into a model granular medium of ~1mm spheres. We simulate the root elongation by continually adding coupled (via linear bonds) stacks of "rings" constructed from circular rings of rigidly coupled spheres. Simulations revealed that hair density is crucial for anchorage enhancement. Both excessively dense and overly sparse hair distributions were less effective in achieving maximum anchoring relative to an intermediate 3mm vertical spacing, covering 13% of the circumferential area. This density provided six times the anchoring force compared to a hairless root of 5 mm diameter. Our research indicates that anchorage is better achieved via the growth of root hairs with specific spacing, rather than an increase in root diameter.

## These teeth aren't made for biting: morphology of the tenacular teeth across depth profiles and taxa

*Kaitlyn (Katie) Kern, EW Misty Paig-Tran*

Chimaeras are chondrichthyan (cartilaginous) fishes that are the only extant animal to have an accessory copulatory structure known as the cephalic tenaculum. The cephalic tenaculum is found at the head of mature male chimaeras, and in rare cases females, which aid in grasping onto the pectoral fin during mating events. These stalk-like structures extend to a bulb that is covered in numerous rows of sharp teeth. The three families of chimaeras (Callorhinchidae, Chimaeridae, Rhinochimaeridae) are found in varying depth profiles ranging from 0 to 4500 meters and have cephalic bulbs that are distinguishable by taxa and depth. We collected morphometric data for teeth located on the cephalic tenacula for all three families (Callorhinchidae N = 6, Chimaeridae N = 24, Rhinochimaeridae N = 6) including: projection or base to apex length, maximum width, density, tooth angle, and curvature. We found that the teeth of the cephalic tenaculum vary in density, shape, width, curvature, and projection across taxa. We found a trend between tooth morphology using geometric morphometrics and depth as well as trends between tooth shape and family. Working with museum specimens allows us to collect critical biological data on fishes that are rarely seen alive.

## The biomechanics of wing coupling in cicadas

*Pranav Khandelwal, Trevor Bryan II, Alan Mach, Joshua Taylor, Jake Socha*

Many four-winged insects couple their fore- and hindwings to fly, effectively forming a single wing on each side. Various mechanisms facilitate this connection, ranging from hooks in bees to a clamp-like structure in stink bugs. Although morphological underpinnings of coupling have been documented, how insects establish, maintain, and detach the physical connection remains unclear. We conducted tethered flight experiments and microtomography on periodical (Magicicada septendecim) and annual (Neocicada spp.) cicadas to investigate mechanisms of wing coupling, decoupling, and in-flight connection. High-speed video recordings of tethered flight (n = 45) showed wing coupling occurring within four wing strokes, though not always simultaneously on both sides. Coupling was initiated during the downstroke as the forewing slid and pressed over the hindwing, allowing the ventral-facing fold on the forewing's trailing edge to slot into the dorsal-facing fold on the hindwing's leading edge. Taping the forewing lobe blocked coupling, confirming the role of the lobes in this process. Decoupling typically occurred when the cicada folded its wings at rest, with the forewing moving over a fully folded hindwing, causing the lobes to snap apart within ∼1 ms. Microtomography revealed the location of coupling contact and how it changes during the quasi-statically simulated wingstroke. Overall, our findings suggest that the lobe structure and wing movement enable rapid coupling and decoupling, facilitating smooth transitions between flight and rest.

## Analyzing opportunistic whale-watch data: variables impacting humpback sightings & behavior

*Eman Khwaja, Kathryn Kavanagh*

Research on humpback whales and other large baleen whales relies heavily on opportunistic field data, such as data from commercial whale watch vessels. This method of data collection is subject to variability in environmental conditions, sea conditions, and observer experience, which can affect data quality and quantity. The goal of this study was to determine which, if any, environmental, temporal, and observer variables impact the quantity of whales observed and the behaviors of whales documented. This analysis was completed on humpback whales (Megaptera novaeangliae) using opportunistic field data collected in the Gulf of Maine aboard commercial whale watch vessels departing from Boston, Massachusetts. A total of 23580 observations of whales documented on 4139 trips between 2014-2021 were analyzed using generalized linear models (GLM) and a principal component analysis (PCA). It was found that the number of whales sighted in a whale watch trip is significantly impacted by the number of observers aboard, the experience of the observers, time of year, and multiple environmental variables including visibility, rain, and sea height. The documented behaviors of whales appear to be impacted by wind speed, sea height, swell height, and time of year. These results are fundamental for adequately mitigating and controlling for variation and bias during statistical analysis on presence/absence and behavioral studies on large whales while utilizing opportunistic field data.

## Activation of the sympathetic-adrenal-medullary system increases DNA damage during the transition to captivity

*Denyelle Kilgour, L. Michael Romero*

Prior work has demonstrated that both acute and chronic stress can increase the number of double-stranded breaks detected in DNA and that the hypothalamic-pituitary-adrenal axis is the primary driver of increases in DNA damage during acute stress. However, the role of the sympathetic-adrenal-medullary (SAM) system in causing the increase in DNA damage observed during chronically stressful situations such as the transition to captivity is less well understood. We explored the role of the release of catecholamines in increasing DNA damage. We hypothesized that activation of the SAM system plays a role in the amount of damage detected after two weeks in captivity. We administered a beta-blocker to wild house sparrow (Passer domesticus) at capture and throughout the day during the first few days of captivity and compared double-stranded DNA breaks. We found that immediately following the treatment period, both control and beta-blocker-treated birds had similar levels of DNA damage, but after two weeks in captivity, treated birds had lower levels of damage, suggesting that SAM system activation plays a role in creating the previously observed patterns of DNA damage during chronic stress and the suppressing its effects may lead to faster recovery and less damage overall.

## How internal states affect behavior and gene regulation in Hydra vulgaris

*Kelly Kim, Jacob Robinson*

Environmental cues and internal states are key modulators of behavior and neural activity. The challenges of comprehensively understanding behaviors increases with the organism's complexity making simple organisms well-suited to study the relationship between neural activity and behavior. With a well-defined set of behavioral motifs and a relatively simple nervous system, Hydra provides a unique opportunity to interrogate behaviors from the organismal to the molecular level. Here, we first show that the millimeter-sized invertebrate Hydra can exhibit phototaxis, a behavior that is more complex than sensorimotor reflexes. We discover that this phototactic behavior is modulated by satiety (i.e., hunger) and we establish an algorithm that describes this behavior. Using in vivo data and computational simulations, we identify three parameters that can be selected to accurately recapitulate animal behavior under different conditions. We further investigate the underlying molecular dynamics that arise from satiety by leveraging single nuclei multiomic sequencing (paired single-nuclei RNAseq and ATACseq) to identify regulatory changes between starved and fed animals. Ultimately, we aim to establish a network model of genetic dynamics that drive phototaxis in Hydra that lead to behavioral change.

## Flotation of California Blackworms and Other Hyponeuston

*Soohwan Kim, Harry Tuazon, Nami Ha, Ishant Tiwari, Saad Bhamla, David Hu*

The California blackworm L. variegatus generally lives underwater but it can extend its posterior end to the water surface to breathe. Little is known about the flotation forces it achieves through this process. In this experimental study, we visualize the meniscus shape for blackworms and plastic rods and compare them to theoretical predictions from Vella, Lee and Kim (2006). We measure the Bond number and specific gravity for blackworms, leeches, and other common invertebrates that inhabit the water surface. Using this theoretical framework, we calculate the factor of safety for flotation of blackworms and other organisms.

## Eversion Mechanics of Bloodworms

*Soohwan Kim, Atsingnwi Tuma, David Qin, Essy Behravesh, Aqua Asberry, Joseph Thompson, Stanislav Emelianov, David Hu*

Eversion is the process where an organ or structure is turned outward. Many animals from starfish to sea cucumbers to sharks use it for feeding, defense, or other purposes. In this study, we perform high speed film and ultrasonic imaging of bloodworms, Glycera dibranchiata. While their ability to evert their proboscis to push through soils has long been studied, little is known of the mechanics of their extension and retraction process. We report the kinematics of worm eversion, compare it to other animals, and rationalize the rates observed through consideration of the mechanics of the skin, internal, and surrounding fluid. Our findings may inspire the design of long, stretchable soft robots that provide gentle contact with humans.

## Effects of historical severe winter weather on Eastern bluebirds

*Taylor Kinchen, Jennifer Grindstaff, Lynn Siefferman, Virginie Rolland*

Recent climate trends have increased the frequency and severity of severe winter weather. Across the globe, unpredictable severe weather can cause die-off events. For Eastern bluebirds (Sialia sialis), populations that are exposed to severe winter weather displayed increased mortality and a decrease in the number of breeding pairs in subsequent years. Survivors of a severe winter weather event in the Southeastern United States in 2021 displayed longer tarsi and longer, deeper, and wider beaks in support of the starvation and thermal endurance hypotheses. Additionally, less-ornamented individuals were more likely to survive, potentially due to exerting less energy toward mate and site acquisition. The objective of this study is to use specimens from museum and teaching collections to investigate the morphology and ornamentation of birds before and after four historical severe winter weather events and identify how populations phenotypically responded. These events include the winters of 1958, 1976-79, 1993 and 2007. We expect populations experienced rapid natural selection towards traits that were more advantageous during periods of prolonged severe winter weather, like larger body size and less ornamentation. With this information, we hope to predict how wildlife populations may respond to future bouts of severe winter weather which is more likely to occur in this time of rapid environmental change.

## Developing snapping shrimp as a model for studying protection against blast-induced neurotrauma

*Alexandra Kingston, Rebekah Hansen, Tanner Mierow, Jacob Bolin, Daniel Speiser*

Shock waves are supersonic high-amplitude pressure waves that cause blast-induced neurotrauma in animals. Snapping shrimp (Decapoda: Alpheidae) produce shock waves during interactions with predators and prey and are frequently exposed to shock waves during agonistic interactions with conspecifics. We discovered that snapping shrimp are protected from shock waves by their helmet-like orbital hoods. When we surgically removed orbital hoods and exposed animals to shock waves, snapping shrimp demonstrated disorientation and loss of motor control. Snapping shrimp are the first animals discovered to have shock wave damping armor and are thus uniquely well-suited for studying natural forms of protection against blast-induced neurotrauma. To make further progress, we need more precise methods for assessing the effects of shock wave exposure in snapping shrimp. In response, we are exposing the snapping shrimp Alpheus heterochaelis to shock waves and then examining behavior, quantifying apoptosis in the brain, and visualizing the expression of biomarkers of neurodegeneration. To assess disorientation, we are examining the paths snapping shrimp take to reach their burrows during shelter-seeking behavioral trials. To investigate molecular correlates of blast-induced neurotrauma, we are quantifying caspase-3 activation as a marker of mid-stage apoptosis. To study neurodegeneration in the brains of snapping shrimp, we are localizing and quantifying the expression levels of proteins including high-mobility group box protein (HMGB), glial fibrillary acidic protein (GFAP), and inducible nitric oxide synthase (iNOS).

## Does social environment impact multimodal signaling in bird-voiced treefrogs?

*Jaden Kinney, Blake Braud, Whitney Walkowski*

Anuran amphibians rely heavily on auditory and visual signaling as a means of obtaining a mate. Shifts in either form of signaling greatly impact female choice, with some frogs changing call frequency, call timing, or visual signal intensity. Social environment, such as male density or positioning within a group, also impacts this form of signaling. Previous work on our study taxa, the bird-voiced treefrog (Hyla avivoca), has shown that males alter calling tactics when in large groups and that females prefer non-overlapping, long-pulsed calls. Our study furthers this work and focuses on how grouping behavior during calling changes auditory and visual signaling tactics, i.e. multimodal signaling. We monitored the position of calling males within a chorus and the density of male groupings. We correlated social positioning with changes in calling dynamics and visual signaling. We found that males calling from the center of choruses have lower pitched, longer pulsed calls. We also found that males in the center of the chorus may display more conspicuous visual signaling. In the future, we would like to explore how this phenomenon affects female preference behavior.

## Anthropogenic disturbance affects the presence of antibiotic-resistant Salmonella in urban birds

*Abigail Kirkpatrick, Alexa Pappalardo, Ann Williams, Amber Brace*

Since the discovery of penicillin and the subsequent "Golden Age" of antibiotic discovery and use, humans have been driving the rapid evolution of antibiotic resistance in bacteria, which has emerged due to overuse in domesticated animals. As antibiotics continue to be introduced to the environment though irresponsible practices, selection for resistance genes in bacteria is resulting in increased exposure of wild animals to antibiotic-resistant pathogens. Additional pressures on wildlife, including rapid and extensive urbanization cause inevitable increases in physiological stress, leading to increased infection risk in these animals. When species congregate around resources such as feeders, the higher density of individuals also has the potential to increase pathogen spread, including antibiotic-resistant Salmonella species. In turn, these resistant bacteria can spillover into human populations, especially in urban areas where human-wildlife interactions are common. Indeed, urban bird species such as blue jays, mourning doves, and cardinals are known carriers of zoonoses, including pathogenic Salmonella. Here, we used camera-trapped bird feeders to examine the relationship between environmental disturbance and the prevalence of antibiotic resistant bacteria (ostensibly Salmonella) in an urban population of birds. Our results suggest that increased levels of anthropogenic disturbance lead to a higher likelihood of antibiotic-resistant bacteria on and around bird feeders. This research will help elucidate whether differing levels of human disturbance can represent potentially greater risks for human and animal health.

## Early motor adaptation to injury revealed in gait signatures with reversible electrical nerve block

*Nathan Kirkpatrick, Robert Butera, Young-Hui Chang*

After nerve injury, redundant degrees of freedom in the legs are leveraged to maintain locomotor performance. Traditionally, transection has been used to study this locomotor adaptation process. However, this technique is temporally imprecise. The animal begins acclimating to the traditional impairment immediately upon recovery from anesthesia, preventing accurate kinematics observations of this early adaptation period. Accordingly, we applied Kilohertz Electrical Stimulation (KES) to temporarily and immediately inhibit action potential transmission in the tibial nerve during locomotion, which innervates several major ankle extensor muscles. Acute experiments have shown KES to be repeatable and reversible, but transitioning to studies with chronically implanted electrodes is poorly understood. High speed biplanar x-ray video of treadmill locomotion was acquired during four post-implantation collection sessions. Gait data were collected immediately before, during and after KES was administered for 30 minutes, and over successive days of exposure to the same protocol. To identify distinct movement strategies during block, the gait signatures dimensional reduction framework was applied to all of the gait kinematics data. A 512-node recurrent neural network was trained on bilateral sagittal plane hindlimb joint angles and projected segment lengths. Principal components analysis was performed on the extracted internal states of the model and compared. Kinematic reconstructions from gait signatures revealed distinct movement strategies were present on sessions 1 and 4, highlighting the individual-specific nature of the early adaptation period.

## Experimentally increased thermal variation but not average temperature reduces avian offspring size

*William Kirkpatrick, Sarah DuRant*

Climate warming will expose parents and offspring to highly variable environments, which can affect parental care behaviors. In cavity nesting birds, parental behavior can be separately influenced by average environmental temperature and thermal variation, though whether their effects on offspring traits differ is unknown. We used 208 nest-boxes across 5 field sites to examine Eastern Bluebird (Sialia sialis) nestling body size in response to parental behavior and the thermal environment in nest boxes modified to experience greater average temperatures or variability. We quantified adult breeding behavior using NestIQ, a machine learning software that recognizes off-bouts by comparing nesting temperatures. Preliminary analysis suggests that the increased temperature variation treatment reduced clutch size and nestling body size while increasing mean temperatures led to larger body sizes. Analysis is ongoing, but these findings suggest that thermal variation and mean temperature can act independently to affect offspring phenotype.

## Uncoiling senescence: Using garter snakes to understand the genetics of aging

*Randy Klabacka, Anne Bronikowski, Jessica Judson, Daniel Nettleton, Laurie Stevison, Suzanne McGaugh, Andrew Lithio, Dawn Reding, Tonia Schwartz*

Aging, defined as the time-dependent decrease in organism function and increase in mortality risk for an individual, is controlled by central features deemed "hallmarks". The genes that drive biological processes within these hallmarks have been examined primarily in model organisms, meaning that much is left to uncover about the genetic mechanisms of aging in natural systems from which the process of aging originates. Here we examine genes and gene networks of three major hallmarks of aging (Metabolic Function, Macromolecule Damage and Repair, and Stress Adaptation) in a species of garter snakes that has two naturally-occurring "ecotypes" (fast-aging and slow-aging) around Eagle Lake, California, USA. Using techniques in transcriptomics and population genetics, we identify genes and gene networks within these hallmarks that are divergent between the two ecotypes and incorporate these findings with the extensive work conducted previously in the Eagle Lake garter snake system.

## Paracentrotus lividus in the warmer Gulf of Kalloni differ notably from those in the adjacent Aegean

*Thomas Klinger, Caitlyn Jencarelli, John Hranitz*

The purple sea urchins, Paracentrotus lividus, in the Gulf of Kalloni, Lesvos, Greece function at higher sea surface temperatures than is experienced by conspecifics in the cooler adjacent Northern Aegean Sea. Despite individuals functioning similarly and well in both the warmer and the cooler environments, notable differences in the relative sizes of the body compartments, in the shape of the individuals, and in nutritional condition were identified. Principle component analysis explained most of the observed morphological variance in terms of relative length of the spines, and the relative masses of Aristotle's lantern, test, and coelomic fluid (component 1); in terms of the compression of the dimensions of the test and jaw support apparatus (component 2); and in terms of the relative mass of the gut tissues (component 3), with the cumulative model explaining 80% of the variation. Although total numbers of growth lines in test ossicles did not differ significantly (GLM, $p>0.05$), comparable ossicles were significantly (ANOVA) larger in sea urchins growing in the Aegean than in the Gulf, suggesting different trajectories for the growth of individuals. DNA is currently being sequenced to investigate the population genetic structure of samples. Understanding accommodations of this important sea urchin to high temperatures is important as the current sea surface temperatures in the Gulf of Kalloni mirror expected future increases for the Aegean as a whole.

## Analyzing expression dynamics of multiple Nematostella minicollagens using HCR and Probe-seq approach

*Anna Klompen, Jenny Duong, Mary McKinney, Jason Morrison, Jose Javier, Kevin Ferro, Shiyuan Chen, Kate Hall, Allison Scott, Kaitlyn Petentler, Lacey Ellington, Anoja Perera, Zulin Yu, Matt Gibson*

The secretory organelle of cnidarian stinging cells, called a cnida (plural: cnidae), is arguably one of the most complex cellular structures in the animal kingdom. Two distinct categories of cnidae include nematocysts, with ∼25 different morphologies across all cnidarians, and ensnaring spirocysts that are exclusive to sea anemones (Anthozoa: Actiniaria). An ongoing question in cnidarian biology is identifying genes specific to distinct cnidae type (nematocyst vs. spirocyst) or nematocyst subtype (isorhiza vs. mastigophore). Previous molecular characterizations of a subset of minicollagens, cnidarian-specific proteins marking stinging cells, suggests that different minicollagens may be temporally and spatially distinct across cnidae types, including cnidae of the starlet sea anemone Nematostella vectensis. Here, we used hybridization chain reaction fluorescent in-situ hybridization (HCR RNA-FISH) to visually explore the expression patterns of all endogenous Nematostella minicollagens, including three previously studied minicollagens and three uncharacterized minicollagens. Through six-color multiplexing experiments, we observed the expression dynamics of all known minicollagens in a single cnidarian individual. We found that four minicollagen genes were expressed throughout the ectoderm of budding and primary polyps, as expected, but two were restricted to the newly-formed tentacles. We further characterized the expression of each of the six minicollagen-positive cell populations using a Probe-seq approach. In combination with public and newly generated scRNAseq datasets, our work suggests two genes are the first minicollagens that are specific to spirocysts.

## Multiple jellyfish toxins are specific to distinct polyp and nematocyst types in a hydrozoan colony

*Anna Klompen, Matthew Travert, Cassandra Kempf, Kevin Ferro, Jenny Duong, Lacey Ellington, Matt Gibson, Paulyn Cartwright*

The phylum Cnidaria deploy their venoms using nematocysts, which are housed in “stinging cells” that are scattered across an individual. The colonial hydrozoan Hydractinia symbiolongicarpus displays a division of labor through functionally and morphologically distinct polyp types. We have shown that Hydractinia partitions expression of toxin-like genes across these tissues, and each polyp type contains distinct nematocyst types. Here, we investigated the spatial distribution of several members of a specific protein family, jellyfish toxins (JFTs), in which multiple paralogs are differentially expressed across the functionally specialized polyps. JFTs are well-documented pore-forming toxins in the venoms of box jellyfish (class Cubozoa), but their role in venom from other medusozoans remains unclear. Using a combination of publicly available single-cell datasets, in situ hybridization, immunohistochemistry, and bottom-up proteomics, we show that 1) Hydractinia JFTs are likely true venom components due to their expression in nematocyst-specific clusters and proteomic detection in nematocyst-enriched cell isolates, 2) the differential expression of Hydractinia JFTs across polyp types is consistent with our previous work, and 3) two specific Hydractinia JFTs are localized to specific types of nematocysts based on custom antibody staining. Overall, we show that JFT expression patterns in Hydractinia are consistent with the subfunctionalization of JFT paralogs across a partitioned venom system within a colonial cnidarian. Furthermore, our work provides further evidence that different nematocyst types maintain and deploy distinct venom compositions.

## On your (land)mark, set, go!: 3D mineral structures vary in shark vertebrae based on swimming style

*Jamie Knaub, Madisan Biordi, Emma Pawlik, Lisa Natanson, Michelle Passerotti, Tricia Meredith, Marianne Porter*

The mackerel sharks (order Lamniformes) are a diverse clade that vary in body shape and swimming mode. Lamnid sharks (family Lamnidae) swim using a thunniform style where lateral oscillations are restricted to the posterior body and caudal fin. Other lamniform families, such as common thresher and sand tiger sharks, use a carangiform mode where oscillations occur across a greater portion of the body. During swimming, lateral oscillations subject the cartilaginous vertebrae to bending loads, and the resulting mechanical behavior varies with mineral amount and arrangement. Here, we aimed to examine 3D mineral structure to investigate the form-function relationship in shark vertebral cartilage. We hypothesized that the mineral structure would differ between swimming styles. We landmarked the 3D mineral structures in three thunniform (lamnids; porbeagle, shortfin mako, and white shark) and two carangiform swimmers (common thresher and sand tiger shark). We used a Generalized Procrustes Analysis and Principal Component Analysis to assess differences across species and between swimming styles. We found that the three lamnids overlapped in the morphospace center, suggesting that thunniform swimming relies on a consistent mineral arrangement. The common thresher and sand tiger sharks occupied opposite ends of the morphospace, suggesting vertebral design for carangiform swimming is more variable, or supports other functional needs (e.g. common thresher shark tail-whipping). These results provide greater insight into the complex form-function relationship in mineralized shark cartilage.

## Urban living improves defenses against invasive parasites in the Galápagos Islands

*Sarah Knutie*

Over the past several decades, the Galápagos Islands of Ecuador have experienced a rise in ecotourism and residential human population size. This change in human activity has also coincided with the introduction of several invasive parasites, such as the avian vampire fly (Philornis downsi) that negatively affects endemic Darwin's finches by exsanguinating nestlings. Our recent work suggests that nestling finches living in urban areas are more resistant (with innate immunity) and tolerant (with red blood cell recovery) to the flies compared to non-urban nestlings. Consequently, the survival of urban nestlings who are parasitized by the flies is 50%, which is significantly higher than the survival of non-urban nestlings (5%). Over the past several years, my research group has tested several potential ecological factors, such as food resources and nest temperature, that could help facilitate resistance and tolerance in the urban population. Unfortunately, we found that experimental food supplementation and nest temperature do not rescue nestling defenses, and thus survival, against parasitism. My talk will review over a decade of our work in the Galapagos Islands, including a discussion of the physiological and ecological mechanisms mediating interactions between avian vampire flies and Darwin's finches in the context of urbanization.

## Tide turners & littoral learners: marine science exploration & communication

*Dany Ko*

Despite having a deep-sea-ted love for the ocean and all it holds, education on marine sciences is not necessarily accessible or relatable to marginalized folks. However, there are many ways to get involved in the field that utilizes the skills and experiences people have amassed thus far in other aspects of their lives to make marine sciences education and research accessible to others, too. In this project, several creative avenues to making ocean sciences experiences and research accessible and interesting for others to engage in will be presented and reviewed. Several materials on the Diversifying Ocean Sciences experience have been produced, including some zines, a novella, and a workshop. The feedback received will be utilized to generate some guidelines on making marine science outreach and education accessible and engaging to a variety of audiences. These guidelines will be shared, along with speaking to what works, doesn't work, and how scientific communication can be improved. Ultimately, if marine science research / education is made accessible and interesting, then there are a number of ways that people engaging with this communication can respond to it and get involved in marine sciences themselves. As such, engaging in various forms of creative science communication is just as important as conducting research, working in labs, and becoming an academic.

## Vibrating with flow: flexible bodies of dead fish enable passive undulation behind obstacles

*Hungtang Ko, Meg Vandenberg, Olivia Hawkins, Adam Summers, Radhika Nagpal, Cassandra Donatelli*

As tidal currents surge and recede, nearshore fishes are subject to dynamic water flow conditions, maneuvering around both natural barriers like bull kelp and human-made structures like piers. The flow behind these obstacles is not random: they generate alternating vortices and periodic forces that displace any object downstream laterally. Previous work suggests that the interplay between this periodic force and the flexibility of fish bodies allows dead fish to generate movement similar to their natural swimming kinematics. However, it remained unclear what determines the kinematics of dead fish. To answer this question, we placed freshly euthanized pacific sand lances (Ammodytes hexapterus) and crescent gunnels (Pholis laeta) behind fixed cylinders of different sizes and in flows at different speeds. The flexible bodies of these fishes indeed undulated similarly to live fish. Furthermore, their tail-beat amplitude and period of oscillation increased with flow speed and cylinder size. Using these data, we calculated the Strouhal number of a dead fish as the product between its tail-beat amplitude and frequency divided by the incoming flow velocity. Remarkably, we discovered this Strouhal number to be a constant across all experimental conditions. Together, our results suggest that while the undulation of a dead fish is energized by the fluid forces, its kinematics is determined by the flexibilities of its body.

## Melatonin regulation of dopamine in the auditory system of a vocal fish

*Kobi Kobi, Xylo Lazrinth, Yassir Azzam, Rachel Rodriguez, Kara Duclosel, Ezan Khan, Paul Forlano, Joseph Sisneros*

Plainfin midshipman fish undergo a robust enhancement of hearing at the level of the inner ear during the summer, reproductive months to better detect and localize the mating call of males. Seasonal changes in dopamine innervation of the inner ear partially drive this seasonal change in hearing in females, but mechanisms that seasonally regulate catecholamines in the peripheral and central auditory system are less understood. Melatonin production changes seasonally and its receptors are expressed in a forebrain region that contains auditory-projecting dopamine neurons, thereby supporting melatonin as a candidate hormone responsible for driving these seasonal changes in catecholamines. Here, we investigated the role of melatonin in regulating catecholamine innervation and synthesis in the central and peripheral auditory system. Summer females were implanted with either a control or 2-Iodomelatonin implant and sacrificed after one week. Brains and saccules, the main end organs of hearing, were collected and processed for immunohistochemical analysis for markers of catecholaminergic innervation and synthesis in auditory nuclei and the saccule. Our preliminary data suggest a role for melatonin in regulating catecholamine synthesis in forebrain dopamine neurons that project to central and peripheral auditory areas as well as in dopamine neurons in the preoptic area, and decreasing catecholaminergic innervation in a forebrain auditory nucleus. These results support melatonin regulating specific dopamine neurons and catecholamine projections that may contribute to seasonal changes in hearing.

## Can we rescue planaria from BPA using PCL and carbon nanotubes?

*Eli Koboski, Bhushan Dharmadhikari, Michael Minicozzi*

Bisphenol-A (BPA) is an industrial chemical used in the production of plastics. BPA is a known endocrine disrupting chemical and is found in most water systems. Planaria, (Dugesia dorotocephela) are a model organism for ecotoxicology due to their ability to regenerate from fragments. To determine the effects of BPA on planaria, we exposed regenerating planaria to three environmentally relevant concentrations (0.1μM BPA, 1μM BPA, and 10μM BPA) and a control. Planaria were transected into three fragments (head, middle, and tail) with head and tail fragments transferred to their respective treatment. Each fragment was photographed daily for fourteen days. These images were used to measure the amount of regenerated tissue compared to preexisting tissue. We found that BPA decreased regeneration in all treatments compared to the control. As a follow up to these results, we aim to remediate BPA using two types of filter mesh made using electrospinning process that are comprised of polycaprolactone (PCL) and composites of PCL and carbon nanotubes (CNT). The four treatment solutions were filtered using these materials and planarian regeneration will be tested using the filtered solutions. It is expected that the PCL filter will produce little to no remediation, while the PCL+CNT filter will showcase more respectable amounts of remediation. We hope that these results can be utilized as a biologically safe method of removing BPA from the natural environment.

## Behavioral ecology meets biochemistry: Lessons in sexual selection from colorful songbirds

*Rebecca Koch, Yufeng Zhang, Geoffrey Hill, Matthew Toomey*

A key challenge within the study of sexually selected traits is understanding the information that such traits communicate. Many intersexual courtship display traits, for example, have been hypothesized to vary in ways that can transmit potentially useful information to receivers, be it as simple as species identity or as complex as individual "quality." A focal system for testing this latter idea of courtship traits as honest indicators of individual quality is the ornaments colored by carotenoid pigments in birds. For decades, studies have explored how and why individuals that express stronger carotenoid-based coloration—such as redder or more saturated colors—are often both healthier and preferred mates compared to their duller counterparts. Recently, carotenoid-based coloration has been hypothesized to vary along with individual quality because both color and quality may hinge on the same subcellular process: mitochondrial aerobic respiration. Here, we consider the implications of recent experimental tests of this hypothesis in wild and captive songbirds, with particular focus on the house finch (Haemorhous mexicanus). We leverage recent discoveries of genes important to carotenoid-based coloration in birds to explore why mitochondrial processes may be more strongly linked to coloration in some taxa than others. Altogether, the concurrent advancement of our understandings of subcellular processes and ornament-specific enzymatic pathways offers a transformative new approach to longstanding questions in sexual selection research.

## Surveillance and histopathological evaluation of acanthocephalan parasites in turtles

*Ryan Koch, Matthew Bolek*

In terms of diversity, turtle acanthocephalans are a small group of helminths, yet they parasitize a quarter of all turtle species in North America. These parasites attach to the intestinal wall of their turtle hosts. In

Oklahoma, few surveys of turtle acanthocephalans exist, making it difficult to assess changes in these parasites over time. Additionally, it remains unclear whether acanthocephalans cause pathological changes to their turtle hosts. Therefore, we sought to 1) evaluate the diversity and infection dynamics of acanthocephalans from Oklahoma turtles, and 2) conduct a histopathological analysis of turtles infected with acanthocephalans. Among all turtles, only red-eared sliders (83%) and common snapping turtles (11%) were infected with acanthocephalans. A total of 11,838 acanthocephalans were recovered from red-eared sliders, infected with 4 species of acanthocephalans. Co-infections were more common (77%) than single species infections (17%). In the single infected common snapping turtle, both turtle and fish acanthocephalans were identified. Lastly, histopathological examination revealed mechanical damage to the intestinal wall of infected turtles, such as villous atrophy, excessive mucous production, and fibrosis, indicating signs of mucoid enteritis disease. This study provides the most comprehensive assessment of acanthocephalans in turtles and sheds light on a novel wildlife disease in turtles.

## Cumacean ‘Omics to Measure Mode of Adaptation to Antarctica (COMMAA)

*Kevin Kocot, William Farris, Victoria Vandersommen, Sarah Gerken*

This project utilizes cumaceans (Crustacea, Peracarida) as a model system to explore genomic adaptations of marine invertebrates to polar regions. Cumaceans are diverse and ecologically important in marine habitats worldwide. They are especially diverse in the Antarctic, where they exhibit a high degree of endemism (89-91%) and can be locally abundant. By comparing genomes of Antarctic cumaceans representing four families to those of closely related congeners from temperate habitats, we aim to explore gene family expansion/reduction, protein domain and GO term enrichment/depletion, and patterns of selection convergently evolved in response to Antarctic conditions. To date, we have generated PacBio Revio HiFi assemblies for Antarctic cumaceans representing three families and found that cumaceans have relatively large (1.5-5 Gbp) and heterozygous genomes. For example, our Diastylis anderssoni assembly is 1.52 Gbp, 2,261 contigs, N50 = 1 Mbp, BUSCO completeness = 88.5% with 24.6% duplication. We have also sequenced transcriptomes from >50 cumaceans representing most families and conducted a phylogenomic analysis based on 817 genes to generate a robust phylogenetic framework for our comparative analyses. Results are strongly supported and largely consistent with a recent multigene study, although we recovered all sampled families monophyletic. These findings lay the foundation for further comparative analyses to investigate the genetic basis of polar adaptations in cumaceans and evolutionary responses to environmental changes in Antarctic habitats.

## Protozoan animal ancestors: Multicellularity and colony form of choanoflagellates affect performance

*Mimi Koehl, Tom Hata, Hoa Nguyen, Lisa Fauci*

Choanoflagellates, which share a common ancestor with animals and can be unicellular or form multicellular colonies, are a model system to study the evolution of multicellularity in animal ancestors. A choanoflagellate cell has one flagellum that propels the cell and creates a water current carrying bacteria to a collar of prey-capturing microvilli surrounding the flagellum. Sponges have similar choanocytes that line chambers, pumping water through the sponge and catching bacteria. Employing experiments and modeling of choanoflagellate hydrodynamics, we determined how some morphological steps in the evolution of animals from choanoflagellate-like ancestors affected performance of activities that can affect fitness: swimming, feeding, avoiding capture by protozoan predators. Using Salpingoeca rosetta to determine consequences of cell morphology and multicellularity, we found that one single-cell morphotype swims rapidly, finding patches of bacterial prey, whereas other unicellular morphotypes are better feeders. Some cells in colonies catch more prey/cell per time than do unicellular choanoflagellates. Raptorial protozoan predators sense hydrodynamic signals of colonies while ignoring single cells, whereas ciliate predators reject larger colonies. We used Choanoeca flexa (which forms cup-shaped colonies that can turn inside-out) to study effects of flagella pointing outwards vs. lining a cavity. Flagella-out colonies swim rapidly and evade predators. Slowly-swimming flagella-in colonies capture more prey, but are grazed by ciliates and amoebae. Selection may have favored the ability to change morphotype in response to variable environments.

## Through the microbial looking glass: how microbiomes act as mediators of animal biology

*Kevin Kohl*

Over the past decades, there has been a particular expansion in our understanding of the variable and intricate ways in which microbes can influence animal biology. Animal species may display variable reliance on their microbiome, with herbivores relying more heavily on these communities for nutritional needs than carnivores. Heritability of these communities may also vary across animal taxa, depending on birth strategy (live-birth or egg-laying) and the strength of parental care. Comparative approaches offer the power to recognize shared and distinct features of host-microbe interactions across vertebrate taxa to understand how the complexity of life has evolved over time. For example, mammals exhibit a pattern where the similarities of their microbiomes reflect the evolutionary history of the hosts, an eco-evolutionary trend known as 'phylosymbiosis'. However, these evolutionary trends are weak or absent in other taxa, such as birds and amphibians, where their microbiome is primarily structured by the environment. Despite being quite labile, these environmentally acquired microbes can still confer significant effects on host fitness. Enhanced sequencing approaches of these systems offer better insight into the microbial ecology and genetic mechanisms of these interactions, and have revealed new understanding, such as functional redundancy across communities. Moving forward, the field of comparative animal physiology should continue integrating the microbiome, with focus on functional implications of these communities to the physiology, ecology, and evolution of their hosts.

## Hydrodynamics of larval urchins: ontogenetic changes and tracer influence

*Katherine Kohn, Will Ballentine, Kit Yu Karen Chan*

Many marine plankters are suspension feeders, relying on efficient particle collection to survive in environments with low food concentrations. Understanding how suspension feeders collect food in dilute environments is crucial to understanding their physical form and ecological function. Echinoderms have a planktonic larval stage that uses ciliated bands for swimming and feeding. Using the pluteus of the urchin Lytechinus variegatus, we examined changes in larval hydrodynamics through ontogeny utilizing micro-Particle Image Velocimetry (µPIV). Additionally, we tested the effect of tracer type on larval velocity and flux by using the alga Isochrysis galbana and 6.62 µm polystyrene beads as tracers in independent trials. We observed Stokeslet-like flow around larvae, for which the streamline velocity increased as the larvae developed. We did not observe vortex arrays nor ciliary tangles as previously observed around larval seastars. The estimated flux towards the oral region of the larvae increased with age and using Isochrysis galbana as tracers led to higher flux estimates compared to polystyrene beads. Larvae in algal tracers were observed swimming in more convoluted paths compared to beads. Comparison between flux estimates and clearance rates can further shed light onto particle selection during feeding. Our work demonstrates an important caveat of µPIV: tracer type may influence larval behaviors. Mindful experimental design and reporting can further our understanding of the hydrodynamics of small ciliated swimmers, and ultimately larval form.

## From Roots to Rafts: Insights from the Biomimetic Simulations of Aquatic Worm Climbing - Part II

*Prathyusha Kokkoorakunnel Ramankutty, Harry Tuazon, Nicholas Correcha, Ivy Li, Saad Bhamla*

California blackworms (Lumbriculus variegatus), are flexible and elongated organisms capable of entangling with one another. These worms can spontaneously aggregate with each other, forming highly dense entangled worm blobs. They can interact with their environment in intricate ways that reveal essential aspects of their behavior and adaptation. For example, they exhibit climbing behavior when interacting with free-floating plants like duckweed in their vicinity. The dangling roots of the duckweed provide support for the maneuvering and climbing of the worms. Assembly of the duckweed and worms acts like a floating raft, enabling the worm to achieve faster collective locomotion. Drawing inspiration from this mechanism, we model the ensemble of worms and duckweed as a system of active and passive polymers, respectively. In our computational description, the worm is modelled as a flexible active polymer endowed with self-propulsion and a chiral head motion making them tangle with each other [1] and duckweed is modelled as a polymer with finite stiffness, anchored or free at one end of the polymer. We demonstrate that the stiffness of the passive polymer and strength of the activity of the polymer are deciding factors in the climbing behavior. We believe that our study, which explores the mechanisms behind worm locomotion and climbing behavior, is essential for advancing the design of bio-inspired robots that can mimic these mechanisms in diverse terrains.

## Scales of evolutionary integration in air-breathing fishes

*Matthew Kolmann, Abigail Radunz, Matt Friedman*

The degree to which adjacent anatomical structures are integrated (covary) or modular can influence how these traits evolve. At intraspecific scales, modularity and integration can act to coordinate morphological change in populations. The outcomes of these population-level processes can then be observed at the macroevolutionary scale as patterns of covariance among and within phenotypes. To what extent phenotypic scales of integration and modularity are preserved at the macroevolutionary level is contentious, as inherited patterns of evolutionary integration can be altered by more recent selection, like a written document being partially erased and then overwritten. Many anabantarian fishes have evolved large air-breathing organs that intrude on adjacent cranial and buccal spaces, which may have altered ancestral patterns of phenotypic integration in the skull and postcranial skeleton. We used two (one intraspecific, one interspecific) 2D radiographic datasets and geometric morphometrics to explore any links between intra- and interspecific patterns of integration in these fishes. First, we estimated the strength of integration within species of air-breathing fishes and their non air-breathing relatives. Then we contrasted intraspecific measures of phenotypic integration to patterns of integration at macroevolutionary scales. We find similar levels of integration and modularity among air-breathers and their non air-breathing relatives, as well as demonstrate that these patterns are shared across intraspecific and interspecific scales.This work was supported by the National Science Foundation awards DEB-2333683 and 2333684.

## A natural behavioral state that confers nociceptive tolerance in *Manduca sexta*

*Gayathri Kondakath, Annushka Veliko-Shapko, Isabel Messinger, Barry Trimmer*

Noxious (harmful) stimuli are detected by a specialized sensory system known as nociception. Nociceptive signals typically evoke defensive behaviors. While these behaviors can be sensitized by strong or repetitive stimuli, the mechanisms that suppress nociception remain unexplored. We observed a natural behavioral state that makes tobacco hornworms (Manduca sexta) less responsive to external stimuli. When gently disturbed, Manduca caterpillars 'freeze,' and stay motionless for extended periods. In this state they adopt a characteristic posture with their head and thorax curled ventrally to resemble the Sphinx. We characterized this "sphinx state" in fifth-instar larvae, showing that it can be triggered by mechanical stimuli and involves reduced responsiveness to noxious thermal stimuli, indicating nociceptive downregulation. Surgical experiments revealed that the brain is essential for larvae to enter the sphinx state but is not essential for nociceptive behaviors. Surprisingly, the sphinx state is more likely to occur in caterpillars that have been sensitized. The suggests that downregulation of nociception in response to ongoing repetitive stimuli may offer advantages that outweigh the risks of not responding. We plan to explore the neural substrates underlying the sphinx state and the mechanisms of nociceptive modulation. Overall, our findings highlight the behavioral flexibility in invertebrates, even in nociception, which has commonly been accepted as hard-wired and stereotyped.

## Skeletal muscle energy use: accounting for subject-specific neuromechanical contributions

*Ryan Konno, Glen Lichtwark, Taylor Dick*

Skeletal muscle is used in animal locomotion to convert chemical potential energy into usable mechanical work. However, as muscle shortens at faster rates, energetic cost increases due to inefficiencies in the contractile mechanisms. During these dynamic contractions, our understanding of the neural control and recruitment strategies is limited, thus reducing our ability to predict the energetic cost. This work develops a subject-specific mathematical model of muscle contraction to better investigate neuromechanical contributions to energetic cost. To ensure a controlled voluntary submaximal muscle contraction, data was collected on humans during fixed angle dorsiflexion contractions. High density electromyography, ultrasound, and indirect calorimetry were used to identify motor unit populations, muscle fascicle dynamics, and energetic costs, respectively. These data were then used to evaluate and inform the model. Our model was able to simulate the motor unit pool firing characteristics, predicted 85 to 92% of the experimentally measured muscle torque traces, and captured the trends in the experimentally measured energetic costs. Further, the model isolated individual motor unit level contributions to whole muscle energetic cost allowing for investigation of muscle recruitment properties. Experimentally measuring motor unit properties during dynamic contractions in vivo is difficult, but this work provides a predictive framework to explore how different neuromuscular properties influence energetic cost. Capturing subject-specific muscle properties helps improve our understanding of muscle recruitment strategies and energetic cost in vivo.

## Muscle architectural gearing dynamics during unconstrained locomotion

*Nicolai Konow, Chris Tijs, Samuel Delap, Andrew Biewener*

As pennate muscles contract, fascicle rotation contributes speed to muscle length-change. Within the architectural gearing framework (AGR = VMUS-

CLE/VFASCICLE), higher gears result from fascicle rotation at low loads, with lower gears occurring at high loads, where fascicle contraction generates more speed. Studies of muscle gearing typically use controlled ergometer conditions with constant load and velocity, leaving unclear how gearing influences unconstrained movement. Perhaps therefore, the importance of pennation in muscle function was recently questioned. We studied gearing dynamics using biplanar videofluoroscopy, activation, and force measurements from the unipennate and compartmentalized medial gastrocnemius in rats on a treadmill. Discovering a robust activation-force relationship across the nine gait (walk, trot, gallop) and slope (upslope, level, downslope) combinations enabled us to evaluate muscle gearing across gradients of load, gait, and mechanical (brake, strut, motor) function. We found gearing differences across stance, from negative to modestly positive during energy dissipation in early stance and greater positive values in late stance where the muscle delivered energy for propulsion. Overall, gearing correlated better with mechanical function across gaits than with load and slope. Incorporating tendon compliance in muscle velocity increased architectural gearing, and we discovered less pronounced gearing in the proximal compartment where pennation is less steep. Our results, although diverging from earlier ergometer measurements, demonstrate that pennation and gearing cannot be ignored when aiming to understand how muscles contract.

## Pursuit and evasion in aquatic systems

*Lars Koopmans, Benjamin Martin*

Pursuit and evasion dynamics are a universal phenomenon observed across terrestrial, aquatic, and aerial environments. Although aquatic animals are generally slower than their terrestrial and aerial counterparts, we predict that their interactions are the most dynamic and have outcomes likely to be sensitive to predators' capture radii and sensory-motor delay. To explore how these factors influence the outcomes of pursuit and evasion encounters, we developed a model based on the turning gambit, integrating biomechanical traits and sensory-motor delays to predict how prey can outmaneuver predators. We tested the model's predictions through a field study on coral reef fish where we employed stereo cameras to reconstruct the three-dimensional trajectories of predator attacks. Our findings reveal that the combination of predator sensory-motor delays and the prey's high maneuverability allows prey to successfully evade predators in the majority of cases.

## Investigating retinal dynamics & focal accommodation in jumping spiders through x-ray video imaging

*Deniz Korman, Olivia Harris, Jackson Michaels, Emma Alexander, Nathan Morehouse*

While vertebrates often possess the ability to dynamically focus their eyes via accommodation, this ability has not been observed in arthropods. We investigated whether jumping spiders are capable of accommodation not by changes to the lens as in vertebrates, but rather thanks to their complex retinal movements, in which eye-muscles specifically move the anterior median eye retinae independent of the lens. Previous ophthalmoscopy efforts in live jumping spiders have succeeded in imaging retinae and tracking gaze movements. However these studies have not provided insight into potential changes in the spatial arrangement of eye-elements related to focusing. To shed light on this matter, we conducted high-energy x-ray video imaging at Argonne National Laboratory to observe the eye-tubes of live Habronattus pyrrithrix as the animals performed a range of eye movements in response to visual stimuli. We then tracked key landmarks on the eye-tube to quantify retinal movements and changes to eye-tube dimensions. Our findings provide the first account of how jumping spider eye-tube movements result in dynamic changes to the optical dimensions of the eye. We find that these spiders do not maintain consistent distances between the retinae and the corneal lens elements, suggesting the possibility that retinal movements may serve a role not only in directing the field of vision of the animal, but also in providing accommodative capabilities.

## The effects the mode of delivery of microcystin-LR has on rusty crayfish behavior and morphology

*Jacqueline Kossey, Paul Moore*

Anthropogenic activities have negatively impacted the health of freshwater ecosystems worldwide, spawning numerous harmful algal bloom events. As blooms become more frequent, the presence of algal toxins, particularly microcystins, in water systems increase the potential harm to the natural ecosystem. Due to mixing of the water column and reworking of substrate by organisms, algal toxins undergo a cycle of deposition into sediment and resuspension into the water column. Crayfish rework benthic substrates and are therefore exposed to toxins in both the benthic and pelagic phase. Given the status as both a keystone species and ecosystem engineer, we strive to understand how the spatial dynamics of aquatic toxins alter their effect on crayfish. Crayfish were exposed to microcystin-LR located either in the water column or in the sediment in a closed system for four days. Subsequent to exposure, crayfish were placed in flow-through mesocosms to monitor alterations in foraging and bioturbation behaviors. Results show that the mechanism of delivery alters crayfish behavior which has implications for ecosystem services and functions.

## Genetic Architecture and Caste- and Sex-Specific Variation in Wing Shape of the Eastern Yellowjacket

*Jennifer Kovacs, Em Gosse, Rachel Hill, Kayla Murray, Sarah Orr, Michael Goodisman*

The Eastern Yellowjacket wasp (Vespula maculifrons) displays distinct morphological traits across different castes, making it an excellent model for investigating the genetic basis of phenotypic variation in social insects. This study examines wing shape variation across castes and sexes in V. maculifrons, building on previous work by Orr et al. (2024). We used geometric morphometrics to analyze wing shape in workers, gynes (reproductive queens), and males from 10 mature colonies. Forewing measurements were taken, and landmark-based analyses were conducted using the geomorphR package in R to quantify shape variation. Preliminary Principal Component Analysis (PCA) of workers and gynes from a subset of colonies revealed distinct clustering by colony and patriline, suggesting a genetic component to wing shape variation. We will present data from all ten colonies for gynes, workers, and males, including heritability estimates calculated using the animal model approach, which accounts for the haplodiploid genetic system of Hymenoptera. Additionally, we will compare coefficients of variation in wing traits and shapes across castes and sexes to assess phenotypic plasticity. This research aims to elucidate the genetic architecture of wing shape in V. maculifrons and contribute to our understanding of morphological evolution in social insects.

## Is bigger better? a comparison of eDNA extraction methods for marine sediments

*Berit Kramer, Jessica Zehnpfennig, Holly Sweat, Christopher Meyer*

Environmental DNA (eDNA) analysis has become a powerful tool to monitor biodiversity in marine aquatic ecosystems. A critical step in eDNA analysis is the extraction of DNA from environmental samples. The choice of extraction method can significantly influence the quality and quantity of the DNA obtained. This study compares the effectiveness of multiple eDNA extraction methods for benthic soil samples: The DNeasy PowerMax Soil Kit and DNEasy PowerSoil Pro Kit in terms of DNA yield, purity, and downstream amplification success. While the PowerMax Soil Kit processes larger sediment volumes, it is far more costly than the PowerSoil Pro Kit. We applied multiple methods to marine sediment samples collected from the Indian River Lagoon, a subtropical estuary located on Florida's east coast. We evaluated the time, cost, sensitivity and ease of use associated with each method to provide a comprehensive comparison between the two kits. Here we present our findings, highlighting the advantages and limitations of each eDNA extraction method for marine sediments and offer recommendations for selecting the most suitable and affordable method for future eDNA studies.

## Comparative hydrodynamics of the shells of aquatic, semi-aquatic and terrestrial turtles

*David Kramer, Frank Fish, Rebecca Bottiglio-Kramer*

The reptilian order Testudines includes species that are fully aquatic, fully terrestrial, and transitional. As a result of evolution associated with the degree of aquatic to terrestrial adaptation, there is a large diversity of shell shape within this group. For freshwater and marine species, emphasis is placed upon streamlining the body to improve hydrodynamics. Hydrodynamic efficiency for a given flow can be measured as the ratio between the amount of lift and drag produced. To examine the influence of shell shape, 3D models of eight different testudines were tested with a six-axis force transducer in a water tunnel at Reynolds number of 140,000. Shells were positioned every $2^\circ$ at angles ranging from - $16^\circ$ to + $16^\circ$. The extremes of shell shapes were exemplified by the streamlined, fusiform shell of the green sea turtle (Chelonia mydas), and the high-arching, rounded shell of the Galápagos tortoise (Chelonoidis niger). Although lift between C. mydas and C. niger remained relatively similar, drag was 68.8% greater in C. niger. This resulted in a L/D ratio that was 73.7% greater in C. mydas, representing greater hydrodynamic efficiency. Additional species (marine, freshwater, and terrestrial turtles) represented shell shapes that yielded intermediate results. By examining the performance of a wide range of shapes, different patterns can be recognized and recreated in bioinspired robotic systems to produce the most hydrodynamically efficient morphology.

## Comparing 2023 and 2024 intertidal monitoring surveys conducted on Yellow Island

*Noah Krebs, Christine Mantegna, Tiara Moore, Camille Gaynus*

The Yellow Island Intertidal Monitoring Program, initiated in 2022, is attempting to address the historical data gap in intertidal ecosystem assessments for Yellow Island, a small island in the San Juan Island archipelago. Our aim is to assess and compare the first two full seasons of data collection to create a benchmark for species inventory and composition at Yellow Island. The intertidal ecosystem of Yellow Island serves as a vital ecological measuring stick for the broader Salish Sea, which faces pressure from many stressors brought about by climate change, such as marine heatwaves, pollution, and an increase in human activity. By utilizing quadrat and transect methods, we conducted comprehensive summer surveys to inventory algal and marine invertebrate species. Statistical analyses in R were utilized to assess species richness and diversity across the island. This analysis aims to establish baseline requirements for intertidal ecosystem health and also evaluate changes in community composition to inform coastal management on other islands in the archipelago. Performing a thorough side by side comparison of the 2023 and 2024 data sets allows us to better understand the intertidal ecosystems year to year dynamics, while also contributing to the improvement of data collection techniques. The findings will also further inform future management efforts, ensuring the proper allocation of resources to address the escalating ecological and anthropogenic stressors facing the Salish Sea.

## The effect of coastal armoring on loggerhead sea turtle nesting success in the Gulf of Mexico

*Sarah Krieger, Jake Lasala, Melissa Macksey*

Coastal armoring are man-made structures that are implemented on beaches to protect inland development from erosion and storm damage. However, these structures can greatly impact sea turtles by restricting the physical space available for nesting. This project compared loggerhead (Caretta caretta) nesting numbers from 2014-2023 on a high density beach in Sarasota County, Florida to determine which armoring types had the greatest impact on nesting success. Additional models were run to identify if beach width, nest density, nest placement north to south, and armoring impacted hatch/emergence succes. Nest density and nesting success were impacted by the presence of coastal armoring, and stepped revetments had the highest impact on nesting success. Nesting success was also significantly impacted by beach width, and nesting success was greatest on beaches that were at least 30 m wide. Nest placement north to south had a significant impact on nesting success and hatch/emergence success as well. Interestingly, beach width had no significant impact on hatch/emergence success. The effect of coastal armoring on Gulf of Mexico loggerhead nesting success will be discussed.

## A comparative analysis of Meissner corpuscle density and size in primate digital pads

*Pranav Krish, Jonathan Shadan, Laury Arazi, Ashley Choi, Avarie Rembert, Alana DiMartino, Michael Deutsch, Connor McDowell, Christine Lee, Gabby Guilhon, Michael Granatosky, Edwin Dickinson*

The mechanosensory capabilities of primate hands represent a key evolutionary innovation that facilitated the order's diversification and eventual tool-making abilities. Despite this importance, comparative studies on primate autopodial mechanosensory distributions remain limited. Our objectives were to assess variation in Meissner corpuscle density and size within the hands and feet of forty primate species and their closest relatives to explore intra-individual anatomical variation, and examine the influence of ecomorphological and evolutionary variables on somatosensory anatomy. Volar skin samples were collected and analyzed using histological techniques to quantify Meissner corpuscle density and size. Ecomorphological analyses explored correlations between mechanoreceptor distribution, body mass, and foraging strategies across species. All species, including closest non-primate relatives treeshrews and colugos, showed the presence of Meissner corpuscles in both hands and feet. Such data refutes long-held beliefs that primates are unique in having Meissner corpuscles. Across species, the size, but not density, of these corpuscles was positively correlated with body mass. Our analyses indicated that laterality and digit number did not influence the density or size of Meissner corpuscles. Across specimens, Meissner corpuscles tended to be larger and denser in the hands than in the feet, with the highest density and size observed in frugivorous species. This supports the hypothesis that foraging strategy is a strong predictor of Meissner corpuscle density and size, aiding in the tactile discrimination of ripe fruit.

## Temporal integration of acoustic information for mate choice decision making in Cope's gray treefrog

*Jain Krishnan, Michael Reichert*

Temporal integration of sensory information allows animals to collect and process various sensory inputs to reach specific decision-making thresholds. Acoustic signals with repetitive subunits are often integrated over time with a weight assigned to each signal element according to its temporal order. Female Cope's gray treefrogs (Hyla chrysoscelis) find their potential mating partners by assessing the signal quality of the male frog's advertisement call. In this study, we manipulated the signal quality by combining the call elements (pulses) of Hyla chrysoscelis with those of a closely related sister species, the Easter gray treefrog (Hyla versicolor). We conducted phonotaxis trials to test the response time of female frogs to varying proportions of conspecific and heterospecific pulse numbers. Additionally, we examined how the temporal order of pulses influences decision-making by comparing the response time to calls with conspecific and heterospecific pulses presented either at the onset or offset of each stimulus. We found that the female frogs prefer calls with more conspecific pulses. The study gives insights into the temporal integration process associated with the mate choice decision-making in Cope's gray treefrogs.

## Tadpole development under different exposure routes of TCDD

*Camryn Kritzell, Raquel Salla, Molly Albecker*

Globally, amphibian populations are declining due in part to degrading environmental quality. Chemical pollutants, such as 2,3,7,8 tetrachlordibenzo-p-dioxin (TCDD), are an important and persistent presence in wetlands that can lower the quality of the habitat. TCDD, for instance, is a toxic thyroid hormone disruptor that has effects on development, endocrine systems, and survival of vertebrates. TCDD is found in trace amounts in wetlands around the globe, and one of the primary exposure methods identified has been through food exposure. However, many previous amphibian studies utilize only a waterborne exposure route. It is unknown whether the exposure route (through water or diet) affects developmental outcomes. To determine the effect of exposure route on amphibian development, we exposed Incilius nebulifer tadpoles to five concentrations (0.001, 0.01, 0.1, 1, 10 μg/L) of TCDD using either food- or waterborne exposure. Survival, development, and size was tracked throughout the larval stage, and we subsampled for physiological assays. Our results suggest that exposure route has an effect on tadpole growth rates, development, and physiology indicating that mode of exposure may affect outcomes to environmental degradation in amphibians.

## Island hopping with blind lizards: a multilocus phylogeographic study of *Dibamus*

*Isaac Krone, Benjamin Karin, Jimmy Mcguire*

Dibamid lizards (family Dibamidae) are one of the most poorly-studied families of squamates. Their fossorial habits make these nearly-eyeless, nearly-limbless lizards difficult to find and observe, resulting in an almost complete lack of literature on their ecology and severe under-representaiton in museum collections. Here, I present the preliminary results of a multilocus phylogeny of Dibamidae using more than 300 genes including RELEC (Rapidly-Evolving Long Exon Capture) and traditional markers. I focus on the interrelationships and phylogeography of the putative "peninsular-island" clade of Dibamus found from Peninsular Malaysia through Wallacea to Western Papua (Townsend et al. 2011). This group contains both island microendemic (e.g. Dibamus seramensis) and extremely widespread species (e.g. D. novaeguineae, D. taylori). Our study reveals significant and underappreciated species-level diversity in Dibamus, calls into question the currently used species concepts for the genus, and suggests an idiosyncratic diversification history in this overlooked fossorial lizard.

## Comparative anatomy of catfish venom glands

*Stephanie Krueger, Mark Terasaki, Andrew Gillis*

Venom is an adaptation that has evolved independently many times across animal lineages. In teleost fishes, venom systems generally consist of glands or cells that produce and store toxins coupled with fin spines that deliver venom into predators or prey. Catfishes (Order: Siluriformes) offer a unique opportunity to investigate the convergent evolution of venom within teleosts. Siluriformes contains half of all venomous teleosts, with venom having evolved 2-3 times independently within the group. Using histology and electron microscopy in two catfish models, we compare the tissue- and cellular-level features of venom glands in the convergent venom systems of the bronze cory catfish (Corydoras aeneus) and the yellow bullhead catfish (Ameiurus natalis). We find that both species possess enlarged, morphologically distinct venom gland cells (VGCs) surrounding their dorsal and pectoral fin spines. The cytoplasm of VGCs in A. natalis is highly granular (likely reflecting abundant secretory granules) and is reminiscent of VGC architecture of other venomous vertebrates. The VGCs of C. aeneus appear less granular, instead containing a unique subcellular structure whose role in venom production/storage is still unclear. Going forward, we are using comparative transcriptomics and studies of venom gland development to resolve the relationships between catfish VGCs and other epidermal and/or neurosecretory cell types. This will allow us to test for convergence in venom evolution at multiple levels of biological organization.

## BCEENET: Bringing digitized natural history collections CUREs into ecology and evolution courses

*Janice Krumm, Elizabeth Shea, Cecily Bronson, Carly Jordan*

Supporting the development and implementation of Course-based Undergraduate Research Experiences (CUREs) in ecology and evolution can be an important step in increasing equity in undergraduate research opportunities. Incorporating research directly into undergraduate coursework has been shown to reduce barriers to participation, such as time and financial limitations. Biological Collections in Ecology and Evolution Network (BCEENET) is a community of collections professionals, undergraduate educators, researchers, and data experts committed to increasing equity in undergraduate research experiences through CUREs. In this presentation, we present four inclusive CUREs created by the BCEENET community using digitized natural history collections data, a unique and growing resource that can help to expand opportunities for research in ecology and evolution. BCEENET CUREs have been implemented at 44 institutions, including 9 2-year institutions and 13 minority serving institutions in online, hybrid, and in-person formats, engaging over 3800 undergraduates in research experiences. We also discuss network development, support and resources for new BCEENET CURE implementers, and opportunities to collaborate in materials development and assessment activities.

## ShK sequence diversity and gene expression profiles across clownfish hosting sea anemones

*Sofiia Kuklina, Jason Macrander, Coral Tolman, Wyatt Rudd*

Neurotoxins play a crucial role in the self-defense and prey capture mechanisms of sea anemones. Sea anemones, with their diverse symbionts, present a unique avenue for animal-derived pharmaceuticals. Clownfish, which host sea anemones, are of particular interest due to their mutualistic relationship, offering protection against predators while receiving essential nutrients. Although they could be impacted by these ion channel targeting toxins, little is known about the co-evolution of neurotoxins and gene regulation during symbiotic interactions. ShK, originally identified in the Caribbean sea anemone Stichodactyla helianthus, inhibits voltage-gated potassium ion channels during prey interactions. Synthetic derivatives have since been developed for human pharmaceutical trials targeting autoimmune diseases. Exploring the role clownfish hosting may play in expanding pharmaceutical applications of ShK-like neurotoxins is promising in treating autoimmune and similar diseases. To address this, we conducted clownfish association experiments and quantified gene expression changes and overall diversity of ShK-like genes. Additionally, we screen transcriptomic datasets from over a dozen different sea anemone species. Our analysis identified 216 ShK-like toxin candidates with conserved cysteine backbones. Upon closer examination of the clownfish hosting species, only one toxin candidate (She_D378_c0_g1i2) had a reduction in its expression level following symbiont association. These results provide some insight into ShK toxin analogs and prompts the necessity for further exploration to use these organisms in the development of marine derived therapeutics.

## How springtails survive collisions with raindrops

*Sunny Kumar, Pranavamathi Kumaran, Saad Bhamla*

During rainy sessions, we typically seek shelter under a roof at home, but how do tiny organisms manage to survive the downpour? Our research investigates how raindrop collision in stagnant water affects jumping soil-based hexapod Fosomia candida springtails. Using a high-speed camera, we observe that the outcomes of collisions depend on factors like raindrop size, springtail morphology, and organism size. When hit by a drop, springtails can be propelled up to $\sim$150 times their body length into the air, spinning and tumbling. Our finding indicates that springtails often attach to a thin liquid sheet (crown formation after 20 ms) by the drops' impact, where springtails remained intact, but few remained in the crater. Subsequently, a Worthington jet evolves, propelling a few springtails into the air and allowing them to spin until they re-enter the water surface. We also explore the possibility of springtails triggering Raleigh Plateau instability, which occurs with the elongation of the Worthington jet and the formation of satellite drops. By combining experimental observations with theoretical analysis (using dimensionless numbers), this research enhances our hydrodynamic understanding of viscous and surface tension forces on tiny organisms. We gain insight into the kinematics of tiny organisms being vaulted by the external stimulus of a water drop.

## Detailed description and anatomical comparison of Neornithes quadrate morphology

*Pei-Chen Kuo, Roger Benson, Daniel Field*

In birds, the quadrate bone serves as a hinge articulating with the lower jaw and the skull, and it plays an important role in cranial kinesis. However, the complex morphology of the bird quadrate has led to a range of different terminologies describing the same anatomical structures and character states, impeding clarity of communication to progress in understanding of the evolution of functional morphology of the avian feeding apparatus. Here, we propose a stable nomenclature system on bird quadrates with a clearly labelled anatomical atlas for future work and investigate macroevolutionary patterns in avian quadrate morphology and make comparisons among crown birds and their extinct relatives. We find that the changes of some characters may have clear biomechanical consequences such as the shift in the position of the otic process in Galliformes (landfowl), and transferal of the subcapitular tubercle from the otic process to the quadrate body in Sphenisciformes (penguins). Furthermore, this investigation of quadrate morphology in extant birds renews questions regarding the unsettled phylogenetic relationships within extant groups such as Strisores and Psittacopasseres. This work provides a clearly labelled nomenclatural system and a detailed morphological description of bird quadrates across the avian crown group, which may help resolve the phylogenetic position of key bird fossils and improve our understanding of functional changes related to cranial kinesis throughout avian evolutionary history.

## Sticking the landing: unraveling mechanisms of proprioceptive feedback in flying insects

*Tse Wei Kuo, Sweta Agrawal*

Successful landing is arguably the most important step of flight. When landing, flying animals must quickly and precisely coordinate multiple limbs to transition to a stable standing posture, often on surfaces varying in stability and orientation. Proprioceptive sensory neurons on the legs signal surface contact and the distribution of load across the legs. These neurons are therefore likely key to coordinating successful landings, but have yet to be studied.

We developed a novel behavioral assay to study how proprioceptive feedback coordinates limb movements during landing using the fruit fly, Drosophila melanogaster. We simulated landing by elevating a platform to contact different leg joints of tethered, flying flies. We then tracked the 3D kinematics of the animal's leg joints and wings to determine how mechanical perturbation of the legs influences landing. Additionally, we genetically perturbed the activity of different subsets of sensory neurons to determine which proprioceptive sensory neurons mediate this behavior.

We observed that landing consists of several subbehaviors, including rhythmic searching leg movements, flight cessation, and wing folding. Contacting the distal tibia-tarsus leg joint is more likely to trigger landing with a lower latency compared to contact of the more proximal coxa-trochanter joint. Additionally, we observed distinct leg coordination patterns that depend on which leg was contacted. Altogether, these experiments will provide novel insights into how proprioceptive feedback rapidly coordinates ethologically important behaviors.

## Morphological variation among urban and rural populations of wild house mice

*Stephen Kupchella, Anne Kort, Megan Phifer-Rixey*

Urbanization represents a significant and ongoing transformation of natural ecosystems driven by anthropogenic activity. Urban environments often introduce a suite of new selective pressures, such as altered food resources and extreme microclimates, with potential to affect phenotypic evolution. While recent work has highlighted the ability of some taxa to readily adjust to these urban stressors, our understanding of how urban areas shape the evolutionary trajectories of wild populations is still developing. Here, we compare populations of wild house mice (Mus musculus domesticus) from urban and rural areas in three major cities (New York City, NY., Philadelphia, PA., and Richmond, VA.) to investigate potential morphological responses to urbanization. First, we investigated variation in a variety of traits including body size, femur length, and organ weight. Second, we asked whether there are differences among habitats in aspects of the cranial skeleton. Mouse skulls were imaged using micro-computed tomography, and geometric morphometric techniques were applied to quantify and assess variation. Preliminary results suggest that there is morphological variation among urban and rural environments. Future work will expand on these results, integrating whole genome resequencing data.

## Plant-pollinator interactions influence pathogenic disease transmission in bumblebees

*Emelia Kusi, Lynn Adler*

Plant-pollinator interactions risk pathogen transmission as pollinators may acquire or deposit pathogens on floral surfaces, with differences in floral morphology potentially influencing this transmission potential. To examine the effect of interspecific variation in floral morphology on pathogen transmission among pollinators, we conducted an experiment using the bumblebee, Bombus impatiens, its prevalent trypanosome gut pathogen, Crithidia bombi and 15 morphologically different native plant species. Our findings reveal plant species-specific differences in both the frequency of pathogen deposition by B. impatiens on plant tissues and the environmental persistence of C. bombi, mediated by floral morphological traits. These insights highlight an overlooked dimension of plant-pollinator interactions and suggest that floral morphology can shape landscape-level pathogen transmission dynamics in bumblebee populations. Integrating these mechanisms into predictive models will enhance our understanding of pollinator disease epidemiology and inform the choice of plant that promotes pollinator health.

## The diversity of butterfly flower color preferences in the Ozark ecoregion

*Dmitry Kutcherov, Erica Westerman*

Flowers are visited by a wide diversity of pollinators, each with their own preference for color, scent, and shape. However, our understanding of these flower preferences within and between taxonomic groups of pollinators is relatively fragmentary due to limitations of laboratory experiments and field surveys. Here, we made use of the recent surge in photographic observations collected by community scientists on platforms such as iNaturalist. We measured the color of flowers visited by butterflies in over 10,000 photographs taken in 2005–2024 in the southwestern Ozark Plateau of the United States, spanning parts of Arkansas, Oklahoma, Kansas, and Missouri. We plotted the colors of these flowers in red-green-blue space and analyzed flower visitation patterns across taxonomic group. We found that, based on flower color span, the pollinators formed a continuum along a generalist-specialist axis. For example, monarchs, fritillaries, and swallowtails visited flowers of nearly all human-perceived hues. The flower color repertoire was more restricted in blues and crescents, which were rare visitors of purple flowers, and narrow in many pierids, which were seen to visit flowers in the white, purple, or red area of the color space. These results highlight the diversity of flowers that attract different groups of butterflies, and provide a base for future tests of variance in visual or neurological physiology which may shape pollinator preferences.

## Feeding affects trait integration across the skeleton of a South American cichlid

*Alexandra Kwiatkowski, Michelle Gilbert, Craig Albertson, Thomas Stewart*

Trait covariation studies are a major focus in evolutionary biology, but recently have researchers begun testing the effects of developmental plasticity on trait covariation. It is, therefore, unclear which integration patterns are genetically determined and which might reflect plasticity. The Amazonian cichlid Satanoperca displays the unique behavior of winnowing, sifting mouthfuls of sediment to capture food. In a previous study, Satanoperca were raised feeding on different substrates, and several craniofacial elements were found to be plastic. Here, we analyze integration of a suite of skeletal traits across body of Satanoperca and show integration patterns across the body reflect plasticity. Using geometric morphometrics, we analyzed the shapes of numerous structures, including the supraoccipital crest, vertebral column, cleithrium, and all fins. Tests of integration reveal that treatments can differ in the structures that are integrated with one another. For example, different patterns of covariation between the supraoccipital crest and cleithrum are observed between treatments, as well as whether the dorsal and anal fins are integrated with one another. These results suggest that the experimental treatment caused distinct swimming behaviors that had widespread effects across the body. These data reveal functional relationships among the anatomical systems and show that plasticity can determine whether fins are integrated. Discovering how different environments affect trait covariation is important for predictions of how anthropogenic disturbances will affect the evolution of wild populations.

## Affiliative behavior and adaptation: the link between primate incisor form and grooming activity

*Darrell La, Savannah Cobb*

Affiliative behavior is an important social interaction in many fauna groups, particularly primates. In primates, grooming behavior is known to be crucial for maintaining monogamous pair-bonding, reducing stress, as well as facilitating cooperative relationships. The functional morphology of the toothcomb as an adaptation for grooming is widely known in prosimians, which include tarsiers and lemurs. However, not much is known regarding the link between incisor form and sociality for anthropoid primates, the group including monkeys and apes.

In this study, we investigate the relationship between lower incisor morphology and grooming activity budget (GAB), a quantitative indicator of the amount of time species spends grooming daily, in crown anthropoid primates. Using a dataset comprising 34 species spanning all major genera, we measured scaled buccolingual breadth and mesiodistal width of central incisors (I1) on cast mandibles sampled from museum collections. Our mixed-effects model found that both I1 breadth and width have a weak but significant positive correlation with GAB that is independent of phylogeny and diet. Implications for fossil platyrrhines including Antillothrix, Caipora, and Soriacebus are discussed in the context of this relationship.

These findings establish a novel connection between primate socioecology and incisor morphology beyond that already known for prosimians and, furthermore, may contribute to a deeper understanding of primate ancestral conditions by enabling more detailed ecological reconstructions in fossil lineages.

## Leaf-cutter ants vary cutting technique to deal with variable mechanical constraints

*David Labonte, Mia Yap, Victor Kang, Frederik Puffel*

Leaf-cutter ants cut fragments from fresh leaves to grow a symbiotic fungus as crop. During cutting, one mandible is typically anchored onto the leaf lamina; the other slices through it like a knife. When initiating cuts into the leaf edge, however, foragers sometimes deviate from this behaviour, and instead cut by drawing both mandibles together symmetrically, akin to a pair of scissors. Via in-vivo behavioural assays, we found that the behavioural preference for either of the two cutting strategies was not random but depended on the geometry of the leaf edge. Natural leaf margins may be straight or serrated with notch-like folds of variable wedge angles. Leaf-cutter ants displayed a strong preference for scissor-cutting when leaf edges were straight or had large notch angles. This preference, however, reversed in favour of knife-cutting when leaf edges had narrow notches. To investigate whether this behavioural difference had a mechanical origin, we mimicked knife-cutting in ex-vivo cutting experiments: when notches were wide, all but the sharpest mandibles failed to initiate cuts, or only did so at large forces, and with substantial leaf buckling and bending. This increased force demand would substantially limit the ability of foragers to cut leaves, and so reduce the colony's access to food sources. Scissor-cutting may thus be an adaptation to the mechanical difficulties associated with the cutting of thin leaves and flower petals.

## Sex-Specific Changes in Immune Function in Reptiles

*Valeria Lacroix, Anne Bronikowski, Jamie Marks, Alex Sills, Tony Gamble, Ryan Cook*

Aging is a progressive decline in normal physical and biochemical functions in living organisms. Sex specific differences in aging may exist and impact longevity, fertility, and mortality. Additionally, these differences could change depending on the species. One age-related phenomenon is 'inflamm-aging' (inflammatory response increasing with age) which can have sex-specific trends. However, there is a huge gap in our knowledge regarding age and sex-related changes in immune function across diverse species such as reptiles. We examined a metric of inflammation across a wide range of age classes in reptiles by measuring Heterophil:Lymphocyte (H:L) ratios. Heterophils are associated with inflammation and infections, while lymphocytes regulate immune responses. Therefore, we tested sex and age differences in H:L ratios in Mediterranean House Geckos (Hemidactylus turcicus) and Painted turtles (Chrysemys picta). These species have different modes of sex determination, which could influence components of age-related immune function. Turtles have temperature dependent sex determination (TSD), while geckos have chromosomal sex determination. Although we did not find a significant effect of age on H:L ratios in either species, sex significantly affected this ratio in both species in different ways. Male turtles had higher H:L ratios than females, while female geckos had higher H:L ratios. These results could mean that sex-determining mechanisms greatly impact immune function, but other mechanisms of aging may be more crucial to reptiles than changes in leukocyte ratios.

## The impact of maternal grey seal diet on reproductive energetics: a stable isotope investigation

*Annaleigh Laine, Cornelia den Heyer, Michelle Rivard, Damian Lidgard, Priyanka Varkey, Greg Breed, Michelle Shero, Seth Newsome, Jennifer Burns*

In capital breeders like the grey seal (Halichoerus grypus), foraging success pre-parturition determines reserves available to nursing pups and, by extension, mom and pup fitness. To assess maternal diet's influence on maternal condition and pup provisioning, we handled 33 grey seal mom-pup pairs from 2022-2024, measured their mass (kg) and body composition, and collected tissues to estimate diet with carbon and nitrogen stable isotope analysis ($\delta$13C, $\delta$15N). Females in 2024 were non-significantly lighter throughout lactation compared to 2022 and 2023 (mean±SE; 169.2±8.1, 178.1±11.1, 181±7.9kg, $p=0.398$). In contrast, pups' birth masses were similar across year (mean±SE; 22.2±0.5kg), but nursing pup growth rates (kg/day) were lower in 2024 than in 2022 and 2023 (mean±SE; 1.5±0.1, 1.8±0.1, 1.7±0.1kg/day, $p=0.122$) and, therefore, pups were weaned 7% lighter. We hypothesize cooler than recent Scotian Shelf bottom water temperatures pre-parturition caused a shift in 2024 maternal diet, altering pup provisioning. Thus, we will characterize maternal diet pre-parturition by comparing whisker and potential prey $\delta$13C and $\delta$15N values, and using a combination of spatial metrics and Bayesian mixing models to quantify dietary variation and composition. This will enable us to distinguish whether females in 2024 consumed more low-fat (e.g., hake) than high-fat (e.g., sandlance) prey compared with earlier years, or if trophic niche remained consistent and biomass consumption decreased. Individual and across-year variability in pup provisioning likely has implications for postweaning survival.

## Effects of limb cycle speed on stability during quadrupedal arboreal locomotion

*Andrew Lammers, Catherine Cornelius, Grace Schepelmann*

Locomotion on narrow branches presents challenges that make falling more likely. Quadrupedal mammals traveling on arboreal supports augment stability via many behavioral traits. However the effects of movement itself contributing to stability is rarely examined. We examine the effects of limb cycle speed on stability. Seven laboratory rats ran on a "rope-mill" (arboreal treadmill). The device simulated locomotion at 28, 45, and 57 cm/s. From footage from two 210Hz cameras, we selected 15 consecutive strides, and measured duty factors of the right-side limbs. We digitized skin markers overlying the glenohumeral joint, hip joint, and distal hands and feet. From these digitized coordinates, we calculated the effective limb length throughout the strides. These kinematic variables are ways that animals can augment static stability – presumably if an individual shows decreased static stability at a particular speed, the movement of the limb might be contributing to stability via some dynamic means. Preliminary data show that effective limb length is longer at the slow and fast speeds compared with the middle-range speed. The shorter limb length at middle speed suggests crouching and lack of stability. However, duty factor vs. speed residuals showed the opposite pattern, where the middle speed had the lowest duty factor, suggesting more stability at that speed. With a completed dataset, we hope to determine if the speed of limb rotations impacts stability.

## Squishy and crunchy invaders: a comparison of qPCR vs metabarcoding based detection

*Emily Lancaster, Kai Watkins, Markus Frederich*

Monitoring invasive species in coastal ecosystems is essential due to threats from rising sea levels, warming waters, and other human-induced stressors impacting native biodiversity. Environmental DNA (eDNA) has become a valuable tool for early detection of invasive species, offering lower cost and ecological impact compared to traditional methods. Detecting eDNA by quantitative PCR (qPCR) or metabarcoding, each have unique strengths: qPCR excels in species-specific detection and quantification, and reduces the risk of primer-bias, while metabarcoding provides a broader view of community diversity and can be applied to various questions. In our study, we compared the detection of invasive invertebrates by metabarcoding and qPCR for in the intertidal zone in Biddeford Pool, Maine, and compared these findings with visual abundances. We examined a range of invertebrates with different levels of exposure of soft tissue to the environment, from "squishy" species like tunicates, to "crunchy" species with exoskeletons or shells, such as crabs. Quantitative PCR effectively followed seasonal changes in abundance for many squishy species, while metabarcoding reliably identified all invasive species and demonstrated quantitative capabilities for some squishy species. Additionally, metabarcoding successfully detected species challenging to detect with qPCR. Both methods provided valuable and complementary insights into invasive species ecology. For long-term monitoring, the optimal method is dependent on the species bauplan, as eDNA shedding and/or detection differs between squishy and crunchy species.

## Evaluating Ant Biodiversity Along an Urban Gradient: Insights for Conservation from New York City Green Spaces

*Sophia Lande*

As urban habitats expand around the globe, it is increasingly important to understand how green spaces function within cities. These spaces are host to complex, understudied ecosystems that contain a variety of uniquely adapted species. It is critical to understand what factors impact biodiversity distribution across all types of urban habitat. Ants are ideal models for this purpose, due to their status as ecosystem engineers, sensitivity to small changes, and widespread presence. I sought to investigate how ant biodiversity varies along a fine-scale urban gradient from medians to parks in Manhattan and Brooklyn, sampling communities on 40 sites. These two boroughs represent a novel geographic comparison, helping to clarify existing contradicting urban ant biodiversity patterns. I found that species richness significantly declined from parks to medians, a pattern shared across boroughs. Anthropogenic variables were always negatively correlated with species richness, as opposed to environmental variables having mixed relationships, suggesting that human impacts are more consistent predictors of ant species richness than environmental characteristics. These results demonstrate that increasing levels of urbanization may decrease the quality and ecological function of green spaces, and illuminate specific median design characteristics to promote ant diversity. Similarities between the boroughs suggest that patterns of ant diversity operate at larger metropolitan scales as opposed to smaller neighborhood scales, encouraging a unified approach to urban conservation management across all city stakeholders.

## Improving with age? The influence of age on testosterone and parental behavior in a wild songbird

*Samuel Lane, Bethany Bespoyasny, Holland Galante, Jaxsyn Delorme, Timothy Greives, Britt Heidinger*

In many organisms, reproductive performance increases with age, but the mechanisms that underlie these effects are not well understood. One mechanism that may be important is testosterone, a highly conserved reproductive hormone that is often positively associated with mating behaviors and negatively associated with parental care. In a long-term, known-age population of male house sparrows (Passer domesticus) we examined how paternal care and reproductive performance (hatching and fledging success) change with age and how they were related to natural variation in testosterone levels. Additionally, we investigated the potential effects of an acute experimental elevation of testosterone on parental care behavior. We monitored parental care for 4 hours, 24 hours prior to treatment. We then captured and injected males with either gonadotropin releasing hormone (GnRH) (experimental birds), to induce a temporary, physiologically relevant increase in testosterone, or saline (controls). Blood samples were collected before and after injection to measure testosterone levels. The following day we recorded parental care for 4 hours, using a combination of video recordings and radio frequency identification. We predicted that older males would have lower testosterone, higher reproductive performance, and be less likely to show a decrease in parental behavior following injection than controls. This research will enhance our understanding of age-related changes in parental care behaviors and the results will be discussed within the context of life-history theory.In many organisms, reproductive performance increases with age, but the mechanisms that underlie these effects are not well understood. One mechanism that may be important is testosterone, a highly conserved reproductive hormone that is often positively associated with mating behaviors and negatively associated with parental care. In a long-term, known-age population of male house sparrows (Passer domesticus) we examined how

## Isolating stem cells via fluorescence activated cell sorting in the hydrozoan Hydractinia

*Zachary Lane, Christine Schnitzler*

The colonial hydroid Hydractinia is a cnidarian model organism. Recently, its genome and transcriptome have been sequenced and made publicly available. Hydractinia shows extensive regenerative capabilities throughout its lifetime. These feats of physiology are made possible by Hydractinia's pluripotent stem cell population. The presence of these pluripotent stem cells, paired with its knack for regeneration and amenability to laboratory conditions, makes Hydractinia a useful model for those interested in investigating the mechanisms that drive stem cell potency and regeneration in early-branching invertebrate taxa. Currently, we aim to develop expression-agnostic flow cytometry techniques that can be used to isolate Hydractinia's stem cells through fluorescence activated cell sorting (FACS). These techniques take advantage of the small differences in size, internal complexity, and fluorochrome affinity that exist between various cell types to optically discriminate between cells and then to physically separate specific cells of interest for further analysis. Commonly, immunofluorescence or fluorescent transgenic reporter animals have been used to sort cells according to their expression of specific genes, but new evidence suggests that Hydractinia's stem cells display complex gene expression making these techniques of limited use. We are working to create a method that can be used to isolate Hydractinia's stem cells without a dependency on their gene expression. If successful, this methodology could likely be used in other cnidarian systems and a number of other animal groups.

## Hummingbirds use compensatory eye movements to stabilize rotational and translational visual motion

*Anthony Lapsansky, Philipp Kreyenmeier, Miriam Spering, Douglas Wylie, Douglas Altshuler*

To maintain stable vision, behaving animals make compensatory eye movements in response to image slip, a reflex known as the optokinetic response (OKR). Although OKR has been studied in several avian species, eye movements during flight are expected to be minimal. This is because vertebrates with laterally placed eyes typically show weak OKR to nasal-to-temporal motion (NT), which simulates typical forward locomotion, compared to temporal-to-nasal motion (TN), which simulates atypical backward locomotion. This OKR asymmetry is also reflected in the pretectum, wherein neurons sensitive to global visual motion also exhibit a TN bias. Hummingbirds, however, stabilize visual motion in all directions through whole-body movements and are unique among vertebrates in that they lack a pretectal bias. We therefore predicted that OKR in hummingbirds would be symmetrical. We measured OKR in restrained hummingbirds by presenting gratings drifting across a range of speeds. OKR in hummingbirds was asymmetrical, though the direction of asymmetry varied with stimulus speed. Hummingbirds moved their eyes largely independent of one another. Consistent with weak eye-to-eye coupling, hummingbirds also exhibited disjunctive OKR to visual motion simulating forward and backward translation. This unexpected oculomotor behavior, previously unexplored in birds, suggests a potential role for compensatory eye movements during flight.

## Genetic Connectivity of Invasive Spotted Lanternfly Populations Across an Urbanization Gradient

*Nicolas Largotta, Brenna Levine*

The planet is experiencing unprecedented rates of change caused by humans. One type of anthropogenic change, urbanization, is rapidly transforming the landscape into a mosaic of rural, non-urban, and urban environments, with major implications for evolutionary processes. Variation in these processes among environments can impact invasive species range expansions, and by consequence, community and ecosystem structure and stability. Yet, we lack resolution regarding how evolutionary processes vary across the rural-urban gradient landscape and the consequences that this variation may have for the future range expansion of invasive species. To begin to address this gap, we used low-coverage whole genome resequencing of 95 invasive spotted lanternflies (Lycorma delicatula; a rapidly spreading invasive species of considerable concern in this USA) collected from sites of varying degrees of urbanization to evaluate how landscape type affects the genetic structure of this species. We identified over 500,000 SNPs present in $> 95\%$ of the samples. Subtle and complex genetic structure was present, with greater homogeneity apparent among the rural samples. We are currently identifying loci under selection in these varying environments to parse the effects of urbanization on the evolution of invasive potential.

## Speciation through Genetic Incompatibilities

*Olivia LaRochelle, Ricardo Azevedo*

This project develops a mechanistic model in Python to simulate reproductive isolation driven by the accumulation of genetic incompatibilities. Building on existing research, the model illustrates how reproductive isolation evolves over time as genetic differences between populations increase. The project aims to provide insights into the mechanisms of speciation and the role of genetic incompatibilities in fostering reproductive isolation. The model will be validated against empirical data and offer a framework for studying speciation dynamics in various taxa, including Drosophila and birds, for which hybridization data exists.

## How do flies get trapped? Identifying the genetic basis of trappability evolution in *D. melanogaster*

*Sophia LaRochelle, Julia Saltz, Lea Pollack*

Evolutionary traps are a type of maladaptive behavioral responses to novel, often human-induced rapid environmental changes. Apple cider vinegar traps are an evolutionary trap for Drosophila melanogaster: when traps are present it is deadly to be attracted to vinegar, but throughout flies prior evolutionary history vinegar indicates a food source. We artificially evolved populations of flies with either deadly traps, or sham control traps, and measured evolved gene expression differences in heads. Next, we assessed candidate genes that were differentially expressed between the four artificially evolved populations and four control populations. Of the 21 genes differentially expressed, we chose 3 to assess based on putative their role in stimulus responses: Obp8a, meep, pickpocket20. Using RNA interference knockdowns in neurons, we assessed whether knocking down a single candidate gene influenced fruit fly apple cider vinegar trap attraction. Our results provide insights into the molecular basis of evolutionary traps.

## Comparing the Honeydew Excretion Kinematics between Male and Female Spotted Lanternflies

*Kendall Larson, Nami Ha, Saad Bhamla*

Spotted lanternflies (Lycorma delicatula, SLFs) are insect species that feed on phloem sap rich in sugars and excrete sticky particle-laden honeydew droplets. Using high-speed imaging techniques, we previously found that female SLFs fling droplets at an ejection velocity of 1.5 m/s using a stylus to expel their viscous liquid waste. The microCT and SEM images show that male SLFs have different morphological characteristics from female SLFs, such as the stylus length scale, which would yield different honeydew ejection speeds and acceleration. Here, we compare the honeydew excretion kinematics between male and female SLFs using high-speed images. First, we compare the micro-CT and SEM images of male and female SLFs to quantify the average stylus length scales of male and female SLFs. We analyze the temporal variations in angular orientation of the male stylus upon droplet growth, spring loading, droplet ejection, and recovery. First and second time derivatives of the stylus angle show the maximum angular speed and acceleration of the stylus. This study will help to understand the fluid dynamics and biomechanics of droplet excretion by insects feeding on the phloem sap.

## The Social Costs of Chorusing Shape Call Morphologies and Call-Timing Mechanisms

*Luke Larter, Michael Ryan, Colby Cushing*

Many frogs and insects form dense choruses from which males call to attract females. Acoustic interference risks in crowded choruses select for male abilities to track fluctuations in the acoustic scene at the chorus, to place their calls into windows of relatively reduced interference. However, densities of callers vary widely in time and space resulting in varied acoustic fluctuation patterns, which necessitates calling strategies that are flexible across social environments. We investigated drivers of flexible interaction patterns in túngara frogs via automated playback. Túngara frog males alternate calls with rivals' calls in smaller choruses, but overlap rivals' calls in a stereotyped manner in larger choruses. We tested male responses to conspecific calls encountered at different delays relative to their own calls, and when preceded by silence versus preceded by several acoustic motifs characteristic of larger choruses (composed of overlapping and synchronous conspecific calls). Males seldom overlapped playback calls encountered at any delays relative to their own calls when they were preceded by silence. However, when playback calls were preceded by chorus motifs, the probability that males overlapped them increased substantially, especially when playback calls were encountered at later delays. Thus, male call-timing mechanisms are tuned to use emergent temporal and acoustic regularities predictably encountered in different social environments to trigger appropriate shifts in interaction patterns, allowing adaptive flexibility across social environments at low cognitive costs.

## Breeding sex ratio of prolific sea turtle nesters on the Gulf of Mexico

*Jake Lasala*

Although populations trend towards a 1:1 adult sex ratio over time, for some species of reptile environmental pressures during development can create downstream biases. For sea turtles, as temperatures increase globally, adult sex ratios will skew female. Unfortunately, we currently don't have a working estimate of how many adult males and females are contributing to our nesting populations. Many of our best estimates of population size derive from nest counts and capture-mark-recapture studies. But these methods a) don't address male numbers and b) are likely overestimating the number of females. Breeding sex ratio estimates from paternity studies could bridge the gap. Examining paternity from single nesters can provide a minimum model for a population, but due to sperm storage and depletion, assessment of repeat nesters allows for a more robust estimate of male contributions. Paternity was assessed on loggerhead (Caretta caretta) and green sea turtle (Chelonia mydas) nests on a growing Gulf of Mexico rookery from 2020-2024. We focused on repeat nesters within years and targeted prolific nesters over multiple years. This is the first assessment of breeding sex ratios on greens and the largest assessment of loggerheads in the Gulf of Mexico. Overall trends show that there are more males than expected, but that repeat and prolific nesters tend to be more monogamous, suggesting mate choice does occur.

## Hot parents in your area: Abiotic and social environment influence parental behavior

*Rikki Laser, Laura Lee, Alexander Ophir*

Variation in the thermal environment during offspring rearing influences parental behavior, which is important for offspring development. Although this has been explored in egg-laying species, few studies have investigated the impacts of thermal environment on mammalian parental care. Notably, lactation increases body temperature in mammals. Therefore, ambient temperature could affect lactating mothers differently than non-lactating fathers. Additionally, pairs of parents may be better able to adjust to ambient temperature than when parents are alone. Here, we use biparental prairie voles (Microtus ochrogaster) to examine the effects of acutely increasing ambient temperature on offspring-relevant parental behaviors (e.g., total contact time with offspring). We found that both mothers and fathers spent more time lying adjacently with pups and less time covering them in high ambient temperature. However, whereas fathers decreased total contact, mothers did not change their total contact with pups if the father was present. We also find that voles take turns parenting, but that fathers still decrease contact with pups more than mothers when in heated conditions. These results suggest maternal contact with pups is prioritized, but that both parents adjust behavior to the thermal environment. Additionally, because variation in parental behavior causes variation in offspring behavior, our study suggests that the interaction between abiotic and behavioral factors can serve as a putative mechanism to promote behavioral variation and phenotypic plasticity in mammals.

## Revisiting thermal gradient experiments: Effects of thermal heterogeneity on salamander behavior

*Julia Laterza Barbosa, Raissa Rainha, Martha Muñoz, Carlos A Navas*

Thermal gradient experiments are commonly used in ectothermic organisms in a variety of scientific inquiries. Often these experiments, performed in the laboratory, are used to infer the behavior of animals in the presence of microclimatic gradients in their environments in the absence of other variables. However, most ectotherms tend to be thermoconformers, so might not respond to thermal gradients by selecting and maintaining a narrow body temperature, not even under laboratory conditions. We tested whether the red-backed salamander (Plethodon cinereus) behaves differently when presented with a thermal gradient arena in comparison to a control arena lacking thermal variation. We found that salamanders respond to a thermal gradient, but their thermoregulatory behavior is limited to the avoidance of the hottest end of the gradient, and not a positive thermotaxis towards a specific temperature as assumed of a thermal "preference".

## Repeated evolutionary recruitment of dehalogenases in luminous brittle stars and octocorals

*Emily Lau, Todd Oakley*

Similar traits convergently evolve by following shared or distinct genetic pathways, patterns shaped by the interplay between function, mutation, and phylogenetic history. However, the factors driving these patterns remain poorly understood. Here, we provide functional evidence supporting a previously hypothesized shared biochemical mechanism for bioluminescence in brittle stars and octocorals and explore genetic processes that may have shaped this trait's repeated evolution. Bioluminescence evolved numerous times and is produced by the enzyme luciferase, which oxidizes the substrate luciferin. Many luminous organisms use the same type of luciferin, called coelenterazine, but convergently evolved luciferases by recruiting non-homologous genes, indicating that the evolution of coelenterazine-based bioluminescence has diverse genetic solutions and is often unrepeatable. Contrary to this pattern, our results demonstrate that octocorals and brittle stars may have repeatedly evolved luciferases by recruiting members of the same gene family, haloalkane dehalogenase. This gene family may have originated in metazoans via a horizontal transfer from bacteria to a cnidarian-bilaterian ancestor, with subsequent gene loss influencing the availability of this gene for evolutionary recruitment. This finding, combined with the numerous potential genetic pathways that can converge to produce coelenterazine-based bioluminescence, may explain why evolution often follows diverse genetic paths to evolving this trait. Our findings challenge assumptions about unpredictability in the evolution of bioluminescence and highlights how horizontal gene transfer and gene loss may shape the repeatability of evolution.

## The shark denticle multiverse: structure and hydrodynamic diversity

*George Lauder, Tess Avery, Jade Collins, Dakota Law, Molly Gabler-Smith*

The skin of sharks is composed of numerous individual denticles (scales) that cover the body surface. Although recent research has documented morphological diversity of shark denticles, ongoing examination of a diversity of species has uncovered a previously unknown extent of ontogenetic and interspecific variation in denticle morphology revealed by 3D imaging. But the function of this diversity is poorly understood. In order to better understand the relationship between denticle structure and hydrodynamic function, we used a custom flow tank and knife-edge plate to visualize water flow over small samples of shark skin from a variety of species compared to flow over a smooth control and biomimetic models. We used high-speed video and particle image velocimetry to visualize flow in the boundary layer, measured near-surface velocity profiles and calculated shear stress within the viscous sublayer to quantify skin friction. We used 3D profilometry to quantify the surface texture of each tested sample to allow correlation of surface texture characteristics with shear stress. Shark skin samples show altered shear stress compared to smooth controls and the shape of the near-surface velocity profile varies among species. Testing a variety of samples that differ in denticle morphology and orientation as well as 3D-printed denticles will help clarify the relationship between denticle morphology and hydrodynamic flow patterns.

## Temporal changes in DNA methylation over 115 years in introduced house sparrows

*Megan Ellesse Lauer, J. Dylan Maddox, Mark Ravinet, Kevin Kohl, Marty Martin, Aaron Schrey*

Introduced species present a unique opportunity to study the role epigenetic mechanisms play in an individual's response to stressors. The introduced house sparrow (Passer domesticus) has colonized most continents within the last 170 years. Evidence is growing that the exceptional success of the house sparrow as an introduced species has been facilitated by DNA methylation. In house sparrows, DNA methylation compensates for reduced genetic diversity and individuals from recently introduced locations have greater variance in, and lower amounts of, DNA methylation compared to native birds. Greater variance in DNA methylation allows individuals to fine-tune their responses to novel stressors. Introduced individuals also have the highest epigenetic potential, which provides greater ability to actualize epigenetic states. Here, we used whole genome enzymatic methyl-sequencing to determine how DNA methylation changes across 4 temporal samples spanning 1895 to 2012 from a single location using museum samples. We will identify genomic elements with differential DNA methylation over time. We hypothesize that birds collected closest in time to the initial introduction will exhibit the greatest variance in DNA methylation because they are actively responding to novel stressors. Our results will elucidate temporal changes in DNA methylation at a single base resolution and will suggest which changes are important in establishment of an introduced population.

## Unveiling the senses: inspiring young scientists through exploration of animal perception

*Ashley Lauraine, Kelly Ronald*

ExploreHope Educational Outreach at Hope College is an American Camps Association-accredited organization that has hosted summer science camps for K-12 students for 27 years. Within this framework, we created a new camp last summer, where 6-8th grade students explored the sensory abilities of the animal kingdom.

Campers learned about the more commonly known visual, auditory, and olfactory systems, as well as lesser-known abilities like proprioception, nociception, and electroreception.

The students had the opportunity to learn about these amazing abilities through eye dissections, working with live animals like termites and mice, and using technologies like specialized sound chambers that record ultrasonic vocalizations. The camp activities equipped participants to understand how animals make sense of their surrounding environments by piecing together the clues gathered by their collective senses. Ultimately, activities were framed from an evolutionary lens where students questioned the adaptive value of this collective umwelt. This immersive and educational experience has helped inspire a new generation of young scientists to explore the world around them in new ways.

## Natural Variation in Caenorhabditis elegans Hypoxia Tolerance in Somatic and Germline Tissues

*Caroline Laury, Rachel Magallon, Sarah Fausett*

Low oxygen (hypoxia) has detrimental effects on the tissues of aerobic organisms. Caenorhabditis elegans nematodes, because of their ecological niche, have an remarkable ability to withstand hypoxia and are even able to tolerate 24 hours of complete anoxia. We are, therefore, interested in the genetic and physiological mechanisms that nematodes use to support hypoxia tolerance. While previous work has uncovered many genetic mechanisms of hypoxia tolerance in C. elegans, these studies have been exclusively conducted in the lab reference strain N2, which may not be representative of C. elegans as a species. Furthermore, little work has been done to show how hypoxia impacts reproductive processes. We hypothesize that wild isolates of C. elegans, with their diversity of genetic variants, vary in both their somatic and germline tolerance to hypoxia. To test this hypothesis, we exposed populations of wild strains to hypoxic (0.1-0.3% $O_2$) and normoxic (room air) conditions at the young adult stage. After exposure we quantified survival and germline proliferative zone size as baseline measures of hypoxia tolerance. Preliminary results indicate that there are indeed differences, and this may be due to genetic differences in the wild strains. In future studies, we will select the strains with the greatest strain x environment effects to determine what the contributory variants are and how they interact with known mechanisms of hypoxia tolerance.

## The effect of physiological state on behavioral plasticity in zebra finches

*Elena Lawson, Angela Riley, Jennifer Grindstaff*

While behavioral plasticity is assumed to be tied to physiological state, the relationship is poorly understood. In this study, we investigated how changes in endocrine and inflammatory responses impact activity, social behavior, and neophobia in captive zebra finches (Taeniopygia guttata). We manipulated physiological states with three treatments: corticosterone, lipopolysaccharide (LPS), and fluoxetine. Pairs of same-sex zebra finches were given these treatments over 18 days. They were first dosed with corticosterone to simulate a stress response. A week later, they were injected with LPS to elevate inflammatory cytokine levels, and after another week, they were injected with fluoxetine to lower cytokine levels. Videos were recorded the day before treatments were administered as a behavioral baseline for each individual. Videos were then recorded after each treatment to assess how behavior may have changed. We scored behavioral variables from the recorded videos to assess activity, prosocial behaviors, and neophobia. We found all three treatments were associated with a decrease in activity, with males driving this effect for corticosterone. The corticosterone treatment also led cagemates to spend less time near each other, while administration of LPS resulted in males spending more time together. We also found that though treatment did not affect neophobic behaviors, males exhibited less neophobia than females. Overall, physiological state altered various behavioral responses, indicating that physiological state does determine behavioral flexibility in response to adversity.

## Daily calling patterns of oyster toadfish and striped cusk-eels in urban and non-urban soundscapes

*Xylo Lazrinth, Rachel Rodriguez, Adrian Skeans, Kara Duclosel, Thomas Quigley, Paul Forlano*

Oyster toadfish (Opsanus tau) and striped cusk-eels (Ophidion marginatum) are two species of vocalizing fish found along the Eastern Seaboard. Acoustic communication plays a crucial role in their reproductive success, with males producing advertisement calls during the summer reproductive season to attract females. Anthropogenic noise, including boat noise, has the potential to mask or interrupt calls, and previous studies have shown that boat noise is becoming more prominent in underwater soundscapes. Long-term passive acoustic monitoring can provide valuable insights into potential effects of anthropogenic noise on soniferous fishes. In this study, acoustic data were collected from May to August in several urban sites around Brooklyn, NY, and one non-urban site in Long Island, NY. Advertisement calls and anthropogenic noise events were manually traced on Raven Pro to record the total number and duration of calls/events. Call rate (calls per minute) and call/noise occupancy (total duration of sound over recording duration) were plotted for every hour of the day to characterize daily calling patterns and interpret variation between locations. We expected the urban sites to experience more anthropogenic noise events due to higher boat traffic, leading to less robust calling patterns in both species. Preliminary analyses suggest that cusk-eels peak in calling activity around sunrise and sunset, while toadfish call throughout the day, with variation in onset, duration, and intensity of peaks across locations.

## Using haltere steering muscles to drive head and wing movements in flying flies

*Kristianna Lea, Bradley Dickerson, Jessica Fox*

Halteres, the reduced hindwings of flies (Diptera), are sensitive mechanosensory organs that are actively controlled by a small set of steering muscles. These muscles are serially homologous to the muscles that regulate the motion of the aerodynamically functional forewings, but little is known about how they drive precise haltere motions and, thus, shape haltere sensory input. Previous studies using large, externally-driven manipulations of the haltere demonstrated that changes in haltere motions lead to changes in wing and head movements. But how do flies use their own muscles to regulate haltere motion, and what are the sensory consequences of these changes? Further, how does this altered sensory input translate to changes in wing and head kinematics?

In recent work, we showed that activating a subset of the haltere steering muscles can change the haltere's oscillation amplitude. Here, we use optogenetics in Drosophila melanogaster to show how active modulation of two small haltere steering muscles contributes to head and wing movements in tethered flying flies. We measured haltere, wing, and head kinematics using high speed videography and found that haltere muscle activation elicited small changes in haltere motion, yet had profound impacts on the movements of the wings and head. Our data suggest that, consistent with prior work, small haltere movements result in a strong sensory signal that drives rapid wing and head movements.

## Impact of warming and acidification on bivalves exposed to *Pseudo-nitzschia* pungens

*Jessica Leal, Cecilia Brothers, Ryan Kenton, Christine Weilhoefer, Rosa León-Zayas, Zachary Blood*

Harmful algal blooms (HABs) form when algae experience uncontrolled growth and often result in the bioaccumulation of toxins in aquatic food webs. Filter feeders such as bivalves indicate the presence of HABs when feeding on algae such as Pseudo-nitzschia spp., which can produce domoic acid (DA), the toxin that causes Amnesic Shellfish Poisoning. Bivalves may also experience negative effects from the accompanying environmental conditions frequently associated with HABs, such as changes in ocean temperatures and pH levels. To study the impact of exposure to HABs under the combined stressors of warming and acidification, purple varnish clams (Nuttallia obscurata) were exposed to Pseudo-nitzschia pungens for seven days, followed by non-HAB Thalassiosira pseudonana for six days. One hundred and sixty-eight clams were divided into four treatments: (1) ambient: 16.62°C; pH 7.81, (2) warming: 18.13°C; pH 7.81, (3) acidification: 16.62°C; pH 7.63, and (4) warming and acidification: 18.13°C; pH 7.63. Survival remained high in all treatments, and there was little growth. The visceral mass, gills, and adductor muscles were sampled, and the changes in glutathione-S-transferase (GST) and glutathione (GSH) activity reflect the oxidative stress and detoxification response in N. obscurata. Understanding the effects of these combined stressors is essential for predicting the recovery of bivalves from HABs, which may have further implications for their long-term health and survival.

## Vision and metabolism across body size in the fiddler crab *Minuca pugnax*

*Rebecca LeBlanc, Elijah Garcia, Jonathan Cohen*

The speed, or temporal resolution, of visual systems is a key factor shaping animal behavior and ecological interactions in many species. Critical flicker fusion frequency (CFF), the maximum rate at which an animal's eyes can perceive a flashing light, appears to increase as body size decreases, at least in vertebrates. The current hypothesis for why this may be is that CFF is correlated with mass-specific metabolic rate, as vision can represent a significant proportion of an animal's energy budget. In this study, Minuca pugnax, the Atlantic Marsh Fiddler Crab, were collected from the Great Marsh in Lewes, DE across a range of body sizes for respiration and electroretinography experiments to determine their mass-specific metabolic rates (MO2) and CFF, respectively. MO2 was found to exponentially decrease with mass. CFF as a function of body size was best fit by a broken-stick regression, where the speed of vision stayed constant around 48Hz until crabs reached a dry tissue weight of 0.4g and then began to decrease linearly. These findings are consistent with a meta-analysis compiling CFF and metabolic rate data across vertebrate species. This research will advance our understanding of how physiology, behavior, and ecology are connected in fiddler crabs and, more broadly, how environmental pressures shaping the allometry of organisms may influence sensory ecology and behavior.

## Testing the heating and cooling rate of the Xylocopa species

*Ashley Lee, Edgar Nickols, Kiara Lopez, Brendon Blake, John Hranitz, Victor Gonzalez, John Barthell*

Prior research detailed temporal foraging niche partitioning among three species of carpenter bee in Mediterranean scrub habitat on Lesvos Island, Greece. Xylocopa olivieri displays crepuscular foraging while X. violacea and X. iris are diurnal foragers. The CTMax of X. iris was higher than X. olivieri, while CTMax for X. violacea was intermediate to both species. When exposed to post-foraging morning sunlight at temperatures below CTMax, X. olivieri experienced higher mortality and shuttle box activity than X. violacea. We tested the hypothesis that high heating and cooling rates constrain X. olivieri to crepuscular foraging. Passive heating and cooling rates of X. violacea, X. iris, and X. olivieri were determined by light-induced heating. Passive rates of heating and cooling scaled inversely with body size of the three bees. The rates of heat gain and loss were highest (P X. olivieri > X. violacea). Intermediate passive rates of heating and cooling by X. olivieri do not support the hypothesis that crepuscular foraging by X. oliveri avoids rapid heat gain. Future research will investigate how reflectance and cuticle color may impact rates of heating or oxidative stress among these carpenter bees.

## Rat or Nat? The ichnotaxonomy of the Chicago Rat Hole

*Christine Lee, Gabby Guilhon, Michael Granatosky*

An enigmatic imprint in the sidewalk, popularly known as the "Chicago rat hole" has sparked widespread curiosity and attention. The phenomenon went viral after comedian Winslow Dumaine tweeted his visit to the area. Since then, both locals and tourists have been making their own pilgrimage to the site leaving behind tributes for the presumed "rat." However, the true taxonomic identity of the animal responsible for the imprint has been called into question. By utilizing linear measurements derived from clear anatomical landmarks in a series of scaled photographs of the "Chicago rat hole," we aimed to uncover the taxonomic identity of the ichnofossil by comparing these measurements to those collected from common species in the Chicago area. From our analyses, the overall snout-to-base-of-tail length, forelimb length, third digit length, and hind paw length were the best discriminators between extant species in the area. Our findings indicate that the "Chicago rat hole" was likely not made by the commonly observed brown rat (Rattus norvegicus), but rather by the Eastern gray squirrel (Sciurus carolinensis). These finding support the opinions of wildlife experts who suggested that a squirrel fell from a tree onto the wet concrete. While this phenomenon created widespread interest in ichnotaxonomy for the larger audience, it also showcased the importance of proper science communication and education of the public.

## Two Tails of the Same Coin: A Shared Release from a Locomotor Constraint

*Christine Lee, Gabby Guilhon, Michael Granatosky*

The mammalian tail exhibits significant diversity in shape and function, varying in length, thickness, and prehensility, with key roles in propulsion, balance, and stability during locomotion. Arboreal species often have longer, more robust tails to enhance stability on precarious supports, while some species have evolved axial skeleton features that reduce the need for a tail in maintaining balance, leading to tail reduction or prehensility. This study uses a comparative phylogenetic framework to test whether anatomical features associated with axial stability correlate with tail modifications in arboreal mammals. In our study, we measured biomechanically relevant measurements of the antepenultimate lumbar vertebrae on 202 different species. Using phylogenetic principal component analyses, we found that prehensile and absent/reduced tailed species have greater axial stiffening compared to species with long tails. Key traits associated with increased axial stiffening include elongated mediolateral length of the lumbar transverse process, increased dorsoventral height of the lumbar vertebral body and more oblique orientation of the transverse process. This data suggests that stiffening the axial skeleton may free the tail from its role in locomotion, leading to tail reduction or the evolution of new functions, such as prehensility, due to a release from locomotor constraints. However, the causal relationship of which came first, tail loss or axial morphology adaptations to locomotor functions, remains in question.

## Differences in form-function relationships between the sexes: A test using Anolis lizards

*Haelin Lee, James Stroud*

Sexual dimorphism in morphology and performance is widespread in animals, however is mainly demonstrated for only morphology. Here, we directly test if morphological sexual dimorphism leads to divergent performance in five species of Anolis lizards representing four ecomorph classes. Specifically, we tested for sexual differences in relative limb length, head size, maximal sprinting speed, and biting force. We will then test for sex-specific correlations between limb length and sprinting speed, and head size and biting force. This study aims to uncover potential sexual differences in the evolution of form-function relationships, shedding light on the role of sexual selection in driving morphological and performance divergence in Anolis lizards.

## Evolution of transcriptional responses to host plant in two saguaro specialists

*Andrew Legan, Carson Allan, Sergio Castrezana, Luciano Matzkin*

In the Sonoran Desert, cactophilic flies Drosophila nigrospiracula and D. mettleri specialize on rotting saguaro cactus (Carnegiea gigantea). They differ in their ecological niches, with D. mettleri specializing on the rot-soaked soil beneath the saguaro while D. nigrospiracula specializes on the rotting vegetative tissue. Selective pressure on detoxification has been strongest on D. mettleri because saguaro secondary metabolites, such as isoquinoline alkaloids, become more concentrated in the soil. These species provide the opportunity to investigate the genetic adaptations underlying the evolution of host convergence and niche partitioning. We used RNA sequencing and qPCR to compare transcriptional responses of larvae and adults of both species raised on diets varying in saguaro content. Overlapping yet distinct transcriptional shifts provide insights into the role of plastic metabolic detoxification responses in ecological specialization, contributing to understanding the genetic basis of host plant specialization.

## Beyond the Hexagon: Meso-structures in the Bee's Honeycomb for Bioinspired Design

*Jacqueline Lehner, Dhruv Bhate, Cahit Ozturk, Clint Penick*

Perhaps no other biological structure has inspired as many engineering applications as the bee's honeycomb. And yet, it is primarily the hexagonal unit cell, with its material minimizing benefits, that has been abstracted as a design principle. This is in part because of design constraints associated with manufacturing honeycomb panels, but also due to our limited understanding of the functional benefit of any other design features of interest. The bee's honeycomb has several interesting meso-structural design elements, like the corner radius and the wall coping, which can be replicated using most additive manufacturing processes. In this work, we first identify and categorize these meso-scale design elements at four levels: (i) the unit cell shape, (ii) it's size and distribution, (iii) the features that make up the unit cell and the parameters associated with them, and (iv) the integration of the cells into the build environment. Once identified, we attribute functional bases to each of these features, leveraging prior and ongoing studies in biology, as well as in materials science and mechanics. We then identify promising design principles for further advancing the engineering of honeycomb structures, as well as call out opportunities for future research. More generally, we argue for the importance of considering meso-structural design elements, beyond just unit cell selection, in the design of architected engineering materials.

## Physiological impacts of chronic microplastic exposure on zebrafish (*Danio rerio*)

*Samantha Leigh, William Nguyen*

Microplastics (MPs) are a pollutant of serious concern. Despite their pervasiveness, we are in the early stages of understanding the full effects of MP pollution on marine organisms. Because MPs are the same size range as microzooplankton and phytoplankton, they are vulnerable for consumption by marine primary consumers. Some potential effects of MP ingestion include blocked and damaged digestive tracts, the leaching of plastic toxicants, and the introduction of foreign microorganisms; all of which could potentially lead to growth deficits, reproductive issues, and decreased lifespan. This is of particular concern for commercially important species since they represent a critical dietary and economic resource. This is why it is critical to understand how chronic MP exposure impacts fish physiology. We are investigating the impacts of microplastic ingestion on the growth, fecundity, digestive efficiency, and gut microbiome community structure in the model organism Danio rerio (zebrafish) in order to understand what adverse effects microplastics could be having on vertebrates. To date, we have determined that increased levels of MP exposure negatively impacts zebrafish growth, fecundity, and digestive efficiency.

## eDNA metabarcoding analysis of biodiversity in urban and non-urban freshwater streams

*Isabella Leisgang, Kenneth Petren*

Environmental DNA (eDNA) metabarcoding is a method of growing interest to enhance aquatic biodiversity monitoring. Fish and macroinvertebrate communities face consequences from local and regional urbanization, specifically impervious surfaces. Southwest Ohio has widespread networks of streams such as the Great Miami, Little Miami, Whitewater, and Mill Creek watersheds which contain many urban and non-urban locations. After testing various filtering, extraction, PCR, and metabarcoding procedures, a standard protocol was applied for processing these samples to create a comprehensive dataset of fish and macroinvertebrates. I sampled thirty-four sites across these four watersheds which showed substantial variation in urbanization to test the hypothesis that biodiversity is impacted by impervious surface concentrations. Taxon biodiversity of fish and macroinvertebrates from metabarcoding were compared to results from standard sampling protocols obtained previously. Biodiversity measures were also compared to the amount of impervious surfaces locally and at larger watershed scales for each sampling location using GIS impervious surface analysis tools. DNA metabarcoding shows promise as a tool for monitoring biodiversity on a regional scale that can complement more traditional methods of sampling.

## Identifying potential play behavior in cuttlefish

*Kira Lemke, Robyn Crook*

Cephalopods are intelligent animals that can solve mazes, have episodic-like memories, and exert self-control, but little is known about best practices for their husbandry. For example, there are currently no validated behavioral assessments to measure welfare. This project aims to begin to fill this gap by examining object play and responses to environmental enrichment in captive Sepia bandensis. Cuttlefish were given a variety of objects including a small plastic water wheel, glass marbles, small rubber ducks, and bubblers, and their behavioral responses recorded over the short- and long-term. Analysis of recorded video footage identified interactions with novel objects and preferences for various enrichments, and detailed analysis is ongoing to determine if there is a correlation between habitat enrichment and play behavior. We hypothesize that object-directed behaviors may correlate with welfare state, and we are testing this by determining if the level of play exhibited can be influenced by chronic stress induced by inadequate housing conditions. This study is important because we currently have few tools to assess cuttlefish welfare, and whether standard environmental enrichments affect welfare state. This project will hopefully generate a new tool for assessing welfare of cuttlefish in aquaria that requires no training of cuttlefish.

## A new approach for direct aerodynamic work loop recordings in bird flight

*David Lentink, Marc Deetjen, Diana Chin, Ashley Heers, Bret Tobalske*

Avian takeoff requires peak pectoralis muscle power to generate sufficient aerodynamic force during the downstroke. Subsequently, the much smaller supracoracoideus recovers the wing during the upstroke. How the pectoralis work loop is tuned to power flight is unclear. We integrate wingbeat-resolved muscle, kinematic, and aerodynamic recordings in vivo with a new mathematical model to disentangle how the pectoralis muscle overcomes wing inertia and generates aerodynamic force during takeoff in doves. Doves reduce the angle of attack of their wing mid-downstroke to efficiently generate aerodynamic force, resulting in an aerodynamic power dip, that allows transferring excess pectoralis power into tensioning the supracoracoideus tendon to assist the upstroke—improving the pectoralis work loop efficiency simultaneously. Integrating extant bird data, our model shows how the pectoralis of birds with faster wingtip speed need to generate proportionally more power. Finally, birds with disproportionally larger wing inertia need to activate the pectoralis earlier to tune their downstroke. The talk will cover how this research approach was inspired by my (DL) postdoc at the Concord Field Station with Dr. Andrew Biewener. This abstract was previously published in eLife: https://elifesciences.org/articles/89968

## Does the effect of nest temperature on skin development influence host-parasite interactions?

*Carissa Leung, Bridget Sleath, Sila Inanoglu, Lorraine Perez, Ashley Love, Sarah Knutie*

Host-parasite interactions can vary in response to changes in environmental conditions, such as temperature variation. For example, elevated temperatures during development can affect host resistance to parasites. Since skin is vital for both thermoregulation and defense against ectoparasites, temperature-induced changes in skin thermoregulatory characteristics during development may explain variation in host resistance to parasites. For our study, we manipulated nest temperature during egg incubation of eastern bluebirds (Sialia sialis) before they were parasitized by blow flies (Protocalliphora sialia). We then measured hatchling body temperatures, characterized skin thermoregulatory characteristics (e.g., patagium skin thickness and brachial vein diameter) of male and female 13 day old nestlings, and resulting blow fly abundance.

Our preliminary results show that temperature treatment had a lasting effect on hatchling body temperature, which reflected their respective heat, cold, or control treatment. Nests from the heat treatment had fewer blow flies than the control or cold-treated nests. Treatment affected vein diameter, but the direction of this effect depended on nestling sex. While the skin thickness was not significantly affected by treatment, males had thicker skin than females, which was likely due to their larger body size. Overall, our results suggest that nest temperature during egg incubation can influence parasite resistance. However, since the effect of temperature depends on nestling sex, skin morphology does not significantly mediate the effect of temperature on host resistance.

## Missing males: exploring potential abiotic drivers of sex ratio bias in *Syngnathus* pipefish

*Samantha Levell*

Populations of three Syngnathus pipefish species in Sarasota Bay are notably female-biased, a phenomenon not yet fully understood due to the absence of known sex chromosomes in these species. This study aims to explore abiotic factors that may influence sex ratios, with a particular focus on the role of dissolved oxygen (DO). Given that male Syngnathus carry the embryos during gestation, I hypothesize that males may preferentially occupy areas with higher DO levels to ensure adequate oxygenation for developing embryos. Preliminary evidence from ongoing monthly censuses suggests a correlation between higher DO levels and male distribution, supporting the hypothesis that DO may be a critical factor in shaping sex ratios in these populations. However, further data collection is necessary to substantiate these findings and to understand the broader ecological implications. This research contributes to our understanding of the factors influencing sex ratios in Syngnathus pipefish, which could have significant implications for their reproductive success and population dynamics.

## Barn swallows do not select nests according to experimental artificial light at night

*Iris Levin, Audrey Gibson, Toshi Tsunekage, Omar Morosse*

Artificial light at night (ALAN) is a ubiquitous feature of modern landscapes, particularly in areas of high human density. The evidence for whether ALAN influences nest site selection in birds is mixed; however, there are few experiments that isolate the role of ALAN in nest selection, particularly in non-cavity nesters. Barn swallows re-use their open cup nests which are built in structures like barns, and typically half of the existing nests are used in any breeding season. We experimentally lit half of the nests (n=74) in one large barn with small LED lights mounted to the ceiling above the nests prior to the birds' arrival to the breeding grounds. Control lights not attached to power were used above the other half of the nests. Lights were programmed to turn on at 19:00 and off at 01:00 and remained active until eggs were laid in the nest. All birds were identified to each nest and captured to collect morphological and other phenotypic measures. Barn swallows did not show any aversion to or preference for ALAN and settled randomly. Furthermore, ventral plumage color, an important social and sexual trait in this species, did not predict settlement patterns with respect to ALAN in either sex. If ALAN negatively affects barn swallows, they may not have yet evolved a proper avoidance mechanism during nest selection.

## The role of vision and the lateral line system in the jumping behavior of silver hatchetfish

*Jeremy Levin, Hridey Kapoor, Anais Azevedo, Kyle Lassen, Jia Zheng, Alyssa Silva, Margot Schwalbe*

Many different types of fish can propel themselves out of water, but less are known to intentionally and repeatedly jump out of the water. Multiple sensory systems, including vision and the mechanosensory lateral line, likely mediate jumping behaviors in fish so that they avoid predators or capture prey. Here, we studied the distribution of the lateral line system in silver hatchetfish (Gasteropelicus sp.), and their ballistic jumping behavior. Fluorescent microscopy revealed that silver hatchetfish have an extensive lateral line system distributed on their body, especially on the top of their skull and on their deep narrow ventral keel. In behavioral trials, fish were triggered to jump using a custom-made device that delivered a vibrational stimulus. Trials were filmed with a high-speed camera and were performed in light and dark conditions (under infrared light) and with and without a functional lateral line system. We determined a species-specific treatment for successful lateral line ablation since common ablation treatments were unsuccessful (confirmed with fluorescence microscopy). Overall, fish responded to the vibration stimulus by consistently jumping in trials and propelling themselves out of the water with a single downstroke of their elongated pectoral fins. Differences in jumping movements were observed under the various sensory conditions and will be discussed. Other sensory modalities may also contribute to silver hatchetfish flight and will be explored in future experiments.

## Big Bad Bugs in the Big City: Effects of Urbanization on Invasive Spotted Lanternfly Body Size

*Brenna Levine, Alyssa Moffitt, Ayush Patel, Renato Mendez*

Body size is a critical parameter for animals, with implications for thermal tolerance, fecundity, and dispersal. In ectotherms, adult body size is inversely related to environmental temperature due to effects on developmental rate. It follows that ectotherms in warmer areas such as cities would be expected to have smaller adult body size. Here, we used the spotted lanternfly (Lycorma delicatula; 'SLF'), an invasive insect experiencing rapid range expansion across urban and non-urban areas in the USA, to test the hypothesis that SLF in cities have smaller adult body size. In Fall 2021, we collected adult male ($n = 980$) and female (1,427) SLF from 94 sites in New Jersey and Pennsylvania (USA) spanning latitudinal and urbanization gradients. We measured the body length of each individual and calculated mean percent impervious surface for a 5-km buffer zone around each site. Contrary to our expectations, we found a significant positive effect of urbanization on body size for males (GLMM: $p = 0.00192$) and females (GLMM: $p < 0.001$). These results underscore that cities promote larger body size in invasive SLF, potentially due to nutrient availability or selection for increased dispersal or thermal tolerance. We are currently exploring the mechanisms underlying the relationship between urbanization and SLF body size, as well as the consequences of SLF body size for future range expansion.

## Seeing and stabbing: evaluating trinocular vision and ballistic strikes in Mantis Shrimp

*Helena Lewis, Allen Mensinger, Kathryn Feller*

Mantis shrimp, or stomatopods, have one of the most sophisticated visual systems in the animal kingdom, featuring a three-part structure that putatively provides trinocular depth perception to each eye. This eye structure is hypothesized to perform monocular range-finding when striking at a target. While their spectral and polarization sensitivity is well-documented, less is known about their motion vision and depth perception, especially concerning their predatory strikes. Nearly all mantis shrimp have this three-part eye structure and perform ultra-fast, ballistic strikes, suggesting a possible co-evolution of these traits. To investigate this, we studied Squilla empusa, a local stomatopod species in Woods Hole, Massachusetts. By fully occluding one eye with liquid eyeliner, we predicted stomatopods would strike at projected looming visual stimuli similarly to when both eyes were unoccluded, however, this was not the case. High-speed video analysis of animal responses when eyes were partially or fully occluded with black, liquid eyeliner yielded a significant reduction in strikes and visual responses. This study aims to determine which visual parameters are crucial for anticipating and intercepting fast-moving targets for the planning and execution of ballistic strikes. This is also the first known study to behaviorally test the monocular range-finding hypothesis, and thus the selective pressures that gave rise to such a highly conserved, yet unusual eye structure in the stomatopod lineage.

## Investigating the relationship between fuel use and metabolic state in brown-banded bamboo sharks

*Johanne Lewis, Chestina Craig, Melanie Salinas*

Elasmobranchs are metabolically unique among vertebrates because their energy metabolism is characterized by low levels of fatty acid oxidation in their muscles (both cardiac and skeletal). Instead, it is hypothesized the muscles of elasmobranchs rely on ketone bodies and amino acids as substrates for energy production. Much of the work on changes in blood concentrations of oxidative substrates has been limited to single sample points in field captured animals, which prevents the ability to analyze changes in circulating levels of fuels in response to abiotic and biotic factors. Our study aims to investigate the effects of lifestyle and activity level on fuel use in elasmobranchs. Measurements of oxygen consumption, ventilation rate, and circulating levels of lactate and oxidative fuels were measured in brown-banded bamboo sharks (Chiloscyllium punctatum) at rest and immediately after two or five minutes of forced swimming. Forced swimming for two minutes resulted in a three-fold increase in oxygen consumption with no additional increase occurring with increased swim duration. Additionally, there was a significant, continual increase in plasma lactate with swimming duration. Combined, these results suggest forced swimming pushed this demersal species to their maximum aerobic capacity and a switch to anaerobic means of energy production were likely being utilized to fuel sustained swimming. Plasma samples are undergoing further analysis to identify the preferred substrate for energy production during aerobic versus anaerobic metabolism.

## Serotonin disruption leads to memory deficits in the whip spider *Phrynus marginemaculatus*

*Sidney Ley, Nicholas Brown, Gabriella Wolff, Daniel Wiegmann, Verner Bingman*

Whip spiders (Phrynus marginemaculatus) are arachnids that navigate primarily by their unusually keen olfactory abilities. Experiments in the laboratory reveal that whip spiders form both short and long-term memories for odors associated with access to a shelter. While bioamine function and location in the whip spider remains completely unexplored, comparative anatomy indicates that their olfactory memory likely depends on bioamine, such as serotonin, signaling in a brain region relevant to olfactory input. Hence, if serotonin activity is pharmacologically disrupted within the whip spider brain, their performance in an associative olfactory learning task should be significantly impaired. Additionally, immunohistochemistry would reveal the presence of serotonin in a region relevant to olfactory information within the whip spider brain. Subjects ($n = 20$) were trained on an olfactory memory paradigm, then injected with either 0.9% physiological saline or the serotonin antagonist methiothepin mesylate (MET) and tested for memory retention 24 hours afterward. Controls injected with saline performed above chance ($p = 0.006$), while the treated groups performed at chance ($p = 0.3748$). There was a significant difference in performance between the treated and control group on test day ($p = 0.048$). Additionally, there were no significant differences in locomotion between the treatment or control group on test day ($p > 0.05$), and the presence of serotonin was found throughout the whip spider brain, including the primary glomeruli and mushroom body calyces. Taken together, these results indicate that the serotonin antagonist MET impairs olfactory memory consolidation without impairing locomotion at 7 mM.

## Suture morphology of sea turtles across ontogeny

*Ivana Lezcano, Jeanette Wyneken, Noor Neha*

Skeletal sutures between flat bones are traditionally considered syndesmoses with little to no movement. These fibrous joints link the edges of bones like those in the skull and turtle shell to provide stability between elements. A major function of sutures is to allow adjacent bones to expand and develop with growth. In turtles, they also offer limited flexibility necessary for shock absorbance and force distribution throughout the shell when under pressure (such as diving or under assault by predators). In published work on red-eared slider (Trachemys scripta) turtles, carapacial sutures have been described as pointed boney teeth arranged in a zig-zag interdigitating pattern. Hard-shelled marine turtle suture morphology provides an interesting comparison due to diving and pressure. We examined the structure and mechanical behavior of sutures in various size classes of hard-shelled sea turtles using micro-computed tomography (CT) and material testing respectively. Micro-CT provides high-resolution, non-destructive visualization, enabling extensive investigation of suture morphology. Height, width, and tooth angle of suture teeth in pleural bone samples was characterized. Data indicate that there is considerable variation in suture morphology across ontogeny. Adult turtles display larger tooth angles and decreased tooth number when compared to smaller sized juvenile turtles. Additionally, the sutures responses to force were suprising given the high stiffness of this collagenous region. Size-related differences in these sutures likely have biomechanical implications that change throughout ontogeny but also inform of the potential evolutionary role of this structural design.

## Functional models from limited data: parametric anatomy and 3D kinematics of basking shark feeding

*Aurora (Tairan) Li, Mike Schindler, Martha Paskin, Venkata Surapaneni, Elliott Scott, Sabine Hauert, Nick Payne, Dave Cade, Jeremy Goldbogen, Frederik Mollen, Daniel Baum, Sean Hanna, Mason Dean*

Basking sharks feed by gaping their mouths and gill slits, greatly reorienting their cranial skeletons to retain food from water. The 3D biomechanics of this behavior, however, are exceptionally difficult to study due to the size, elusiveness, and CITES-status of these animals and the rarity of well-preserved specimens. To overcome these challenges, we integrate anatomical, digital design and computer imaging approaches to reconstruct poseable 3D skeletal models of feeding basking sharks. The skeleton, segmented from CT-scans of intact heads, was abstracted as a bio-realistic rigging for guiding skeletal positioning in 3D space. Directed by anatomies of museum and dissected beached specimens, the digital scaffolding helped virtually correct skeletal distortions (e.g. from specimen collapse), resetting the skeleton to closed-mouth symmetry. Open-mouthed feeding postures were recreated by repositioning skeletal joints to biologically-relevant destination coordinates defined from videos of feeding sharks, exploiting the basking shark's undeviating feeding posture to build 3D photogrammetry models from successive video frames. The resultant "digital puppet" bridges diverse imaging data while capturing the coordinated motion of "hidden" cranial joints, deconstructing complex form-function relationships into computationally controllable parameters for exploring 3D skeletal movement. This biological fidelity gives insights into dynamic feeding processes impossible to observe in the laboratory and a platform for future kinematic modeling (e.g. of individual variation, other species), while demonstrating interdisciplinary approaches for studying large and elusive wildlife.

## Proteomic insights into winner-loser effects: aggression, learning, and brain protein profiles

*Cheng-Yu Li, Audrey Ward, Eric Haag, Dietmar Kueltz, Ryan Earley*

Fighting experience significantly affects aggressive behavior and physiology, known as winner-loser effects, which are conserved from invertebrates to vertebrates, though the underlying mechanisms remain unclear. While much research has focused on how winning and losing alter aggression, growing evidence suggests these experiences also influence other behaviors, including learning. In mangrove rivulus fish (Kryptolebias marmoratus), winners become more aggressive and excel in spatial learning whereas losers show reduced aggression but improved risk-avoidance learning. This suggests that fighting experiences may shape various behaviors through key brain regions within the social decision-making network, particularly the dorsolateral pallium (Dl; homologous to the hippocampus) and dorsomedial pallium (Dm; homologous to the basolateral amygdala).

We examined whole-proteome expression in the forebrain (where Dl and Dm are located) of adult rivulus fish with winning or losing experiences. A total of 1,307 brain proteins were identified, with 23 showing significant differential expression between winners and losers. Losers' forebrain protein expression indicated modulation of cellular processes, recovery from energy deficits, and altered learning. In contrast, winners' protein profiles suggested restoration of neuroendocrine balance, energy utilization, neuronal plasticity, and distinct learning processes. These findings highlight functional differences in the brains of winners and losers, revealing potential mechanisms underlying the modulation of aggression and learning. Future genetic manipulation studies are needed to establish causality between specific protein expressions and behavior changes induced by experience.

## Variation in nighttime thermal preference in diurnal lizards

*Maya Li, Brooke Bodensteiner, Martha Muñoz*

In many parts of the world nighttime temperatures are increasing faster than daytime temperatures. In comparison to rising daytime temperatures, however, assessing the impact of increasing nocturnal temperatures on ectothermic organisms has received relatively little attention. Previous studies in plants and invertebrates demonstrated contrasting physiological responses to warming in the day versus the night. Here we compare daytime and nighttime thermal preference in six closely related species of Anolis lizards from the Dominican Republic. These six species occupy different thermal habitats; whereas some species are found near sea level, others are montane specialists. Because these lizards are diurnal thermoregulators, we expect the daytime preferred temperature to be similar across elevation. However, because nighttime temperatures get progressively colder with elevation and because anoles are nocturnally inactive, we expect the nighttime preferred temperature to decline with elevation. Given that the rate of physiological processes varies with temperature in ectotherms, the degree of mismatch between preferred temperatures may imply different energetic demands across elevation. Theory suggests that tropical ectotherms are particularly vulnerable to climate warming, yet few studies explicitly consider their nocturnal thermal physiology. To create a more complete understanding of how rising temperatures impact organisms, we must consider how organisms interact with temperature across both daytime and nighttime settings.

## Diversity in hyolingual morphology is decoupled from diversity in tongue base retraction mechanisms

*Peishu Li, Kaleb Sellers, Courtney Orsbon, J.D. Laurence-Chasen, Riya Gumidyala, George Huerta, Madison Yuan, Teresa Lever, Nicholas Gidmark, Zhe-Xi Luo, Callum Ross*

Bolus movement is central to swallowing performance. During swallowing, a diverse range of mammals — from opossums to humans — propel the bolus out of the oropharynx by retracting the tongue base. The widespread phylogenetic distribution of this tongue base retraction (TBR) behavior suggests it could have a deep evolutionary origin, but the biomechanical mechanisms of TBR remain poorly understood. Previous research in macaque primates and opossums implies differences in TBR mechanisms could be related to interspecific variation in hyolingual morphology. Using biplanar videoradiography and the XROMM workflow, we collected high-resolution 3D hyolingual kinematic data in dogs, opossums, and macaques to examine the hypothetical relationships between hyolingual diversity and TBR mechanics across mammalian evolution. Despite differences in hyolingual morphology and resting hyoid position, both dogs and macaques utilize a hyoid-powered hydraulic mechanism of TBR: hyoid protraction and elevation reduce the oral volume, which squeezes the tongue base posteriorly like a hydraulic fluid. In contrast, despite similarity in hyoid morphology with macaques, opossums initiate TBR through a muscular-hydrostat pattern of lingual deformation, independent of hyoid movement and oral volume change. Our data suggest the functional diversity of TBR mechanisms is decoupled from the morphological diversity of the mammalian hyolingual system. This decoupling may have facilitated the evolution of novel hyolingual phenotypes while avoiding trade-offs in bolus propulsion performance during swallowing.

## The Role of Alternative Metalloproteins in Nitric Oxide Stress Response of Salmonella Typhimurium

*Yihan Li, Elaine Frawley*

The ability to adapt to environmental challenges is crucial for the success of organisms, including bacterial pathogens like Salmonella Typhimurium. Within a host, S. Typhimurium encounters stressors from the immune system such as nitric oxide (NO). One way NO functions is by modifying certain proteins, including metalloproteins containing iron or zinc cofactors. During NO stress, S. Typhimurium exports iron and zinc but increases uptake of manganese, suggesting a potential shift to alternative metalloproteins that utilize manganese cofactors.

This study examined the expression and physiological role of coproporphyrinogen III oxidases and ribonucleotide-diphosphate reductases encoded by hem and nrd genes respectively. We deleted the nrdDG, nrdEF, hemN and hemFgenes in both the wild-type strain and a manganese-import mutant strain. We determined sensitivity to NO by treating cultures with the NO donor Spermine NONOate, then monitoring growth using spectrophotometry to determine when each strain was able to exit lag phase and resume growth. Deletion of nrdEF but not nrdDG affects recovery from NO while deleting either hemN or hemF delays recovery. When S. Typhimurium cannot import manganese, recovery from NO stress is impaired but deleting these additional genes does not enhance the growth delay. We expected manganese would be required for the function of both hemF and nrdEF, but the hemN result was surprising since it is not predicted to use manganese as a cofactor.

## How wolf spiders get through rough patches: running kinematics and paths on different granular media

*Haitong Lian, Jack Vice, S. Tonia Hsieh, Suzanne Kane*

Terrestrial spiders must move rapidly over diverse terrains to capture prey and escape predators. To study these behaviors, we filmed Carolina wolf spiders (Hogna carolinensis) at 500 frame/s in two camera views while they ran on granular media typical of their native habitats. Half of the experimental arena floor was covered sand and the other with either gravel or rocks. As a control, they also ran on sandpaper half covered with a fixed layer of gravel, to test for possible effects of particle motion. This design allowed the trajectories and kinematics of spiders to be quantified for running on each substrate and transitioning between media. Spiders ran at the same mean speed on either fixed or loose sand and gravel but 18% faster on loose sand than rock; their mean acceleration was significantly greater on rocks, loose and fixed gravel than on loose or fixed sand. The path tortuosity (a measure of nonlinearity) had no significant dependence on substrate, and indicated spiders followed linear trajectories that minimized distance, not winding paths that minimized work against gravity. Spiders left footprints in the loose sand but they did not displace rocks and only rarely moved the gravel (100X and 1X body weight, respectively) during locomotion. In future analysis, we also plan to quantify how gait characteristics depend on substrate roughness.

## Swedish orca ecology: isotopic analysis reveals feeding behavior of the past 175 years

*Ashley Liao, Daniela Kalthoff, Robin Trayler, Anna Roos, David Bernvi, Sora Kim*

There is very limited detailed knowledge of orca (Orcinus orca) prey choice in the Northeastern Atlantic and a lack of data regarding how apex marine predators have adapted to environmental changes through time. Furthermore, orca prey specialization can vary within limited geographic areas based on prey availability and population structure. The trophic niche and dietary patterns of organisms can be determined by stable isotope analysis of their tissues. We analyzed bone and muscle samples from orcas and potential prey from the Northeastern Atlantic for $\delta$13C and $\delta$15N values to gain insight into whether and how the marine ecosystem has been affected by and adapted to factors including resource availability and climate change throughout the past ~175 years. We used a Bayesian mixing model to calculate the proportion of each prey species in the diet of the orcas. We found that our samples reflect two distinct dietary groupings: marine mammal, small shark, and cephalopod-eaters with higher $\delta$15N values (range = 14.0-18.5‰, n = 19) compared to specialized mackerel-eaters with lower $\delta$15N values (range = 10.8-12.9‰, n = 10). Orca $\delta$15N values were not affected by year of sample collection (1847-2023). Species that are specialists are known to have a higher susceptibility to environmental changes. Our results will help identify long-term needs and challenges that this marine predator faces and support conservation efforts for this species.

## The effect of flow conditions and group size on the 3-D dynamics of a schooling carangid fish

*James Liao, Ishani Mukherjee*

Collective behavior is one of the most remarkable phenomena in nature, where groups of individuals can act as a cohesive unit through local interactions alone. Fish have been widely studied to uncover the mechanisms behind this behavior, but most research has focused on quasi-2D environments in still water with captive species. The natural, three-dimensional dynamics of fish schooling under varying flow conditions remain largely unexplored. We collected wild Atlantic bumper (Chloroscombrus chrysurus) living in tidal flows to investigate how fish swim in different group sizes (N=2-8), flow speeds (22- 44 cm/s), and levels of turbulence (with and without a 5 cm diameter cylinder). Swimming behavior was recorded at a high frame rate (100 fps) for up to 10 hours using synchronized cameras from both bottom and side views and tracked with deep learning-based 3D posture tracking. Our findings reveal that carangids alter their school structure in 3D depending on group size and flow speed. Specifically, increasing flow speed enhances group polarization while reducing nearest-neighbor distance. These results suggest that wild fish schools in unique species can provide new insights into the mechanisms underlying collective behavior.

## Stress-induced changes in corticosterone and mitochondrial efficiency affect DNA oxidative damage in Leach's storm-petrels (*Hydrobates leucorhous*)

*Kayla Lichtner, Nicole Joseph, Sarah Chapman, Tori Chace, Robert Mauck, Patricia Jones, Mark Haussmann*

Mitochondrial function is central to cellular metabolism. Despite technological advances, our understanding of mitochondrial performance is still limited for many wild populations. This study investigates how parental provisioning and chick nutritional condition affect mitochondrial function and DNA oxidative damage in Leach's Storm-Petrels (Hydrobates leucorhous). Due to the nature of pelagic foraging, storm-petrel chicks often experience frequent fasting between adult burrow visits, in which a chick can be fed by one parent or both parents. This foraging style may expose chicks to high variation in nutritional condition and associated metabolic stress. We provide an in-depth analysis of an individual's mitochondrial profile using an Oroboros O2k, allowing us to quantify baseline respiration, maximum rate of respiration, and leak respiration. Starting at day 8 post-hatch, chicks were massed daily to quantify parental feeding frequency and meal size. On average, the interval between parental feeding visits was 1.47±0.64 days and the proportion of nights in which chicks were fed was 0.67±0.06. Additionally, average meal sizes were 7.33±0.94g. Blood was collected on days 10, 20, and 30 of the chick-rearing period to measure DNA oxidative damage (8-OHdG) and mitochondrial function. We discuss how adult provisioning affects chick mitochondrial function and highlight the potential shifts in mitochondrial efficiency when chicks are fed or fasted during sensitive periods of development.

## Exploring the Effects of Intensity of Aggression on Exploration in Crickets

*Elena Liebl, Mason Miller, Michael Reichert*

Male house crickets (Acheta domesticus) display aggressive behaviors and engage in aggressive contests. Experience in contests affects future contest behavior (winner-loser effect), but less is known about whether contest experience also affects behaviors in other contexts. However, not only the outcome, but also the intensity of aggression could impact future behavior. We predicted that winning a contest would make individuals more willing to explore, and losing would make them less willing to explore. Secondly, we predicted the more intense contests would have more of an effect on exploration tendency. To test this, we measured exploration behavior before and after a contest in which the focal individual won or lost by timing how long they took to exit a shelter. We also filmed each contest and analyzed the videos to assign an aggression score to each contestant representing the escalation of the interaction. We found that individuals that won a contest exited the shelter faster, while crickets that lost exited the shelter slower. However, we did not find any significant relationship between aggression score and exploration tendency, emphasizing that winning or losing a contest is a more important factor than how aggressive the fight was. Analyzing and quantifying the crickets' aggressive behaviors provides further insight into the impact that the winner-loser effect can have on individuals' mental states and consequent decision making.

## House sparrows demonstrate tissue-level differences in oxidative stress during thermal acclimation

*Zach Lightfoot, Eliza Podlas, Chelsi Marolf, Sampath Anandan, Leyli Mammedowa, David Swanson, Ana Jimenez*

With climate change increasing not just the mean temperatures but also the frequency of cold snaps and heat waves, animals occupying thermally variable areas may be faced with thermal conditions for which they are not equipped. Studies of physiological adaptations of temperate resident birds to such short-term thermal variability, however, are rare. To help address this gap, we acclimated summer-phenotype house sparrows (Passer domesticus) to stable warm, stable cold, and fluctuating cold temperatures. We then measured several metrics of the oxidative stress (OS) system, including enzymatic and non-enzymatic antioxidants and lipid oxidative damage, in brain (post-mitotic), kidney (mitotic), liver (mitotic) and pectoralis muscle (post-mitotic) to determine whether thermal variability affects oxidative status. For most antioxidant measurements, including enzymatic activities of catalase (CAT), glutathione peroxidase (GPx), concentration of superoxide dismutase (SOD) and scavenging capacity for peroxyl radicals, we found significant differences across tissues, but no significant differences among thermal treatment groups. Additionally, we found no differences in lipid oxidative damage across tissues or thermal treatments. Thus, our data suggests that ROS production and antioxidant capacities are not generally associated with metabolic flexibility in response to short or long-term thermal variability in house sparrows.

## Integrating pollinators' movements into pollination's models

*Mathieu Lihoreau, Juliane Mailly, Louise Riotte-Lambert*

Predicting pollination is a key challenge for the conservation of natural ecosystems and sustainable food production. While most pollination ecology models assume pollen dispersal follows random movements centered around flowers, behavioural research shows how many key pollinators, including bees, bats and birds, do not forage randomly. In fact, these animals heavily rely on sensory cues, learning and memory, to collect nectar in an efficient manner. These foraging behaviour often result in complex - yet predictable - movement patterns that may significantly shape pollen dispersal. Here, we argue that we need to better consider these pollinators' non-random movements when studying pollination. We illustrate this idea using simulations an agent based model of pollen dispersal mediated through bee movements, and generate new hypotheses about plant mating patterns and fitness that can be tested experimentally. Such crosstalk between pollination ecology and animal behaviour holds the potential to provide powerful mechanistic tools for predicting and acting on pollination, in the alarming context of a looming crisis.

## Do solar storms impact hatchling sea turtle magnetic orientation behavior?

*Dana Lim, Catherine Lohmann, Kenneth Lohmann*

Animals from diverse taxa sense and use Earth's magnetic field to guide their orientation and movements. However, unpredictable solar activity has the capacity to alter Earth's magnetic field and interfere with magnetic field perception either by (1) temporarily rendering magnetic field information inaccurate, or (2) disrupting the magnetic receptor of the animal itself by generating radiofrequency (RF) noise, which is known to interfere with magnetoreception in several animals. Here, we investigate the possible association of solar storm activity with the behavior of hatchling loggerhead sea turtles (Caretta caretta) in a magnetic orientation assay in which tethered hatchlings were allowed to swim under magnetic conditions that elicit oriented swimming. Using a multi-year set of orientation data, we examine whether the strength of orientation as measured by the Rayleigh r-value correlates with several measures of either solar activity or features of Earth's magnetosphere that are affected by solar storms (sunspot number, Kp-index, RF index, Ap-index). Results from our study will reveal whether the strength of orientation is associated with the presence of magnetic disturbances due to solar activity and may thus help explain some of the variation in magnetic orientation responses of animals.

## Glutamatergic neurons in breeding and non-breeding green anole lizard (Anolis carolinensis) brains

*Nicolet Limas Mejia, Rachel Cohen*

Glutamate, the most prevalent and main excitatory neurotransmitter in the mammalian brain, is released and produced by glutamatergic neurons. This neurotransmitter is important for brain processes related to memory, mood regulation, and learning. However, the presence of these neurons has not been well studied in other vertebrate species, including reptiles. Green anole lizards (Anolis carolinensis) are an excellent model for investigating seasonal changes in the brain. During their breeding season, steroid hormone levels increase with larger gonads and an increase in aggressive and reproductive behavior. In this study, we aimed to determine the distribution of glutamatergic neurons in the brain of green anoles and compare this distribution across the breeding and non-breeding seasons. Thus, using immunohistochemistry and a glutamatergic marker, we investigated the presence of glutamatergic neurons in male and female green anole brains. We are currently mapping the presence of glutamatergic fibers in the brain and have found immunopositive fibers in the amygdala, preoptic area and ventromedial hypothalamus of green anoles, which could be involved in the regulation of social behaviors across seasons, such as aggression and courtship. We are currently quantifying fibers in these areas and will also investigate the presence of GABAergic neurons in the anole brain. This study could provide additional evidence for the idea that brain structures involved in the social behavior network are highly conserved across multiple vertebrate groups.

## Water repellency of birds

*Alice Lin, Xueyi Xie, Arjun Dixit, Reina Wakimoto, Zhijian Liang, Adam Butuel, Benjamin Freeman, David Hu*

A common belief is that birds are water-repellent: take, for example, the idiom "like water off a duck's back." Understanding how birds repel water may inspire improved water-repellent materials, saving energy and reducing waste. Previous studies, such as by AM Rijke in the 1970s, focused on individual feathers. Little is known about how whole birds contend with water. In this study, we filmed birds bathing in the wild and dunked frozen birds in water. We find birds absorb about 10 percent of their body mass in water, with larger birds absorbing relatively more. In comparison, humans emerging from water maintain 1 percent of their body weight in water on their skin. The air volume in a bird's feathers accounts well for the water absorbed as a function of body size. We use microscopy to track water absorption dynamics and surface tension forces' ability to organize feather barbules.

## Urban oases: bird diversity, wetlands, and the urban heat island

*Emerald Lin, Olivia Weklar, Kristin Winchell*

Urbanization is a leading cause of declining avian diversity due to habitat loss and fragmentation. While generally the presence of urban water bodies ("blue spaces") increases bird diversity by providing habitat and drinking/bathing sources, it remains contested whether only waterbirds utilize blue spaces or if terrestrial birds also benefit. Blue spaces may increase bird diversity by relieving the Urban Heat Island (UHI) effect, which describes the phenomenon where cities experience higher temperatures than surrounding rural areas. The UHI imposes thermal stress on birds, which may be relieved by the cooling effect of blue spaces. However, how wetland characteristics interact with urban and greenspace features to mitigate the UHI remains unknown. To investigate the relationship between wetland characteristics, UHI, and bird diversity, we conducted surveys at water bodies in New York City across a gradient of UHI intensity and wetland characteristics, incorporating features at both site- and landscape-scale (size, shape, vegetation vs impervious edge, and surrounding land cover type). The findings provide insight into how wetland characteristics influence environmental temperatures, specifically in their capacity to alleviate the UHI, and how this correlates with patterns of bird diversity. Our results allow us to better understand the environmental and ecological dynamics of urban wetlands, which is critical in the context of urban expansion, climate change, and biodiversity loss.

## Why spiders dynamically crouch their legs on webs to sense prey—evidence from robophysical modeling

*Eugene Lin, Yishun Zhou, Hsin-Yi Hung, Luke Moon, Andrew Gordus, Chen Li*

Many spiders rely on sensing vibrations to identify and locate prey on the web, during which they often dynamically crouch their legs. This was hypothesized to enhance prey perception, but is not conclusive due to difficulties in biological measurements. Here, we used robophysical modeling to provide quantitative evidence to explain how this behavior aids sensing. We measured the orb-weaver Uloborus diversus's sensing behavior. It dynamically crouches its legs and then pauses on the web during prey sensing. We generated similar dynamic leg crouching and pausing in a spider robot, which senses vibrations to detect a prey robot on an artificial web. We measured both the web's and spider robot legs' vibrations. By dynamical leg crouching, the spider robot induced all objects on the web to vibrate at their natural frequencies, enabling itself during its pausing to detect the prey robot through the latter's frequency. The sensed signal was dominated by the spider robot's own natural frequency when the prey robot was farther away, but by the latter's natural frequency when it was closer. Using this difference, the spider robot can differentiate how far the prey robot is. Overall, our findings suggest that web spiders can dynamically crouch their legs to perform a novel form of "echolocation" to identify and locate prey, by actively inducing, sensing, and interpreting vibrations using their web.

## "Tombo Dry": How dragonflies perform a multi-revolution aerial somersault to shake off water

*Huai-Ti Lin, Samuel Fabian, Alexandra Yarger, Rui Zhou*

Dragonflies are accomplished flyers that perform various aerial behaviors with style. When wetted, dragonflies spontaneously execute a forward multi-revolution somersault in the air to shed off excess water. This impressive aerial maneuver is prevalent across dragonfly taxa but is not observed in other flying insects. Spin drying was observed in 10 species of temperate and subtropical dragonflies and seems to be part of their innate flight maneuver repertoire. In this study, we combine high-speed videography in the field, high-precision motion capture in the lab, and a realistic dragonfly 3D model to reconstruct the dynamics of this behavior. Dragonflies typically fly into a vertically orientated hover prior to spinning. The mean tumbling angular speed can peak over 10000 °/s within 100 ms, imposing 50∼100 G of acceleration on the wet abdomen. Inverse dynamics results suggest that the angular momentum is generated through abdominal flicking, while the wings provide a coordinated aerodynamic damping. To arrest the rotation, the wings and body perform a coordinated breaking before the dragonfly recovers to a hovering state. Our ongoing fieldwork focuses on collecting detailed wing kinematics and deformation to further understand the aerodynamic control of this unique flight behavior.

## Effects of local and coupled body elasticity in overdamped undulatory locomotion

*Jianfeng Lin, Christopher Pierce, Tianyu Wang, Baxi Zhong, Daniel Goldman*

Animals with elongated bodies commonly undulate to locomote, involving interaction between their elastic body and environments. While elasticity enhances locomotion efficiency in inertial systems (e.g., enabling resonance oscillation in fish), its role in overdamped locomotion (e.g., nematode worms and sandfish lizards) remains unclear. Body elasticity can act locally (affecting a single joint) or be coupled (influencing multiple segments, as in snakes' multi-articular muscles). This study examines how body elasticity influences phase lag (the delay between torque and bending angle previously observed in like nematodes) and locomotion energy efficiency using a theoretical and robophysical three-link model (BL =0.42m) with local and coupled springs at joints. Simulations based on viscous-fluid resistive force theory were developed to analyze phase lags under varying environmental parameters. With coupled elasticity, increasing the fluid viscosity uniformly increases phase lag across both joints. In contrast, for local elasticity, increasing viscosity increases the difference of phase lag between two joints. The simulations and theory show that neither type of elasticity affects overall energy consumption. However, coupled elasticity redistributes energy across joints relative to local elasticity under the same gait. We hypothesize that this energy redistribution, determined by gait and stiffness of coupled elasticity, can balance muscle workload along the body in overdamped undulatory animals. Preliminary experiments of the robophysical model swimming in a granular medium reveal these effects persist in frictional fluids.

## The mitochondrial genomics of the Channel Islands gopher snake supports subspecies status

*Alexis Lindsey, Tonia Schwartz, Amanda Sparkman*

Island ecosystems often host organisms distinct from their mainland counterparts in physiology, behavior, and morphology. A trend observed globally on islands is a drastic increase or reduction in body size. The Channel Islands, off the coast of California, are home to several endemic species exhibiting reduced body sizes relative to the mainland; one species is the Santa Cruz Island gopher snake, Pituophis catenifer pumilus. Morphological and physiological data from two Channel Islands demonstrate that island populations are 30% smaller in body size, and have lower baseline glucose than their mainland counterparts, P. c. annectens and P. c. catenifer. In this study, we aim to understand the mitochondrial genetic divergence among island and mainland populations and their relative genetic diversity estimates as a proxy for their potential to respond to evolutionary pressures. To do this we use whole genome resequencing data from 77 P. catenifer individuals across islands and mainland locations, focusing on the mitochondrial genome. Mitochondrial haplotype networks indicate that the two islands cluster into haplogroups distinct from each other and the mainland locations. Evaluation of the amino acid changes indicates mutations exclusive to each island. Overall, our results support the subspecies distinction of island populations and reveal potentially functional genetic changes unique to each island. This novel information may be used to inform management decisions across island and mainland populations.

## Divergence in microbe-driven life history responses in a fig-associated nematode

*Austin Link, Kimberly Moser, Gavin Woodruff*

Both an organism's diet and its associated microbial communities can have profound influences on life history traits. For some nematodes, microbes are food. Variation in microbial environments and diets are then likely to be important drivers of divergence in these animals. Caenorhabditis elegans is a model organism associated with plant detritus; its sister species, C. inopinata, thrives in fresh figs. We are characterizing the natural microbes associated with C. inopinata. Fig metabarcoding has revealed over 3,000 OTUs associated with C. inopinata. Both nematode occupancy and pollinator number impact microbial communities. One OTU associated with fig interiors overlapped with a bacterial isolate we have cultured from figs. This novel Klebsiella species is capable of doubling the population growth rate of C. inopinata in comparison to standard laboratory bacterial food. Klebsiella sp. is capable of increasing population-level fecundity of both C. inopinata and C. elegans. However, whereas Klebsiella sp. promotes rapid maturation in C. inopinata, it has no impact on the developmental rate of C. elegans. Klebsiella sp. dramatically reduces larval-to-adult viability in C. elegans, whereas viability is unaffected in C. inopinata. Thus, divergence in microbial environments co-occurs with microbe-driven life history changes in hosts. Future work will leverage the sophisticated developmental genetic tools of the C. elegans to understand the evolution and genetic bases of host-microbe interactions in these animals.

## Using Google Trends to improve monitoring of the invasive spotted lanternfly in the United States

*Kade Lippitt, Caroline Maciejewski, Alex Huynh, Jonathan Katzenmoyer, Austin Dotta*

Invasive species pose significant threats to ecosystems and human industry and are being rapidly exacerbated by increased globalization and climate change. Effective monitoring of invasive species is crucial for control and eradication efforts, but traditional methods can be costly and resource-intensive. This study explores the use of Google Trends, a tool that quantifies internet searches made on the Google search engine, to monitor the spread of the spotted lanternfly (Lycorma delicatula), a recent invasive insect in the United States. We analyzed Google search data from 2014 to 2022 and compared it to official occurrence data pooled from a variety of government and citizen science-based sources. Our results show a significant relationship between the number of Google searches and the presence of the spotted lanternfly. Yearly patterns in Google search data align with observed population sizes, and seasonal patterns with the emergence of mature adult spotted lanternflies. Our results indicate that Google Trends may be particularly useful in complementing traditional monitoring methods. This approach could enhance future monitoring of the spotted lanternfly and possibly other invasive species to better inform conservation efforts.

## Multivariate models of animal sex: Breaking binaries in the brain, hormones, and behavior

*Sara Lipshutz*

Scientists often rely on a binarized operationalization of animal sex, in which two discrete sexes are defined by gamete type. However, "biological sex" can describe a complex suite of traits across multiple organizational levels, including neural, endocrine, and behavioral. To capture the full range of sex variability and diversity, we must critically assess our research approaches for studying sex-associated traits. Using several case studies from wild, free-living birds, I provide practical guidance for conceptual frameworks, experimental designs, and analytical methods for studying sex. There inclusive approaches advance our biological understanding of sex, and promote academically and socially responsible outcomes of our research.

## Constraints on thermoregulation explain disruptive selection on body size after an historic heatwave

*Jack Litle, Kindall Murie, Robin Fales, Emily Carrington*

A key challenge to understanding climate change impacts is predicting how warming will affect fitness-related traits in populations over time. One of the most universal responses to climate change is a reduction in body size. In ectotherms, body size reductions are due to either inability to compensate for heightened metabolic needs or development outpacing growth (the "temperature-size" rule). While the effects of long-term directional warming on size in ectotherms are well explained by metabolic scaling principles, the mechanisms by which short-term extremes (e.g. heatwaves) affect size are unclear. Here, we model heat and mass transfer in an intertidal population of the mussel Mytilus californianus to explain disruptive selection for body size observed in field surveys following an historic heatwave. We demonstrate that the direction of selection is dependent on microhabitat, with selection for small size in the high intertidal but large size in the low intertidal. Our biophysical model shows that constraints on evaporative cooling determine the direction in which selection acts: in the low intertidal, larger mussels avoid desiccation and stay cooler than small mussels. Conversely, in the high intertidal, where all mussels desiccate during long emersions, small mussels that rely on convective cooling have lower body temperatures. Overall, we uncover a mechanism that accounts for the effects of short-term extreme events on body size that contradict those caused by long term directional change.

## Genetic and epigentic characteristics of fine-scale dispersal in the Florida Sand Skink

*Victoire Litre, Faith Loggins, Katherine Miller, Paul Wieczorek, Chandler Eaglestone, Daniella Ray, Henry Mushinsky, Earl McCoy, Aaron Schrey*

Molecular markers can provide insights into the consequences of fine-scale dispersal of a species, which is critical for habitat management and species conservation. We report a genetic and epigenetic investigation of fine-scale dispersal in the Florida Sand Skink. This small, fossorial lizard is listed as threatened under the US Endangered Species Act and a species of greatest conservation need in Florida USA. The species is precinctive to the highly imperiled Florida scrub habitat, which is fire dependent and now exists as a series of fragmented habitat patches. We used microsatellites to characterize the genetic patterns and overlaid movement data to determine if there was a signature of dispersal. We used epiRADseq to measure DNA methylation. Dispersing individuals had higher heterozygosity and lower inbreeding than non-dispersers, and there was no allelic predictor of dispersal. DNA methylation differed among individuals with different dispersal distances. Integrating these findings with previous data indicates; 1) different highland ridges and fragmented scrubs have differentiated populations, 2) large scrubs also may have genetically and epigenetically differentiated populations, 3) fire history affects genetic and epigenetic characteristics, 4) there may be no strong genetic predictor of individual dispersal, yet there is evidence of an epigenetic signal of dispersal, and 5) home range size is approximately 700–1,960 m2.

## Advantages of centralized neuromechanical control architectures for locomoting on rough terrain

*Ellen Liu, Naris Asawalertsak, Poramate Manoonpong, Simon Sponberg*

Insects traverse uneven terrains effectively through complex interactions between their environment, body mechanics and neural control. The combined neuromechanical control architecture can be centralized, involving coordinated changes across many limbs, or decentralized, involving local corrections. Centralization is an emergent property of interactions of neural and mechanical coupling. We developed an empirical, model-free measure based on partial information decomposition to assess this coupling between neuromechanical modules.

We cannot easily prescribe and change the degree of centralization without concomitant changes throughout the animal, making it challenging to assess performance advantages of centralization. Instead, we designed a robot capable of varying its mechanical and neural coupling independently while maintaining the same control law. Changing the error for the feedback control from a single limb to an average across all limbs increased neural coupling. Reducing joint compliance between body segments and legs increased mechanical coupling.

This robophysical model indicates that more centralized architectures generally perform better on rough terrains, particularly in terms of speed. Neurally decentralized control may be more centralized overall, compared to a neurally centralized control with the same weak (decentralized) mechanical coupling. The environment itself affects centralization as the same mechanical and neural control strategy results in higher centralization on rougher terrain. This highlights the importance of environmental interactions and centralization as a complex trait in organisms and an important emergent design target in robotics.

## Population viability analysis of *Pan troglodytes schweinfurthii* in Gombe National Park

*Pamod Liyanagedara*

Compared to the total population size of Pan troglodytes schweinfurthii across its entire range, the Gombe National Park (GNP) population is relatively small. This is one of the most extensively studied populations of chimpanzees. Deterministic demography analysis (elasticity analysis), stochastic demographic analysis, and a structured population viability analysis (PVA) were performed for the GNP population, using the available 45-year age-structured matrix population model data. An elasticity analysis was performed to identify which age class's small relative changes in vital rates have the most impact on the asymptotic population growth rate. The stochastic demographic analysis involved calculating the stochastic population growth rate and associated confidence intervals for 1000 simulations. In the PVA, the population size after 50 years, the probability of quasi-extinction, the mean, median, and the earliest time of extinction were predicted. According to the elasticity analysis, the survival of age class 17 has the biggest impact on the population's growth rate. If no action is enforced and environmental conditions stay the same, there's a 99% chance the population will go quasi-extinct within 16-50 years (mean = 32 years). Expanding chimpanzee habitat to increase carrying capacity, reducing mortality rates by controlling diseases and eliminating poaching, increasing survival of age class 17, and introducing reproductive females from other populations could ensure the long-term persistence of the Eastern Chimpanzee in GNP.

## Longitudinal impacts of habitat fragmentation on Bartonella and hemoplasma dynamics in vampire bats

*Lauren Lock, Kristin Dyer, Anni Yang, Dmitriy Volokhov, Brock Fenton, Nancy Simmons, Daniel Becker*

Habitat fragmentation can have negative impacts on bats, including increased infectious disease risk. To assess temporal changes in pathogen dynamics in bats impacted by habitat fragmentation, we compared the prevalence and genotypic diversity of two blood-borne pathogens between vampire bats (Desmodus rotundus) from large and small forest fragments in northern Belize across five years. We predicted that infections would be more prevalent but less diverse in 1) the small vs large fragment, and 2) years associated with more forest loss. Forest loss within the matrix surrounding both sites was quantified to determine yearly fragmentation rates. DNA from 352 blood samples were screened for Bartonella and hemotropic Mycoplasma (hemoplasma) species through PCR amplification of the gltA and 16S rRNA genes, respectively. General linear mixed models were used to test if the effects of regional forest loss per year or site-specific factors influenced infection likelihood. We also tested the effects of bat sex, age, and reproductive status. There was no local site difference in infection prevalence when considering site alone for either pathogen. Bartonella prevalence was positively affected by forest loss in the large fragment only. Hemoplasma prevalence was not affected by forest loss, but genotypic composition was. The effects of habitat fragmentation on infection prevalence depended on both the pathogen and specific lineage. This complicates expectations of how habitat fragmentation affects infectious disease dynamics in bats.

## Symbiont density, chlorophyll a, & color intensity of temperate coral *Oculina arbuscula* from N.C

*Jamie Long, Troye Curtin, Claire Collier, Maya Powell, Karl Castillo*

Corals are the foundation of reef ecosystems that are instrumental to the health and abundance of a vast diversity of marine life. Anthropogenic increases in atmospheric carbon dioxide have led to rising ocean temperatures, which are correlated with decreasing symbiont density and chlorophyll a (chla) levels. Extreme levels of temperature stress can cause coral bleaching or complete loss of symbionts. Facultatively symbiotic corals, like Oculina arbuscula, can survive without symbionts by relying more on heterotrophic carbon and are thus useful models to study the physiological effects of coral bleaching. This study measured the natural variation in color intensity, symbiont density, and chla content between symbiotic and aposymbiotic colonies of the temperate coral Oculina arbuscula. Colonies of O. arbuscula were collected from Radio Island, NC, and symbiont density, chla, and color intensity were quantified. We found that symbiont density and chlorophyll a were significantly lower, and color intensity was brighter in aposymbiotic colonies, and these trends varied across seasons. These results demonstrate fluctuation in symbiont density, chla per cell, and color intensity in O. arbuscula based on symbiotic state, and could help improve our understanding of the effects of climate change-induced bleaching on coral reefs.

## Trends in herpesvirus prevalence and intensity in sea turtles stranded in coastal Florida

*Joseph Long, Katie Martin, Chris Sarkis, Anna Forsman, Erin Seney, Anna Savage*

Fibropapillomatosis (FP) is an infectious tumor disease that contributes to morbidity and mortality in endangered and threatened sea turtle populations and is especially prevalent in juvenile green turtles (Chelonia mydas). Population-level impacts of FP remain unclear due to lack of data and sampling scope. Chelonid alphaherpesvirus 5 (ChHV5) is the likely causative agent of FP, but differences observed in FP and ChHV5 prevalence among sea turtle populations occupying similar habitats are still poorly understood. We used qPCR to quantify ChHV5 in kidneys sampled from 187 dead green, loggerhead (Caretta caretta), and Kemp's ridley (Lepidochelys kempii) sea turtles that stranded on the Atlantic and Gulf coasts of Florida, USA in 2012 and 2017-2019. None of the C. caretta or L. kempii individuals were positive for ChHV5 or had FP tumors, but 14.6% of C. mydas were positive for ChHV5 and 83.6% had external FP tumors. ChHV5 and FP were significantly more prevalent in C. mydas stranded on the Gulf coast than on the Atlantic coast, and ChHV5 prevalence was significantly higher in 2017 than in 2019. ChHV5 intensity did not vary significantly by coast, sex, season, or year. Our results suggest that more thorough geographic sampling may reveal important factors driving FP in similar habitats. Our study highlights the value of using strandings-derived data to broadly characterize ChHV5 and FP occurrence in sea turtles.

## The effects of parasite risk on host physiology

*Patricia Lopes, Bennett Hardy, Arly Adame, Amir Adams, Madeleine Chang, Sean McCallum, Luana Oliveira, Morgan Rea, Sophia Santangelo*

It is well established that parasites can alter both the physiology and behavior of their hosts post-infection. However, there is evidence suggesting that parasites can affect hosts even before infection, as animals may detect and respond to the risk of parasitism. This concept has been primarily explored from a behavioral ecology standpoint, leaving the physiological responses to parasitism risk relatively unexplored. To investigate these potential physiological changes, we conducted an experiment where healthy domestic canaries (Serinus canaria) observed canaries either infected with Mycoplasma gallisepticum (MG), which present behavioral and physical symptoms of infection, or symptom-free, sham-infected controls. After six days, we collected samples from the observers' blood, liver, spleen, and hypothalamus. We also stimulated an aliquot of the sampled blood with an antigen (lipopolysaccharides, LPS). RNA was obtained from these five sample types. Using RNA-seq, we analyzed gene expression differences between observers of MG-infected and sham-infected canaries. While the hypothalamus, spleen, and unstimulated blood showed minimal differences, the liver and, most dramatically, stimulated blood samples showed drastic differences between observer treatments. Specifically, molecular pathways, such as increased complement activity, were more active in the LPS-stimulated blood of observers exposed to parasitized conspecifics, indicating a heightened immune response. These results suggest that the perception of parasitism risk can trigger anticipatory physiological responses, thus broadening our understanding of how parasite risk affects populations.

## Enhancing aquaculture through selective breeding: producing disease-resistant *Crassostrea virginica*

*Denia Lopez, Jessica Small, Amanda Chesler-Poole*

Despite years of overfishing and suffering mass mortality due to the presence of oyster disease, prevailing research efforts have led to the rapid growth of the oyster aquaculture industry along the eastern coast of the United States. Here we focus on the continuous oyster-breeding research program conducted by Virginia Institute of Marine Science (VIMS) – Aquaculture Genetics & Breeding Technology Center (ABC). Through selectively breeding eastern oysters (Crassostrea virginica) and rearing them under controlled conditions, we aim to genetically improve ABC's unique brood stock by enhancing disease resistance and industry favored traits – survival, total weight, meat yield, and cup shape. To produce the best possible new generation of brood stock, we followed strict early life stage husbandry procedures prior to field grow-out. Daily water quality of tank systems was also monitored along with the completion of health assessments every two days prior to reaching the pediveliger stage of the life cycle. This overview of cultivating superior oysters for industry success encompasses our methodology throughout the life cycle of an oyster from single gamete to mature adult.

## Utilizing agent-based modeling to understand amphibian life cycle ecology and evolution

*Jesus Lopez, Ashley Teufel, Robert Page*

Many amphibian species undergo complex life cycles, where larvae develop in a deteriorating environment. Larvae must balance consuming resources and metamorphosing quickly enough to escape their shrinking pond. This process has been difficult to model due to the complex interplay of environmental, physiological, and genetic factors influencing metamorphosis. We have developed an agent-based model leveraging data on Ambystoma maculatum to capture the key features of the ecology and evolution in many amphibian life cycles. Our model simulates agents through four developmental stages: egg, larva, juvenile, and adult, with parameters corresponding to the real-life attributes of amphibian organisms. These include chromosomes with genes that can either contribute additively to metamorphic risk or remain functionally neutral. The environment in the model consists of patches with parameters for agent mortality risk, habitat permeability, and food availability, with the ability to import GIS data files. The model is highly configurable, allowing for the modeling of different amphibian species and heterogeneous environments across various parameters. Additionally, it supports different use cases, offering flexibility through a user-friendly interface or parameter and output files for more specific needs. We have utilized the model to study gene flow and natural selection under several spatial scenarios with varying numbers of ponds with unique hydroperiods. The model has the potential to serve as a powerful tool for conservation, research, and education.

## Investigation of Acute Activity Responses in Honey Bees Exposed to Thermal and Desiccation Stress

*Kiara Lopez, Brendon Blake, John Hranitz, Victor Gonzalez, John Barthell, Thomas Tscheulin, Theodora Petanidou*

Pollinator numbers are declining, caused partly by climate change. Prior research suggests that honey bees rely on the circadian rhythm of everyday activities, such as foraging, social communication, and time memory, to use environmental resources. The effect of stressors on the circadian rhythm of pollinators, and aspects of plant-pollinator phenology, are poorly understood. Because climate change introduces many stresses, especially thermal and desiccation stress, we hypothesized that thermal stress and desiccation stress impact honey bee circadian rhythm. This research was a pilot study of Apis mellifera on the Greek island of Lesvos. We used a Drosophila Activity Monitor to record the movements 24h before and after treatment. We studied four 3-h treatments: negative control, positive control (ethanol-induced stress), heat stress (40 °C), and desiccation stress (0% RH). Bees in heat and negative control groups showed coincident increased activity levels over time (P desiccation stress showed activity like the heat stress and negative control groups but changes were not different over time ($P>0.05$). Positive control bees decreased (P after treatment. Our results suggest that (1) acute responses were driven by the existing circadian rhythm in three treatment groups and (2) the positive control effectively altered activity level. Our future studies should assess the impact over multiple days and multiple exposures to study effects on honey bee circadian rhythm.

## A dead bone's story: Antlers as signals or tools?

*Nicole Lopez*

Sexually selected weapons are morphological adaptations that arose from strong intrasexual competition. While the benefits of large weapon sizes are well understood, relatively little is known about the variation in weapon shape. Sexually selected weapons may function as "tools" of battle and as "signals" in threat displays, both likely contributing to their evolutionary diversification. Yet it has been difficult to assess whether specific aspects of weapon shape evolved for fight performance or as sexual signals. In my study, I use finite element models (FEMs) to study form-function relationships in antlers of North American elk (Cervus canadensis) to quantitatively tease apart components of antler shape specifically related to signaling. Using computed tomography (CT) scans of adult male elk skulls and natural morphological variation measured in the field, we created highly accurate three-dimensional (3D) models of elk antlers. Using finite element software, we applied force loads, like those experienced in dangerous fights, to predict likely locations of weapon failure and allow me to define parts of the antler functioning primarily as signals rather than tools. My project offers a critical first step towards a larger comparative study of the importance of agonistic signaling to the evolutionary diversification of cervid antlers.

## Investigating the evolution of fighting tentacles in two species of sea anemones

*Rowan Lopez, Sarah Arnold, Kennedy Bolstad, Leslie Babonis*

The clonal sea anemone, Metridium senile, develops specialized fighting tentacles, called catch tentacles, from feeding tentacles to defend their territories against non-clonal individuals. Catch tentacles are populated by a special type of stinging cell found only in this tissue and contact with these cells can result in necrosis and even death. Metridium farcimen, a sister species of M. senile living in the same habitat, does not make catch tentacles. This phenomenon raises the question: How do novel traits arise? To answer this question, we compared the different tentacle types from the two species to identify the cellular and molecular traits unique to catch tentacles. Using light microscopy, we show that the stinging cells in catch tentacles are more homogeneous and more regionalized than they are in feeding tentacles. Using a marker of cell proliferation, we identified a population of progenitor cells in the base of the catch tentacle that are the likely source of the catch-tentacle specific cnidocytes. Furthermore, we sequenced the transcriptomes of both catch tentacles and feeding tentacles to identify the differentially expressed genes in the catch tentacles. These experiments connect gene expression to cell identity to understand the processes that affect the genome's capacity to make novel traits.

## Exploring the drivers of gut microbiome diversification in *Anolis* lizards

*Yanileth Lopez, Carrie Alfonso, Karla Alujevic, Leah Bakewell, Samantha Fontaine, Jaden Keller, Nathaly Ponce, Alejandro Vivas, Claire Williams, Kelly Wuthrich, Christian Cox, Michael Logan, W. Owen McMillan*

Animals maintain complex associations with diverse microbiota residing in their guts. The composition of the gut microbiome can be influenced by various factors, including the environment and the host's genetic background. In several taxonomic groups, studies have shown a positive correlation between host genetic and microbiome divergence among species, a phenomenon called phylosymbiosis. While our understanding of the relative roles of host species and environments in microbial community assembly is growing, it remains limited in reptiles. Anolis lizards are an excellent model for studying the factors that drive microbiome diversification as anoles often live-in diverse communities of related species that occupy different microhábitats and consume different prey items. To achieve this, we studied a community of anoles from a lowland tropical rainforest site in the mainland and islands in central Panama to determine if microhabitat or species identity has a stronger effect on gut microbiome composition. We collected fecal samples from six species in the mainland and from two species on an experimental island in the Panama Canal across 2 years and used 16S rRNA gene sequencing to inventory their gut bacterial communities. We use these data to understand the drivers of diversification in Anolis gut microbiomes, and their stability across years. Our work will give insight into how the microbiome can influence resilience to rapid environmental change in vulnerable species.

## Nudibranch novelty: Spatial-transcriptional characterization of cerata in Berghia stephanieae

*Rebecca Lopez-Anido, Teresa Attenborough, Kate Rawlinson, Jessica Goodheart*

One important driver of diversification is the emergence of novel traits. As an incredibly diverse group of shell-less marine gastropods, nudibranchs exhibit many unique characteristics that are thought to contribute to their diversity. This is exemplified in cladobranch nudibranchs' cerata, which are elongated dorsal extensions that house their branched digestive gland. In select taxa, cerata evolved a specialized organ called the cnidosac, where they steal and store stinging organelles (nematocysts) from their prey. However, we do not fully understand how this novelty arose. To address this, we must consider which genetic modifications are involved in transforming ancestral cerata tissues into the novel cnidosac. Here we leveraged Visium Spatial Gene Expression in the model nudibranch Berghia stephanieae to characterize the genetic signatures of different tissues within the cerata, which allows us to understand how the cnidosac is specialized from ancestral tissues. We confirmed the presence of distinct digestive and cnidosac clusters within the cerata, and we identified the most upregulated genes in each cluster. In the cnidosac, we found expression of both highly conserved phagocytotic genes and clade-specific unannotated genes. This suggests that both gene co-option and novelty are important mechanisms in cnidosac construction. Together, our results provide a new layer of morphological and transcriptomic information that not only furthers our knowledge of nudibranch novelty, but also enhances our broader understanding of how novel tissues arise.

## Olfactory rhythms and sleep patterns in *Aedes aegypti*

*Lan Lou, Karthikeyan Chandrasegaran, Joshua Benoit, Zhijian Tu, Chloe Lahondere, Clement Vinauger*

Biological rhythms are crucial to the epidemiological role of mosquitoes by synchronizing their activity and host-seeking behavior with moments of the day when hosts are available and least defensive. In particular, olfactory rhythms allow mosquitoes to be active and responsive to host cues at optimal times of the day. However, despite clear epidemiological relevance, we know very little about the mechanisms underlying the interaction between the chronobiology and the olfactory behavior of Aedes aegypti mosquitoes. Combining analytical chemistry, quantitative analysis of behavior, and transcriptomic analyses, we found that daily rhythms in genes coding for sensory proteins and genes implicated in blood digestion underlie the host-seeking patterns of the yellow fever mosquito Ae. aegypti. Using CRISPR/Cas9, we generated a timeless knockout line of Ae. aegypti that is arrhythmic when maintained under constant darkness conditions. This line, whose molecular clock is deficient, allowed us to identify key aspects of olfactory rhythms controlled by the mosquito's circadian clock. In addition, knocking out the timeless gene affected the sleep-wake patterns of the mosquitoes, demonstrating the role of the central clock in regulating sleep-like states in this species. Results will be discussed in the context of the evolution of host preference and the potential for vector control strategies.

## Microplastic abundance in fish species with differing feeding habits in a large midwestern river

*Michael Louison*

Microplastics have emerged as a major contaminant of concern in a host of ecosystems, including freshwater systems. Previous work has documented the abundance of microplastics in the bodies of various organisms, finding that aspects of an animal's niche (feeding habits, habitat choice, etc.) may influence exposure to microplastic contamination. To further our understanding of microplastic abundance in freshwater systems, we conducted a survey of freshwater fish taken from the lower Kaskaskia River in Southern Illinois, USA. The first sampling site (done via direct current boat electrofishing) was stationed directly below the Carlyle Lake dam (a heavily used recreational site with abundant pollution from litter) with two additional downstream sites also sampled. Five species of fish (flathead catfish Pylodictis olivaris, freshwater drum Aplodinotus grunniens, smallmouth buffalo Ictiobus bubalus, white crappie Pomoxis annularis, and gizzard shad Dorosoma cepedianum) of differing feeding ecologies were sampled, dissected, and subsequently examined for microplastics both visually (examinations of gills and stomach contents under microscope) and chemically (analysis of nanoplastic concentration in muscle tissue). Results revealed differences in microplastic load between fish species and between sites, as well as differences in measures of contamination using visual and chemical methods. Our results add to the present knowledge of microplastic abundance in organisms, and specifically how feeding type and proximity to sources of human pollution may impact microplastic abundance in freshwater fish.

## Reflections on evo-devo as a mature scientific discipline: looking back and peering forward

*Alan Love*

Modern evo-devo burst onto the scene with the discovery of conserved Hox genes that control anterior-posterior formation in animals. However, it was seeded by earlier work from different approaches. This diversity of approaches became constricted through the 1990s as developmental-genetic tools became standardized and applied to many non-model organisms. However, the formalization of evo-devo in 2000 as a discipline within SICB initially retained much of this diversity, in part because it could be found in other divisions. The diversity was also present in new journals established around that time (e.g., Evolution & Development).

Much of this diversity was subsequently erased and not necessarily for unexpected reasons. The coordination of diverse approaches and their evaluation is a difficult task; scientific disciplines require a narrowing of methods and approaches to sufficiently "discipline" these professional units. Additional structure, such as the Pan-American Society for Evolutionary Developmental Biology, has exacerbated this dynamic. By looking back at this recent history of evo-devo, we are positioned to peer forward into its future and potentially shape it more productively. Recovering some of this lost disciplinary diversity is crucial to answer research questions related to the evolution of development and developmental basis of evolution. I offer one concrete example from new work on the importance of cellular metabolism in explaining the origination of tissue and organ level organization within organisms.

## Exploring radiation stress and the immune landscape in Chornobyl

*Cara Love, Brian Arnold, Stacey Lance, Nicolas Rochette, Tom Hinton, James Beasley, Dmirty Shamovich, Michael Byrne, Sarah Webster, Shane Campbell-Staton*

Understanding the complex interactions between contaminant exposure, physiology, and evolution in wild populations is essential for assessing the impacts of human-driven environmental changes. Such research can illuminate broader health implications of these changes and offer novel models for studying adaptive responses to complex diseases. In this context, we investigate the effects of chronic exposure to an immune modulator and oncogenic stressor, ionizing radiation, on gray wolves (Canis lupus) in the Chornobyl Exclusion Zone (CEZ). With analysis of epigenetic alterations and genomic structural variants, we identify putative candidates that contribute to molecular signatures of immune regulation and adaptive evolution. Through a multilevel approach we explore persistent changes in PBMC populations among Chornobyl wolves and highlight regulatory divergence at both single-gene and co-regulatory levels. Altered expression mechanisms and structural variants contribute to modified gene expression patterns and putative genomic regions under selection. These findings highlight radiation-induced immune modulation, cellular apoptosis, and candidate adaptive antitumor biological responses as potential physiological outcomes of chronic radiation stress in this CEZ population.

## Water restriction during development impacts water balance physiology and fertility in Octodon degus

*Josephine Low, Carolyn Bauer, Yuta Sato, Tate Garcia*

Octodon degus is a caviomorph rodent species endemic to the Chilean matorral. In this habitat, degus experience predictable seasonal variation in precipitation, where most of the year's rainfall occurs during the winter when degus are pregnant. However, annual rainfall is highly variable, and is currently becoming more so due to climate change-induced aridification. Because winter rainfall is the main predictor of annual food availability, water cues during gestation likely have important impacts on offspring development and future fitness. We hypothesized that degu pups which developed under water-restricted maternal conditions would express more conservative water balance physiology. Throughout gestation and lactation, captive-bred pregnant females were given either 80% of their average daily water intake or ad libitum water. Pups were weighed regularly until 28 days post-parturition. We then used open-flow respirometry to evaluate basal metabolic rate and evaporative water loss in pups, and collected water-deprived urine samples to assess urine concentrations via osmometry. Finally, we mated female offspring at 4 months of age to assess whether developmental water restriction impacted reproductive output.

## What is driving zooplankton community changes in eutrophic lakes?

*Kaylee Luchansky, Joseph Covi*

Zooplankton are not included in water quality monitoring in North Carolina and this oversight could allow zooplankton community changes to go unnoticed during eutrophication. Eutrophication is caused by the influx of nutrients, like nitrogen and phosphorus, and can produce harmful algal blooms that generate dangerous toxins. Algal toxins can harm zooplankton, which are a crucial intermediary species in energy transfer between phytoplankton and larger organisms, such as fish. The goal of this study is to identify the connections between zooplankton community changes and eutrophication. Zooplankton were collected from one eutrophic to hypereutrophic lake (Jordan Lake, NC) and one historically oligotrophic lake (Shearon Harris Reservoir, NC). The active zooplankton were assessed for abundance, biomass, and diversity to compare community structures between lakes of differing trophic status. During eutrophication season in Jordan Lake, zooplankton abundance increased as blooms occurred, and subsequently declined following bloom crashes. While overall abundance increased, copepods and cladocerans decreased in abundance while rotifers increased. A detailed analysis of zooplankton community dynamics over the course of a eutrophication season will be presented.

## Solving the species-boundary puzzle in the clownfish-hosting sea anemones: Clade Heteractinia

*Nina Luckas, Aurélien De Jode, Estefanía Rodríguez, Benjamin Titus*

The most famous mutualistic symbiosis, between clownfishes and their sea anemone hosts (Anthozoa: Actinaria), can be found throughout tropical coral reefs in the Indian and Pacific Ocean. Ten described species of sea anemones can be divided into three clades that have evolved symbiosis with clownfishes independently. Though less diverse in number, the clownfish-hosting sea anemones have only been described morphologically yet display a wide range of intraspecific phenotypic appearances that can make in situ field identifications challenging. The exact number of host species is unknown. Of the three host clades, Clade Heteractina, is particularly challenging systematically and contains the least well studied host anemones. Here we conduct phylogeographic sampling of Clade Heteractina and use UCE (ultraconserved element) and RAD-Seq to test species boundaries in Heteractis aurora, Radianthus crispa and R. doreensis where they co-occur. Each species forms clear species boundaries from samples collected outside the Japanese Archipelago, yet form a single clade where they co-occur in Japan. These results suggest ongoing hybridization and poor reproductive isolating mechanisms in Clade Heteractina. All three species from Japan were identified in the field via photo ID. Detailed morphological investigations are needed to further clarify the systematics of this group, as well as the incorporation of R. malu into genomic analyses. Further sampling is also needed to test whether hybridization within Heteractina is common outside the Japanese Archipelago.

## Three direct steering muscles fine-tune robust roll control in freely-flying drosophila

*Kemper Ludlow, Samuel Whitehead, Han Kheng Teoh, Itai Cohen*

Flapping flight is an inherently dynamically unstable endeavor, yet insects such as fruit flies perform remarkable feats of aerial maneuverability and maintain their stability on timescales of mere milliseconds. Elucidating the neuromuscular basis of this fast flight control provides significant insights into motor control more broadly. Here, we focus on the fly's most unstable degree of freedom: roll. We selected three steering muscles, i1, i2, and b3, which share inputs from the haltere and were implicated previously in roll control in tethered preparations. Using a set of sparse split-gal4 lines, we assess their function in free flight with optogenetic activation, optogenetic inhibition, and chronic inhibition experiments. Simultaneously, we can introduce aerial "stumbles" to directly probe the response to sudden changes in body roll.

In response to these stumbles, we find flies use a flexible combination of distinct wing kinematic strategies to correct their body roll angle. Quasisteady aerodynamic simulations confirm each of these changes can independently drive roll torque. Free-flight optogenetic activation and inhibition experiments show each motor neuron affects wing kinematic changes consistent with a subset of these strategies. Interestingly, inhibition of individual motor neurons during perturbations alters the distribution of correction strategies without affecting the overall ability to maintain its roll stability. These experimental results demonstrate a strategy for robust stability control using a relatively sparse motor system in a complex, unpredictable environment.

## Thermal preferences in wild mangrove rivulus fish (*Kryptolebias marmoratus*)

*Reid Ludwick, Alexander Cheng, Noah Ohsiek, Aidan Salcido, Belle Fant, Mary Monroe, Riley Wood, Ryan Earley*

As climate change accelerates and quality habitats grow more scarce due to human activities, it is crucial to understand where in these vulnerable ecosystems animals prefer to exist. In mangrove systems, microclimates are naturally formed due to sporadic canopy cover, which forces organisms to cope with thermal challenges daily. This study investigates the thermal preference and activity levels of the mangrove rivulus fish (Kryptolebias marmoratus) in Twin Cayes, Belize. We aimed to determine how variations in water temperature, driven by varying canopy cover, affects thermal preference and activity levels. We hypothesized that rivulus would exhibit a preference for water temperatures similar to those found in their native microhabitats (e.g., 25-27°C), with decreased activity levels in these preferred conditions. Trials were conducted in thermal gradient arenas, divided into three sections: full shade (cool), partial shade (warm), and full sun (hot) with constant temperature monitoring. Fish were acclimated in partial shade for 5 minutes before being released to choose their preferred thermal environment. Activity levels and selected microclimate were recorded over a 10-minute observation period. Our preliminary results will provide insights into how animals within highly heterogeneous mangrove ecosystems might behaviorally thermoregulate.

## Local adaptation to temperature in a coastal fish: implications for resilience in a warming ocean

*Alexis Lundquist, Darren Johnson, Thea Cole*

Ocean warming is a threat to many species, but the long-term outlook for any population will depend on the population's capacity to evolve. One potential source of genetic variation is local adaptation to environmental conditions. For example, if individuals inhabiting cooler waters have cold-tolerant genotypes and individuals inhabiting warmer waters have warm-tolerant genotypes, then local adaptation could promote genetic variation in the population as a whole. We tested for local adaptation of thermal sensitivity in populations of California Grunion. We collected the gametes of northern and southern populations and reared embryos and larvae in a common laboratory environment. Larvae were reared across temperatures reflecting their natural range and we measured growth and mortality. Southern populations were much more sensitive to temperature and had a higher capacity for growth under higher temperatures. Mortality was lowest at intermediate temperatures and northern and southern populations did not show a strong difference in thermal sensitivity of mortality. When examining the effects of temperature on biomass production (combination of survival and growth), we found that southern populations indeed have a higher thermal optimum than northern populations. Grunion experience gene flow at large spatial scales and our results suggest that adaptation to local temperature conditions can increase overall heritability in thermal sensitivity by 25 to 75%. Local adaptation may thus increase the population-wide capacity for evolutionary adaptation to climate change.

## The Effects of Vertebral abnormalities on Swimming Performance in Lumpfish, Cyclopterus lumpus

*Taylor Lunningham, Katelyn Sewcharran, Jules Johnson, Elizabeth Fairchild, Jessica Robinson, Stacy Farina*

Vertebral deformities such as abnormal curvatures and shapes may influence biomechanical performance of fishes during swimming. For example, stiffening of the vertebral column is known to influence locomotion in significant ways. The study was performed to track the occurrence of vertebral deformity in lumpfish (Cyclopterus lumpus) to better understand the frequency and conditions in which bone deformation occurs in this species. Observations were made with video analysis of 105 juvenile lumpfish. Individuals were selected from roughly 1,500 others, raised as cleaner fish for salmonid farms, in the flow-through seawater system at the University of New Hampshire Coastal Marine Laboratory. Lumpfish were filmed individually while housed with 15-20 other individuals to reflect their regular rearing density. Each of the groups of lumpfish were observed in 10-second video intervals and then immediately euthanized for X-ray. Using ImageJ and R, we calculated the distance traveled over time for average speed. Initial analysis of videos and X-rays of 20 individuals show that lumpfish with a high degree of skeletal abnormalities have similar volitional swimming speeds to lumpfish with no abnormalities. Body shape analysis in R showed high deformity individuals were outliers. While there was no significant difference in voluntary straight swimming, we will present other swimming kinematics, extracted from DeepLabCut using deep neural networks for markerless pose estimation, such as tailbeat frequency, tailbeat amplitude, and midline curvature.

## Quantifying and characterizing microplastic contamination in the greater Philadelphia area

*Emily Lybashev, Alex Korbobo, John Balmonte, Colleen Bove*

Plastic is one of the world's most useful and versatile materials, so no wonder 400 million tonnes are produced yearly. When exposed to weathering and heat, plastic degrades and produces microplastics. These microplastics have managed to leech into our oceans, local waterways, bodies, and even our air. The negative implications of microplastic contamination in our environment are slowly being uncovered and more accurate estimates of microplastic concentrations in aquatic ecosystems are necessary. Here, we present the preliminary results of a temporal and spatial microplastic study across the Schuylkill River Watershed and Perkiomen Creek in eastern Pennsylvania. Based on preliminary sample collections, we observed that the Schuylkill River Watershed contains microplastics across all sampling sites, including the headwaters. The plastics contributing most to this debris are primarily the result of consumerism and infrastructure, such as tributyl phosphate, poly(vinyl formal), polyethylene, and 1,2-polybutadiene. Finally, to evaluate the physiological effects of microplastic exposure on aquatic organisms, we performed a laboratory mesocosm experiment exposing the invasive crayfish species, Faxonius Rusticus, to different microplastic concentrations. Together, this work highlights the cosmopolitan nature of microplastics across local aquatic ecosystems and provides insight into the physiological implications plastics have on aquatic organisms.

## Uniting Tinbergen's four questions to understand brood parasitism in birds

*Kathleen Lynch*

Avian brood parasites lay their eggs in the nest of other species rather than provide parental care to their own offspring. By shirking caregiving behaviors, brood parasites increase their annual fecundity by at least ten times compared to that of other related species. Thus, brood parasites tradeoff parental care for increased reproductive output. Even though brood parasitism has fascinated biologists and non-biologists for centuries, it still represents a behavior in which Tinbergen's four questions regarding the ultimate and proximate causes of behavior remain disconnected. This is because nearly all studies of this behavior focus wholly on the ultimate perspective. I will discuss our studies using the comparative approach to understand the neuroethological and behavioral endocrinological basis of this behavior. We have compared closely related species that are parasitic and non-parasitic to identify differences in reproductive and stress physiology as well as transcript abundance of prolactin receptors in socially relevant brain regions. We also have identified species differences in how hormones, such as mesotocin, modify parental-related transcripts in specific brain regions. I will present these studies together to discuss what we know so far about the proximate mechanisms associated with parasitic behavior and the future directions we should take to identify whether these mechanisms are a cause or a consequence of losing parental care in these species.

## Intraspecific variation in the vestibular system of North American river otter

*Leigha Lynch, Dominik Valdez, Celeste Delap, Heather Smith*

Inner ear morphology has been studied extensively across mammals to characterize evolutionary relationships and behavioral variation. Yet despite our interspecific understanding of this system, little is known about how behavioral and environmental variation influence intraspecific vestibular morphology. Using Lontra canadensis, a geographically, environmentally, and behaviorally diverse species, as a model, we tested the relationship between variation in the inner ear and environment. We measured semicircular canal length, volume, and surface area in 24 river otters collected from Washington, Alaska, Arkansas, Tennessee, and Florida. In almost all specimens, posterior semicircular canals were largest followed by lateral and then anterior. Morphology of the vestibular system significantly differed among populations, with individuals from WA having larger lateral and posterior canal volumes, lengths, and surface areas. Interestingly, we found no allometric relationship between skull and vestibular system size suggesting that these differences are not simply a result of these WA specimens being larger. We then tested whether there was a correlation between vestibular morphology and water and climatic variables from each specimen's county and year of collection. Morphology significantly correlates with water discharge levels, driven by high discharge in WA. This suggests that faster moving bodies of water drive evolution of larger, more robust semicircular canals to maintain balance and adjust during aquatic locomotion and prey capture. Continued research into locomotor variation among these populations may reveal further information.

## Hidden trophic diversity in early ray-finned fishes: evidence from the Carboniferous Sphaerolepis

*Zachary Lyons-Weiler, Sam Giles, Matt Friedman*

Paleozoic ray-finned fishes (actinopterygians) have long been considered morphologically depauperate, often grouped into "wastebin" taxa that obscure true interrelationships. The late Paleozoic is a crucial period in actinopterygian evolution, with the crown radiation estimated to have originated around this time. Advancements in micro-computed tomography (μCT) have shed light on aspects of early actinopterygian structure, particularly on jaws and teeth which provide clues both about the paleoecology of early actinopterygians and faunal changes in aquatic settings in the fossil record. Renewed fieldwork and study of collections at the Carnegie Museum reveal a fauna of Carboniferous (Gzhelian, 302 Ma) fishes rich with anatomical disparity. One form, Sphaerolepis, is known from contemporary deposits in Europe and has been reconstructed as having a typical "palaeoniscoid" skull with unusual mandibular teeth. μCT of articulated specimens from the Casselman Formation shows that Sphaerolepis corroborates these reports and shows a unique pattern of peg-like teeth on the palate and opposing dermal elements of the mandible. Sphareolepis does not appear closely related to eurynotiforms, a coeval group with a palatal bite, pointing to independent origins of this specialization among Carboniferous ray-fins.These findings provide further evidence that early actinopterygians were more morphologically disparate than previously imagined, providing a new perspective on their first major evolutionary radiation. This research was funded by NSF grant EAR-2219007.

## Using directed graphs to test the riverine barrier hypothesis with genetic data

*Garett Maag, Austin Biddy, Maya Stokes, Greer Dolby*

While rivers are thought to be barriers, evidence for this in the literature is conflicting. However, conflicting evidence could be due to the diversity of river and organisms characteristics. To address this, we used published genomic data for organisms whose range spans a river channel and paired that with river attribute data (discharge, seasonality of discharge, and river width) for locations where the genomic data was taken. In total we measured river-associated differentiation in 27 genomic datasets of lizards, snakes, birds, trees, an herb, and a mouse that collectively spanned 24 different river segments across the contiguous United States. We used Directed Acyclic Graphs to articulate direct and indirect relationships of river variables, geographic distance, and tested effects using structural equation modeling in 38 models. We found that discharge positively affected population differentiation but was negated by its indirect effects on other river attributes. Low dispersing species were more affected by river width, but this relationship was consistently negative. While surprising, we interpret this as: 1) narrow channels occur more at higher elevation where incision is deeper and potential dispersal-impeding topography is greater, and 2) river meanders and avulsions increase river width, occur in low-lying areas, and can facilitate dispersal. Overall, we find graph structures may be a helpful tool to capture the nuance and internal complexities of physiographic features.

## New genome and vision-related genes of an eyed hydrozoan (Cnidaria)

*Aide Macias-Muñoz, Rebecca Varney, Eva Katcher, Maia Everhart, Todd Oakley*

The extent to which similar complex traits arise by using similar genetic components remains elusive. Eyes are a complex trait that have evolved convergently at least 40 times among animals. A rise in research of visual systems in non-model organisms shows that there are many ways to make an eye and detect light. Yet, gaps remain as to the principles of genetics underlying eye evolution. Cnidaria, the phylum that encompasses jellyfish, sea anemones, and corals, has at least 9 instances of convergently evolved eyes, making it an interesting group in which to investigate the molecular evolution of vision-related genes. Here, we present a new genome for the eyed Bougainvillia muscus and explore the evolution of gene families with known visual functions in model organisms. Our genome consists of 350 scaffolds with an N50 of 10 MB, a total genome length of 375.328 MB, a BUSCO score of 90.1%, and 46,431 predicted protein coding genes. We identified 24 opsin-like genes, 20 of which are likely cnidopsins. Investigation of gene families used for eye development and phototransduction found that Bougainvillia genes grouped together with other Hydrozoans. While the opsins are undergoing duplication events, we did not find many duplications in other vision-related genes. This new genome can be used for comparative studies providing insight into changes at the genome-level that may contribute to the development of eyes.

## Measuring avoidance of predator odor cues in wild birds

*Caroline Maciejewski, Austin Dotta, Jonathan Katzenmoyer, Kade Lippitt, James Knowles, Afaf Nazif, Alex Huynh*

Advances in our understanding of avian chemical communication have highlighted the importance of olfaction in various aspects of avian behavior, including communication and foraging. However, prior research has yielded mixed results regarding how different bird species respond to predator odor cues. This study, which will be carried out in September 2024, aims to assess whether a community of birds in eastern Pennsylvania exhibits avoidance behaviors in response to predator odor cues. We will use clay caterpillars to quantify predation activity by insectivorous birds in an agricultural setting (corn). Caterpillars will be paired with one of three odor treatments: predator (bobcat) urine, non-predator (rabbit) urine, and water. Caterpillars will be checked daily for evidence of bird attacks (i.e. peck marks). We hypothesize that birds will reduce foraging activity in the presence of predator odor compared to non-predator and water controls. Our results will contribute to our growing understanding of avian olfaction and its specific role in predator-prey interactions.

## Behavioral and neural correlates of magnetic sensing in poison frogs

*Alayna Mackiewicz, Abigail Trocinski, Kenneth Lohmann, Sabrina Burmeister*

Although diverse animals, including amphibians, can sense Earth's magnetic field, the biophysical mechanisms underlying magnetoreception remain enigmatic. Poison frogs in the family Dendrobatidae are capable of short-distance homing and exhibit complex spatial navigational strategies to aid their intensive parental care. The goal of this research was to determine if green-and-black poison frogs (Dendrodates auratus) possess magnetic sensitivity and investigate the neural basis of magnetoreception. Individuals were first tested using a spontaneous magnetic orientation behavioral assay. Frogs as a group exhibited bimodal orientation along the magnetic northwest-southeast axis, demonstrating magnetic sensitivity. To determine where in the brain magnetic information is processed, frogs were exposed to either a changing magnetic field, sham magnetic field, or no change in magnetic field stimulus. We then compared patterns of neural activity in various brain regions using immunohistochemistry for phosphorylated ribosomes (pS6) as a proxy for neural activation. Results from this study may help localize areas of the brain used in magnetoreception and provide insight into the underlying mechanisms of magnetic sensing in amphibians.

## Effects of anthropogenic sound on bluegill (*Lepomis macrochirus*) nesting behavior

*Macey MacLean, Leah Glimsdal, Allen Mensinger*

Anthropogenic sound negatively impacts fish spawning behavior, and sound intensities increase in northern lakes during summer due to increased recreational motor craft activity. Male bluegill (Lepomis macrochirus) establish nests and protect developing young from predators. Therefore, the effects of anthropogenic sound on guardian male behavior was assessed. Underwater viewing arrays (UVAs) utilized GoPro cameras, a SoundTrap hydrophone, and an underwater speaker to observe male bluegill spawning behavior during prerecorded boat motor sound. UVAs were submerged near bluegill nests on Elliott

Lake in Makinen, MN. Fifteen minutes after deployment, motor sound broadcasted for two minutes at twelve-minute intervals for a total of four sound presentations. Control trials had equipment deployment without sound playback. Videos were analyzed using Behavioral Observation Research Interactive Software (BORIS) for fish presence, nest rim circling, time paused from circling, and phonotaxis. Significantly more fish were present during sound trials compared to control trials ($p<0.001$). Following sound offset, guardian males stayed near nests, and non-nesting fish entered the view resulting in the guardian males temporarily abandoning nests to chase invaders with invader number increasing after each sound interval ($p<0.001$). Motor sound indirectly impacts nesting bluegill by decreasing time spent protecting nests thus increasing larval mortality. The increase of invading fish during experimental trials can be attributed to distracted circling fish leaving their nests. Abandoned nests provide opportunities for predators to ambush nests.

## Phylogenomics and floral evolution in *Agave* subgenus Manfreda

*Bryan MacNeill, Michael McKain, Eduardo Ruiz-Sanchez, Juan Pablo Ortiz-Brunel, Aaron Rodriguez*

Floral anatomy across the angiosperms is diverse and believed to have formed by interactions with different pollinators over millions of years. Variations in floral components may favor a particular pollinator group and, through evolutionary selection, lead to shifts in floral phenotypes. These changes go as far as excluding other pollinators, resulting in pollination syndromes. Agave is one of the most species-rich genera in the family Asparagaceae. Agave subgenus Manfreda has its center of diversity in Mexico and exhibits highly variable floral architecture attracting a wide array of pollinators. Here, we use plastome phylogenomics to build a basic framework to analyze floral and pollinator data and a custom probe set to assess paralogy, species relationships, and evidence of hybridization/incomplete lineage sorting. Phylogenomic analyses using plastome and sequence capture loci indicate non-monophyletic relationships within Manfreda and the potential for incomplete lineage sorting and hybridization. We will synergistically use these products to develop a profile of how convergent floral forms evolved across Manfreda within a pollinator-driven framework. Consequently, these findings will also contribute to how ecologically driven selective pressures - like pollination - drive angiosperm evolution. Species conservation efforts can also use the results of this research to inform their practices, as many species in Manfreda are endangered and threatened by human development.

## How do clownfish make friends with anemones that are enemies?

*Jason Macrander, Alyah Bennett, Katie Statile, Coral Tolman, Wyatt Rudd, Sofiia Kuklina, Gabe Langford*

Mutualistic relationships between clownfish and sea anemones are iconic examples of marine symbioses, having independently evolved at least three times across the sea anemone phylogenetic tree. Despite extensive behavioral studies shedding light on how these symbioses are established, the molecular signaling mechanisms underlying the initiation and maintenance of these interactions remain largely unexplored. Since clownfish are naturally susceptible to sea anemone venom, their ability to modulate toxin gene expression likely plays a critical role in establishing and sustaining this partnership. To investigate the molecular dynamics of this relationship, we conducted a comparative transcriptomic analysis examining changes in sea anemone gene expression that take place 12 and 48+ hours after clownfish symbiosis is established. Our study spans three distinct lineages of sea anemones that host clownfish species, offering a broad perspective on the molecular pathways involved. Additionally, we examined two non-host sea anemones, Condylactis gigantea and Stichodactyla helianthus, that can establish symbioses with clownfish in aquaria but not in the wild, to identify molecular signals potentially facilitating symbiosis outside natural hosting lineages. Our findings offer valuable insights into the molecular processes sea anemones employ to initiate and sustain these critical symbiotic relationships.

## What's going on in Florida? Life History tradeoffs in the Benthic Sea Anemone Nematostella vectensis

*Jason Macrander, Joachim Surm, Sydney Birch, Ed Smith, Adrian Jaimes Becerra, Adam Reitzel, Yehu Moran*

The evolutionary interplay between survival and reproduction shapes the intricate strategies of venomous organisms, wherein limited resources are allocated to either self-preservation mechanisms or reproductive endeavors. Preliminary investigations focusing on this tradeoff in the benthic sea anemone Nematostella vectensis explores the genomic underpinnings of Nv1 venom diversity within a population of N. vectensis elucidating the molecular processes driving drastic changes in complex phenotypes across their geographic distribution. By examining the co-evolutionary dynamics between venom repertoire, genomic processes, and reproductive effort we reveal the arms race between predator and prey, shaped by adaptive evolution and gene regulatory mechanisms. Our research underscores the significance of ecological interactions in driving rapid shifts in venom phenotypes and genomic diversity, offering insights into the evolutionary strategies of venomous organisms. As a model organism, Nematostella vectensis provides a valuable platform for studying the ecological and evolutionary relationships between toxin genes, genomic repertoire, and interspecific interactions. Through genomic analyses and experimental manipulations, we uncover the evolutionary origins of venom components and their functional roles in prey capture and defense. Our findings shed light on the intricate dynamics of venom evolution and its ecological implications, advancing our understanding of the adaptive strategies employed by venomous organisms in dynamic environments.

## Paternal absence alters milk proteome in the biparental prairie vole (*Microtus ochrogaster*)

*Jesus Madrid, Travis Covitz, Abbey Kampel, Ehren Bentz, Alexander Ophir*

Prairie voles naturally provide both biparental and uniparental caregiving. This variation in nest composition impacts the development of the offspring. Offspring raised in single parented nests are less alloparental as juveniles, differ in social behavior, delay pairbond formation, and are more likely to assume non-monogamous mating tactics as adults, compared to those raised in double parented nests. The mechanisms by which caregiving produces these differences are poorly understood. We asked if partner absence produces differences in milk composition, because milk nutrients are known to mediate offspring development. We identified and quantified the relative protein abundance in milk collected from mothers at post-natal day 3 (n=8 Partner Present; n=8 Partner Absent). Proteomic analyses showed that 255 proteins were significantly differentially abundant (126 overabundant in milk from mothers with a Partner Present; 129 overabundant in milk from mothers with a Partner Absent). Clustering analyses demonstrated that protein values were enough to correctly categorize each sample into each condition. A Gene Ontology Enrichment Analysis showed that most proteins differentially abundant in Partner Present milk were associated regulation of protein breakdown, immune function, and developmental signals. Proteins differentially abundant in Partner Absent milk were mostly associated with ribosomal assembly and cellular metabolism. The data suggest that milk is a likely candidate through which maternal social environment influences offspring development.

## Insights into the burying behavior of the Antarctic sea spider *Nymphon australe*

*Andrew Mahon, Chandler Olson, Jessica Zehnpfennig, Rebecca Varney, Kenneth Halanych*

Nymphon australe Hodgson, 1902 is the most abundant and commonly collected sea spider in the Southern Ocean (Antarctica), reaching densities of ∼1000 individuals per m2. However, even with these numbers, the remoteness and logistical issues of sampling on the continental shelf regions in Antarctica make documenting the life history behaviors of these enigmatic creatures difficult. For example, feeding and feeding behaviors in N. australe (and pycnogonids in general) are poorly known, with most observations related solely to co-collections of pycnogonids and other organisms (epiphytes, soft bodied species). In 2023, on our research cruise to East Antarctica (NBP 23-03), while opportunistically photographing N. australe, we noted an unusual burying behavior for the species after it was placed in a small tank of sediments. Seeing this, we placed multiple individuals in a flow through tank containing sediment and monitored them. Individuals were seen burying and unburying multiple times, moving throughout the tank. This led us to hypothesize that this behavior could be because individuals were feeding on microorganisms and other organics in the sediments. To test this, we sequenced and screened the gut contents of N. australe to compare to the bacterial contents of Antarctic continental shelf sediments. Our study presents novel video evidence of this enigmatic burying in N. australe and we will discuss hypotheses for the purpose of this is behavior.

## Modulations in locomotor behavior during climbing waterfalls in Galaxias fasciatus

*Takashi Maie, Aneeq Mir, Gerard Closs*

Adapted to life in turbulent environments, many fishes have evolved mechanisms to enhance surface adhesion through structural modifications in various body parts and fins. Climbing galaxiids, for example, possess posteriorly projected ridges on their pectoral and pelvic fins. These ridges allow them to gain traction with their paired fins engaged, enabling them to flex their bodies, pivot their fins around a center of rotation, and produce sprawling motions as they climb waterfalls. Although galaxiids are well-known for their climbing behavior, little is known about how they negotiate climbing surfaces and approach inclines during upstream migration. In this study, specimens of Galaxias fasciatus were collected from Opoho Creek, Dunedin, New Zealand, across a wide range of body sizes for high-speed videography in an experimental climbing setup. When challenged with a 45° incline and a direct water flow (ave. 490 mL/min), juvenile G. fasciatus used primarily axial undulation to generate thrust and propel themselves forward. However, when moving out of the water while climbing, their behavior shifted to a sprawling motion, with the paired fins spread and used as the primary means of forward movement. Adult G. fasciatus were tested on a milder incline (5°) without water flow. Although adults are less likely to encounter changes in media as frequently as juveniles, all individuals exhibited sprawling motion, indicating the retention of this behavioral trait throughout ontogeny.

## Correlation between morphology and environment in perch (Perca fluviatilis & P. flavescens)

*Takashi Maie, Briella Schmidt*

Morphology of functional designs in animals often provides a reliable inference regarding how the design optimizes functional performance of particular behavior and how it changes to become better suited to meet specific functional demands from environments. Many teleosts exhibit intra- and inter-specific morphological variation that often correlates with differences in bioavailable resources and ecological characteristics in natural habitat. For example, difference in visibility of lake water may indicate the predator-prey interaction between species operates at different proximity when reacting to each other. With ontogenetic scaling analysis, we evaluated both intra- and inter-specific variation in body and fin morphology in eurasian perch, Perca flavescens from two lakes from Minnesota and P. fluviatilis, from two lakes in Norway (Store Le and Østensjø vann). Although most of the morphological variables (e.g., pectoral fin base, anal fin base, caudal peduncle, caudal fin height, and second dorsal fin base) indicated a maintenance of shape in P. flavescens during ontogeny, these variables in P. fluviatilis exhibited negative allometry with respect to body size. However, thickness of specific body segments in both of these percids scaled in either isometry or positive allometry. These preliminary results may indicate correlations between morphology and environmental conditions, to which these fish are exposed, as well as potential genetic differences between species.

## Dissecting the contributions of neural activation and strain trajectories to muscle force production

*Carissa Mallonee, Monica Daley, Kiisa Nishikawa*

Guinea fowl with autogenic proprioceptive deficit due to lateral gastrocnemius reinnervation have different activation timing, strain trajectories, peak force, and velocity at peak force than intact guinea fowl during running on a treadmill with obstacles. We used the ex vivo 'avatar' technique to investigate the contributions of activation timing and strain trajectory to muscle force. We used in vivo length, activation, time, and force data from one reinnervated (R) and one intact (I) guinea fowl. Representative level (L) and obstacle (O) strides were selected and scaled for use on ex vivo mouse extensor digitorum longus muscles. Intact and reinnervated stimulation onset were used with each strain trajectory, resulting in eight conditions (strain + stimulation + stride type). Homologous strain/stimulation stresses were similar to in vivo stresses (I+I L: $R2 = 0.7$-0.9, I+I O: $R2 = 0.7$-0.9, R+R L: $R2 = 0.5$-0.9, R+R O: $R2 = 0.7$-0.9). In contrast to in vivo strides, peak stress was lower for reinnervated compared to intact strain trajectories perhaps because in vivo the reinnervated guinea fowl have a longer muscle starting length than intact birds. Reinnervated stimulation reduced peak stress for intact strain trajectories. Velocity at peak stress was unaffected by stimulation type. Reinnervated strain trajectories were not sensitive to the stimulation type, supporting the hypothesis that shifts in muscle intrinsic properties may contribute to the observed differences between intact and reinnervated birds in vivo.

## Joint mobility as a bridge between form and function, or, the power of ex vivo XROMM

*Armita Manafzadeh*

Over the past two decades, XROMM-based studies have become a regular feature of the SICB landscape. Most of these studies use joint coordinate systems to measure kinematics from animations of living animals breathing, eating, or locomoting in the laboratory – but XROMM can also be used to measure full potential joint mobility from cadaveric specimens. In this talk, I will advocate for the value of ex vivo XROMM in advancing our understanding of how joints work. I will detail how joint mobility allows us to break down the study of articular form-function relationships into more tractable studies of (1) form-mobility and (2) mobility-function relationships, and discuss how I have begun implementing this framework to investigate joints in taxa ranging from dinosaurs to humans. Finally, I will discuss how ex vivo XROMM studies have motivated the development of novel visualization techniques, unlocking new ways to explore the complexity of vertebrate animal motion.

## The Mitochondrial Constellation: Mitogenomic Perspective on Phylogeny and Evolution of Sea Stars

*Harrison Mancke, Lauren Baena, Andrew Mahon, Kenneth Halanych*

Asteroidea (Echinodermata), starfish or sea stars, are ecologically important, diverse, and span from the intertidal to the abyssal zone (~6000m). Surprisingly little attention has been paid to exploring the phylogenetic relationships and codon evolution of Asteroidea, which this study aims to do through mitogenomics. Ten recently collected asteroids from Florida and Antarctica have been sequenced and included in a maximum likelihood analysis of a total of fifty-one mitochondrial genomes. The representation spans Valvatida, Spinulosida, Velatida, Forcipulatida, Brisingida, and Paxillosida, where only Notomyotida lacks any representation. Valvatida, the most well sampled group, is an order that has traditionally been considered monophyletic, a finding that has been contested by both recent previous works and this study. In addition, the gene order is identical across Asteroidea, with thirteen protein-coding genes, two rRNA genes, twenty-two tRNA genes and one origin of replication region. Forcipulatida and Velatida occupy a more basal position, where Paxillosida is more derived. We found a significant unequal variance towards A+T in the nucleotide composition. The most used codons, excluding start and stop codons, were AUC (Ile), AUA (Ile), CUG (Leu), GUC (Val) which is different to other echinoderms like holothuroids and echinoids. This study will provide a robust analysis of the complicated relationships and molecular dynamics of Asteroidea, allowing a more informed understanding of asteroid phylogeny and evolution.

## The bird that broke the binary

*Donna Maney*

The development of sex-related traits is astonishingly diverse not only across species but within them. In white-throated sparrows, a heteromorphic autosome is recapitulating the early evolution of sex chromosomes, leading to fascinating and informative segregation of 'masculine' and 'feminine' behaviors into phenotypes orthogonal to 'male' and 'female' sex categories. Over the past 20 years, my lab has been working to show that variation in these behaviors, which include territorial singing and parental provisioning, is driven in part by identifiable genetic cis-regulatory variation between the two forms of this heteromorphic autosome. We have shown evidence that this cis-regulatory variation affects the epigenetic control and allelic expression of two genes, located near each other on this autosome, in ways that are likely causal for within-sex behavioral divergence in this species. This powerful animal model helps move our thinking beyond the sex binary by forcing us to acknowledge sources of variability other than sex category, which is only a small contributor to variability for many species.

## Thermal images shed light on role of the wing membrane in thermoregulation during flight in bats

*Kate Manges Douglas, Brooke Quinn, Andrea Rummel*

Bats face a unique set of circumstances that challenge their ability to maintain energy balance: many bats are relatively small-bodied, and bat wings are exceptionally thin, virtually uninsulated, and result in high surface-area-to-mass ratios. While flight is energetically expensive, requiring high metabolic rates and generating endogenous heat, it also introduces mechanisms for heat loss that most terrestrial mammals do not encounter, primarily convection and radiation. The large surface area of bat wings thus make them an integral structure for heat exchange during flight, and likely a major component of thermoregulation both during locomotion and at rest. Here, we collected thermal images of the wings taken before and immediately after flight (a proxy for in-flight temperatures) to assess temperatures in the musculoskeletal structures and membranes of the wing. We predicted that wing membrane temperatures would fall during flight, even as limb temperatures rise as a result of muscle activity. We found that wing membrane and musculoskeletal structure temperatures were highly variable; we suggest that changes in wing membrane and limb temperatures function to balance excess convective heat loss across the wings and excess core heat generation during flight. Temperature variability in the wing likely has implications for wing muscle function, flight performance, and flight energetics.

## Analysis of the taxonomic ambiguity of the invasive apple snail (*Pomacea* sp.) in Florida

*Hailey Manitz, Pamela Brannock*

Apple snails (Pomacea sp,) are considered one of the most invasive species globally, posing a significant threat to tropical ecosystems. Previous research in the Brannock laboratory aimed to resolve the taxonomic ambiguity of invasive apple snail individuals in Florida and explore whether Pomacea hybridization is occurring. In efforts to improve the DNA extraction methods to increase successful amplification, four extraction methods were tested and DNA was amplified at the elongation factor 1 alpha (EF1$\alpha$) nuclear and cytochrome c oxidase I (COI) mitochondrial (mtDNA) genes. Of the 124 individuals extracted, amplification thus far was successful for EF1$\alpha$ in 60 and COI in 94 individuals. P. maculata was the most prevalent genotype for EF1$\alpha$ across the four Florida sample locations. No P. canaliculata mtDNA haplotypes were found in any Florida sampled location to date. One potential F1 hybrid was found in Cape Coral. Three P. canaliculataindividuals with P. maculata mtDNA were found at Cape Coral and Grassy Waters, indicating potential advanced hybridization. Future directions include broader geographic sampling, sequencing hybrid individuals to confirm assignment, and genotyping remaining individuals at both loci. These findings underscore the need for targeted management strategies to control invasive apple snails in Florida. The evidence of hybridization highlights the complexity of invasive species dynamics, necessitating informed conservation policies to protect vulnerable habitats.

## Microbiome shifts under disease stress in Acropora cervicornis revealed by 16S rRNA sequencing

*Chloe Manley, Lauren Speare*

Tropical coral reefs are facing unprecedented threats from anthropogenic stressors, including disease. The keystone species that support these marine rainforests, Scleractinian corals, rely heavily on their diverse community of bacteria, archaea, viruses, and eukaryotic microorganisms to defend against disease and provide nutrients. Although disease is one of the leading causes of mortality for corals, we know relatively little about how diseases progress and shape microbiome composition. Using a newly established disease model in the Caribbean Staghorn coral Acropora cervicornis, this study aimed to determine the impact of experimental disease stressors on microbiome composition by performing 16S rRNA gene sequencing. Coral tissue samples were collected from three experimental treatments- non-inoculation control, inoculation of a beneficial taxa, and inoculation of a pathogen at three distinct time points: prior to the start of the experiment, upon the first signs of disease, and just before mortality, resulting in a total of 84 samples. Our findings provide insights into how foreign microbes can shape coral microbiome structure over time based on their functional identity, enhancing our understanding of coral-microbiome interactions and their response to anthropogenic changes.

## Dissecting contributions of strain and frequency interactions to force and work of mouse EDL muscles

*Katelyn Manross, Kiisa Nishikawa*

The intrinsic response of muscles to rapid perturbations during locomotion allows animals to maintain steady movement in unsteady terrain. In vivo studies of guinea fowl demonstrate uncoupling between neural activation and muscle force, suggesting an important role for tunable intrinsic muscle properties in stabilizing movement during perturbed locomotion. As a tunable material, the interaction between activation and strain during dynamic contraction is significant. Muscle viscoelastic properties appear to be tuned not only by length and activation but also by frequency. To dissect contributions of frequency, strain transients, and their interactions to muscle force production, we used the ex vivo workloops in mouse EDL muscles ($n = 6$). In work loops, we applied four synthetic strain trajectories, based on in vivo galloping in rats, with different perturbation amplitudes to the EDL muscles at four stride frequencies (1, 2, 3 and 5 Hz). We analyzed peak active stress, peak passive stress, positive work, negative work, and maximum power for each work loop. We found that the stride frequency that maximized power and positive work production per cycle varied with work loop frequency, and that work absorbed by the muscle was greater at slower frequencies, and for larger strain transients. The results support the hypothesis that muscle is a tunable active material whose viscoelastic properties are modulated by interactions between strain and frequency.

## Assessing contaminant impact on mussels (*Mytilus trossulus*) in Puget Sound

*Christine Mantegna, Steven Roberts, Alison Gardell*

Legacy chemicals plague global waterways including Puget Sound. The coastal ecosystem faces challenges from many contaminants, but two of the most persistent chemicals, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) along with heavy metals pose a sustained threat. Washington Department of Fish and Wildlife conducts nearshore monitoring to quantify the presence of these contaminants across Puget Sound by outplanting mussels (Mytilus trossulus) and analyzing their tissues post retrieval. Mussels are an ideal specimen for monitoring as they are filter feeders who accumulate contaminants within their tissues and serve as a foundational species in coastal habitats. Seventy-four sites were assessed for the impact of PAHs, PCBs and metals on enzymes and shell properties by measuring cytochrome P450 activity, superoxide dismutase activity, and shell morphometrics. We found that in areas of highest urbanization, both cytochrome P450 and superoxide dismutase activity in mussels was elevated. Likewise, enzyme activity was lowest in least urbanized areas. While this pattern was expected, variability within localized areas was observed. There was no correlation of shell thickness with enzyme activity, however shell thickness increased with increasing levels of PAHs and PCBs. This could indicate the effects of bioaccumulation, or possibly induced defense mechanisms. Clarifying their response to multi-stressor environments is crucial to both ecological and industrial motivations. Complementing ecosystem impact with organism impact can most thoroughly inform policy and conservation stakeholders.

## Expression of distal limb patterning genes in the tardigrade, Hypsibius exemplaris

*Marc Mapalo, Mandy Game, Frank Smith, Javier Ortega-Hernandez*

Panarthropods, a group comprised of arthropods, onychophorans, and tardigrades, are the only limb-bearing members of Ecdysozoa. The complexity of panarthropod limbs has prompted interest in their development to better understand the formation of these structures and the genes involved in this process. However, most studies are focused on arthropods, and almost lacking for tardigrades. This precludes a comparative analysis of how panarthropod legs evolved. In this study, we investigated tardigrade homologs of seven arthropod distal limb patterning genes (apterous [ap], aristaless [al], BarH1, clawless [cll], Lim1, rotund [rn], and spineless [ss]) to better characterize tardigrade limb development in a comparative context. We detected homologs of all seven genes in the eutardigrade Hypsibius exemplaris and heterotardigrade Echiniscoides cf. sigismundi suggesting their conservation in both tardigrade lineages. Hybridization chain reaction experiments in H. exemplaris revealed a regionalized expression pattern for al, BarH1, cll, rn, and ss. This might reflect morphological features of tardigrade legs such as the distal claws and proximal sensory organs. Comparison between the expression of the seven genes in H. exemplaris relative to other panarthropods suggest their conserved role in the last common panarthropod ancestor, such as establishing the distal limb end and the distribution of sensory structures. Our results support the hypothesis that tardigrade legs are homologous to the distal region of other panarthropod limbs, as suggested by previous work in H. exemplaris.

## The developmental and molecular bases of amniote cranial proportions

*Marta Marchini, Greta Keller, Adriana Saliceti Galarza, Naaz Kahn, Rushabh Shah, Katherine Starr, Thomas Sanger*

The diversity of the amniote skull represents an incredible array of lifestyles and feeding adaptations. The upper jaw, the portion of the skull comprised of the maxilla, premaxilla, and nasal bones, has been the focus of comparative and experimental studies of development for decades. This led to a developmental model of craniofacial development thought to apply across amniotes. Yet, most of those studies focused on only a small subset of cranial diversity, avian and mammalian model. We have undertaken a developmental analysis of the squamate face using the brown anole (Anolis sagrei). We have developed experimental tools that allow us to interrogate the function of signaling pathways thought to be integral to the proper formation of the amniote face. Herein, we test the hypothesis that the classic model of craniofacial development also applies to squamates. Our studies reveal that this model is not consistent with the development of the squamate face. Instead, those signaling pathways have far more nuanced roles in controlling the relative proportion of the premaxilla and maxilla. Our results indicate that the diversity of the amniote facial skeleton may be controlled by molecules regulating the early outgrowth of the facial prominences.

## The effect of the social environment on the mating behavior of females of Cope's gray tree frogs

*Alejandro Marcillo, Michael Reichert*

Frog reproduction is marked by the complexity of the social environment, particularly by the presence of neighbors that can modify the mating behavior of male individuals. These neighbors exhibit aggressive behavior when they perceive their territories are being invaded. Consequently, the presence of aggressive neighbors might negatively influence the attractiveness of males, thereby reducing their reproductive success. The purpose of this project is to understand the effect of the social aggressive environment on the attractiveness of males. Here, we ran phonotaxis trials using females of Cope's gray tree frogs on a two-choice arena and included the effect of the aggressive calls at different amplitudes in order to determine if it altered the attractiveness of the advertisement calls. Additionally, we modified the timing and position of the aggressive calls relative to the advertisement calls. After three years of experimentation, we found that aggressive calls negatively affected the attractiveness of an advertisement caller when the amplitudes of the aggressive calls were 84 and 90dB, with a stronger negative effect when the aggressive and advertisement calls overlapped. In conclusion, frog choruses are systems where the social environment plays an important role in modifying the mating behavior of males.

## Grabbing evolution by the throat: axio-appendicular co-evolution across the dinosaur-bird transition

*Ryan Marek, Ryan Felice*

The avian neck is extraordinarily diverse and, in tandem with the beak, replaces the grasping-incapable wing as a 'surrogate' forelimb. How this diversity arose from such a morphofunctionally conservative theropod ancestor, whereby the neck is adapted for carnivory, is unclear. We test the hypothesis that the neck, forelimb and head co-evolved across the dinosaur-bird transition as the theropod forelimb became a wing, and as relative head size decreased. We assembled a supertree of birds and non-avian theropod dinosaurs (n=223) stretching back 237 million-years. We then modelled shifts in adaptive optima and rates of evolution of the neck, head and forelimb across theropods and birds. We show a concurrent shift in adaptive optima of neck morphology and forelimb proportion at the base of Avialae, with an additional optimum shift of forelimb proportions on the branch leading to Maniraptora. These shifts are accompanied by shifts to lower rates of evolution for neck morphology and forelimb proportion, and these patterns are driven by changes in the tempo of body size evolution. We demonstrate that it is the co-evolution of the forelimb and the neck, and not a reduction in head size, that is responsible for the large morphofunctional diversity of the neck of extant Aves. This work highlights the extent to which musculoskeletal systems must evolve concurrently to support key behavioural innovations such as powered flight.

## Hemolymph flow and its role in flexing of insect antennae

*Lucas Marsh, Kostya Kornev, Griffin Donley, Artis Brasovs*

Equipped with the stirring muscules only at the pedicel-scape pair, the muscle-free antennae of many insects can be twisted and bent on the insect demand. We hypothesized that the hemolymph circulating through antennae provides a pressure that facilitates twisting and bending. In a series of experiments on the live American cockroach Periplaneta americana, we investigate the hypothesis by measuring the pressure of hemolymph along the antenna. This was accomplished by puncturing the antenna and letting hemolymph flow out and form a droplet. As the pressure in the droplet equilibrates with the pressure inside the antenna, the flow stops, and the drop takes on its equilibrium spherical shape. The drop radius can be used to calculate pressure differential through the Young–Laplace equation of capillarity. Puncturing antennae on dorsal and ventral sides at different locations along the antenna axis, we were able to evaluate the pressure distribution and estimate the pressure level. The pressure reaches its maximum of 3.4 KPa close to the base. There is a significant pressure differential based on antenna position; the ventral positioning showed higher pressure than the dorsal.

Using optical video microscopy and SEM imaging, we identified the location of the antennal vessel and estimated the flow velocity. These data allowed us to set up a model of hemolymph flow through antennae and its effect on antenna bending.

## Mucosal corticosterone mediates chytrid disease dynamics in the Blacksmith tree frog

*Vanessa Marshall, Wesley Neely, Samantha Siomko, Shannon Buttimer, Jack Boyette, Carlos Becker, Ryan Earley*

Glucocorticoids are important for host metabolic balance and mediating immune responses, providing insight into how organisms cope with ecological challenges. However, few studies incorporate host physiological metrics into the disease ecology framework for a broader understanding of how both environmental and pathogenic stressors impact wild organisms. In this study, we tested the hypothesis that forest fragmentation metrics and skin microbiome treatments would impact amphibian-Batrachochytrium dendrobatidis (Bd) host-pathogen dynamics and host glucocorticoid responses. We attached radio transmitters to blacksmith tree frogs (Boana faber) in the Atlantic Forest of Brazil from September – November of 2021. We sampled these frogs up to four times over the course of 47 days, collecting data on body condition, and skin mucosal swabs to quantify the skin microbiome, Bd infection loads, and "stress" corticosterone (CORT) levels. Forest fragmentation metrics and environmental resistance to host movement were also quantified. Microbiome manipulation treatments included a control, probiotic, and antibiotic. Though Bd prevalence is naturally low, we predicted that 1) higher CORT levels would be associated with lower Bd levels, and that 2) fragmentation and environmental resistance would be associated with lower Bd loads. Preliminary results reveal that 1) significantly lower CORT levels are associated with the probiotic treatment, 2) CORT and percent of forest border predict Bd prevalence, 3) and CORT, percent of forest border, and environmental resistance to host movement predict Bd loads.

## Diving in semi-aquatic *Anolis* lizards results in heat loss with sex-specific cooling tolerance

*Alexandra Martin, Christopher Boccia, Lindsey Swierk*

The sexes often differ in antipredator behaviors, particularly when there are costs to mating opportunities or territory defense. When using thermally suboptimal refugia, ectotherms are vulnerable to these costs, as performance links to body temperature. To flee from predators, semi-aquatic Anolis lizards dive underwater for long periods and rebreathe a bubble of air. We hypothesized that using aquatic refugia would result in body heat loss, that dive duration is influenced by sex, and that oxygen consumption when diving would help explain sex differences. We tested these hypotheses by measuring dive length and body temperatures in A. aquaticus, and by recording oxygen consumption and final pO2 during controlled dives in several semi-aquatic Anolis species. Not only was there a significant thermal cost to diving, but A. aquaticus males and females appeared to tolerate different levels of this cost: males re-surfaced more quickly and at higher body temperatures. Body temperature decreased following an exponential decay function, dropping up to 6°C in 5 min. Oxygen consumption rates in semi-aquatic anoles were primarily explained by the expected allometric scaling relationship with mass and are unlikely to lead to sex differences in physiological dive limits. Instead, shorter male dives may help maintain physiological performance, mating opportunities or territory defense. Antipredator diving behavior is costly but undoubtedly beneficial to both sexes, highlighting the need for further study of sex-based antipredator optimization.

## Turtle tears? Understanding the magneto-microbiome of the sea turtle lacrimal gland

*Julianna Martin, Robert Fitak*

The magnetic sense of sea turtles has been well documented, however the underlying mechanism for this sensory system remains enigmatic. The symbiotic magnetic sensing hypothesis proposes that a magnetic sense may be conferred by a relationship between an organism and magnetotactic bacteria (MTB). These bacteria are characterized by their ability to align with magnetic fields due to magnetic particles stored inside organelles called magnetosomes. MTB have been documented in soils and sediments, but their presence in the microbiomes of organisms has yet to be systematically described. To study the possible link between magnetotactic bacteria and magnetoreception in sea turtles, we must first describe the community of MTB living with these organisms, hereafter called the magneto-microbiome. The lacrimal gland has been identified as a location of interest due to its proximity to nerves implicated in magnetoreception. We used 16S metabarcoding of green (Chelonia mydas), loggerhead (Caretta caretta), and Kemp's Ridley (Lepidochelys kempii) lacrimal gland secretions (ie. tears) to characterize the magneto-microbiome associated with the eye. Preliminary data indicate that MTB populate the lacrimal gland of green and loggerhead turtles, and higher-resolution sequencing has been used to describe the community structure in juvenile turtles across three species. Results from this study provide additional insight into the plausibility of the symbiotic magnetic sensing hypothesis.

## Differential gene expression in two marine turtle species variably impacted by a tumor disease

*Katie Martin, Kate Mansfield, Anna Savage*

IInfectious disease poses a global threat to wild organisms. Differential gene expression (DGE) analysis of healthy versus diseased tissue in hosts with different levels of susceptibility is a promising avenue for identifying processes involved in disease response, and is particularly relevant in species of conservation concern, such as marine turtles. Fibropapillomatosis (FP) is an infectious tumor disease in marine turtles, and is most prevalent and severe in juvenile green sea turtles (Chelonia mydas). Whether similar genes are differentially expressed across marine turtle species with FP remains unknown. We measured DGE in skin, blood, and tumor from juvenile C. mydas and loggerhead (Caretta caretta) turtles with and without FP. Genes related to DNA damage response and to both the acquired and innate immune systems were differentially expressed in the blood and skin of FP+ C. mydas, whereas innate immune system genes were primarily differentially expressed in the blood of FP+ C. caretta. Nearly four times the number of genes were differentially expressed in FP tumors from C. mydas compared to that of C. caretta. We find that antigen-processing genes are upregulated in tumors from both species relative to healthy tissue. This study is the first to compare DGE between two marine turtle species variably affected by this disease, and will help us to more broadly understand the variation underlying immune function and disease response in reptiles.

## Environmental effects on host competence for two zoonotic pathogens

*Marty Martin, Vania R Assis, Meredith DeWitt, Tom Unnasch, Kailey McCain, John Orrock, Clinton Francis*

Host competence can be defined as the behavioral and physiological traits by which one host organism becomes exposed to, infected by, and transmissive of a parasite or pathogen to another host. Although this concept has been central to some ideas in disease ecology and epidemiology, by and large, competence has been assumed to be a relatively fixed trait of species such that all individuals in a population are assumed to be similar in their propensity to serve as reservoirs of infection. In this talk, I share how collaborators and I have revealed important influences of natural and anthropogenic forces on host competence for two important zoonotic agents, West Nile virus (WNV) and the bacterial species that causes Lyme disease, Borrelia burgdorferi. In the former case, we find that both physiological stress and artificial light at night alter house sparrow (Passer domesticus) competence for WNV. In the latter case, we find that climate affects tick-relevant behaviors and the standing state of the immune system of Peromyscus leucopus, probably the most important host of B. burgdorferi. Onoging work is investigating how these patterns relate to disease prevalence and range expansion given continuing changes in climate occurring where Lyme, WNV and other vector-borne diseases are common.

## SSARP: an R package for easily creating species- and speciation-area relationships

*Kristen Martinet, Luke Harmon, Cristian Román-Palacios*

Species-area relationships (SARs) help quantify patterns of biodiversity, and are especially useful for visualizing biodiversity on islands by plotting the relationship between species richness and the area of the island on which the species live. Comparing SARs across global island systems is an extremely difficult task because gathering enough species occurrence data and island data often requires researchers to conduct lengthy literature searches and combine datasets from several different sources. Online databases such as GBIF (Global Biodiversity Information Facility) host valuable global occurrence data, so creating SARs should be simple through the use of GBIF. The R package presented here, SSARP (Species/Speciation-Area Relationship Projector), provides a simple workflow for creating SARs using occurrence records from GBIF. The SSARP workflow allows users to gather occurrence data from GBIF, use mapping tools to determine whether the GPS points in the occurrence data refer to valid land masses, associate those land masses with their areas using a built-in dataset of island names and areas, and create SARs using linear and segmented regression. This SAR workflow can also be modified to create speciation-area relationships when a phylogeny is provided and a speciation rate estimation method is chosen. We demonstrate the utility of SSARP by creating a species-area relationship and a speciation-area relationship for island-dwelling species in the lizard genus Anolis and comparing these results to previously published relationships.

## Effect of tail molting on the perching flight of a hawk

*Alfonso Martinez, Michelle Hawkins, Kyle Buehring, Christina Harvey, Huanglun Zhu*

To land on a perch, a bird will extend its wings and rapidly increase its angle of attack, generating transient flow features. Current aerodynamic models struggle to accurately predict the unsteady force produced during this perching maneuver. As a result, there are substantial gaps in our understanding of the physics of perching, be it for a bird or an aerial vehicle. In particular, flight dynamic models often rely on quasi-steady aerodynamics theory that cannot account for the associated transient effects.

To fill this gap, we quantified the unsteady 2D aerodynamic characteristics that are associated with biologically relevant airfoil-shape changes and kinematics. First, we used high-speed cameras to track three points along the wing chord of a perching red-tailed hawk (Buteo jamaicensis) taking off from three different heights. The chord's camber and kinematics throughout the maneuver were digitized using the software DLTdv. Next, airfoil morphology and kinematics are implemented in a vortex-particle model to estimate the lift, drag and pitching moment as a function of time.

We expect to find that camber morphing helps to tailor the aerodynamic force production for different perching conditions. This aerodynamic data can be used to improve models of perching flight dynamics and advance the field towards a holistic understanding of the force production of avian wings during unsteady perching maneuvers.

## Prophenoloxidase as an immune indicator in geographically distinct populations of *Astrangia poculata*

*Anabel Martinez, Jaime Acero, Isabella Changsut, Lauren Fuess*

Coral reef ecosystems face significant threats from anthropogenically driven climate change, leading to rising water temperatures and increased coral disease outbreaks globally. The prophenoloxidase (PPO) cascade, a crucial component of invertebrate immune systems, plays a vital role in the defense mechanisms of corals against these stressors. In this study, we investigate the PPO cascade in Astrangia poculata, a facultatively symbiotic temperate coral, to explore how symbiosis influences immune responses. By using A. poculata, we can examine the immune function, specifically the PPO pathway, without introducing external stressors. While most research on Astrangia has concentrated on a single population in Jamestown, RI, this study expands the scope by comparing PPO activity and related immune responses across multiple populations of A. poculata from RI, VA, FL, and TX. This geographically extensive study aims to identify differences and similarities in PPO-mediated immune responses along a latitudinal gradient. Samples were collected and flash frozen in liquid nitrogen before analysis at Texas State University, where key immune parameters were assessed using biochemical assays. Our findings offer new insights into the role of the PPO cascade in coral immunity and its variation across different environmental conditions, contributing to a deeper understanding of cnidarian immune processes in the context of climate change.

## Exploring Squaliformes dermal denticle morphology diversity and evolution

*Arleth Martinez, Elizabeth Sibert, Leah Rubin, Nicholas Wallis-Mauro*

Whole shark bodies are rarely preserved in fossil records due to their cartilaginous skeletons and are mineralized to have a “skin-teeth” texture covering their skin called dermal denticles. These dermal denticles are made of the same material as teeth (dentin and enamel) and are well-preserved in most marine sediments, providing a valuable tool for researching the evolutionary history of sharks. Here we attempt to fill in gaps between fossil denticles with known shark taxonomy building a catalog of extant shark denticle morphology across the Shark Phylogenetic Tree. Exploring dermal denticle morphology - the shape, size, and structure will give us a visual comparison within and between shark taxonomic groups of how similar or different they are. We developed a dataset of denticle morphology from 25 standardized locations across the bodies of 9 species on the order Squalifromes - a clade of deep-sea sharks and found that denticles from these 25 standardized locations have significant differences in denticle morphology both within and between species. While still in its early stages, an ongoing database with more development will give a more in-depth insight into shark denticle morphology from across the shark tree of life. Our findings suggest that the order Squaliformes has unique denticle features that could help us have a better understanding of deep-sea shark evolution.

## Testing the Limits: Functional Strengths and Weaknesses of Poacher (Agonidae) Armor

*Lorenzo Martinez, Meg Vandenberg, Adam Summers, Karly Cohen, Cassandra Donatelli*

Dermal armor serves a variety of functions across animal lineages such as defense, display, and prehension. Small differences in armor structure, plate size, or overlap may drive large differences in behavior or ecology. In this study, we characterize damage to poacher (Agonidae) armor and skeleton under different force regimes, including crushing, puncture, abrasion, and blunt impact. We assessed and quantified damage using micro-computed tomography, scanning electron microscopy, and material testing. We found that armor in the posterior region of the fish can withstand higher shear stress during crushing, suggesting that a poacher is best suited to face away from a crushing predator, and may be able to escape an attack on its tail without fatal injury. We also found that it takes more work to puncture the anterior armor, suggesting that against a potential puncture, poachers are more protected facing the threat head-on. We also found a near erasure of dorsal plate spines from abrasion and blunt impact, indicating that the spineless ventral plates may be a response to strong sub-tidal currents causing collision with a rocky substrate that would quicky nullify ventral spines. The imbricated armor of Bathyagonus alascanus provides an impressive defense system by enhancing body stiffness and allowing for better acceleration that may help them escape predators before sustaining severe damage.

## Elastocapillary Water Dynamics in Sandgrouse Feathers: Absorption and Evaporation Study

*Maria Martinez, Nami Ha, Saad Bhamla*

The (Pterocles namaqua) sandgrouse bird, native to the arid regions of Asia and Africa, possesses a remarkable ability to absorb and transport water for long distances due to its specialized underbelly feather structures. These feathers feature helically coiled barbules designed to capture and retain water during flight. Unlike typical feathers having straight, mesh-like barbules that enhance their ability to repel water, sandgrouse barbules exhibit uncoiling and coiling behaviors in response to water, allowing for efficient water delivery to their young. This research compares the water absorption and evaporation performance of these feathers by utilizing a linear motor, vibrative actuator, and electronic scale to perform a series of feather dipping and evaporation tests. We aim to investigate the elastocapillary-driven coiling-uncoiling behavior of the barbules, focusing on varying the structural parameters and type of feathers from other avian species, testing duration, mechanical stresses, and environmental conditions that will influence the absorption and evaporation rates. While quantitatively comparing the amount of water absorbed and evaporation lost. Our results will provide further clarification on the morphological characteristics of sandgrouse feathers in relation to their water management properties and in comparison, to those of other organisms and avian species, potentially guiding the development of advanced bio-inspired materials with ultra-fast water absorption capabilities.

## Dynamic differentiation of honey bee nest architecture throughout development

*Peter Marting, Ben Koger, Michael Smith*

To understand the functional anatomy of a superorganism, we must examine the development and differentiation of the colony's nest architecture. How bees organize the contents of their nest over time may impact colony growth and survival, but measuring this at-scale is challenging. With the help of machine learning, we tracked the contents of each cell in 3D nests (n=12 colonies) weekly, starting at nest initiation, and continuing throughout the growing season (211 days). Nests showed areas of specialization at the cell, comb, and nest levels, akin to the differentiation of an organism's organs. Colonies had consistent patterns of organization that varied seasonally; contents were self-clustered and vertically stratified with pollen accumulating on one side of the nest and nectar on the other. For a subset of colonies, we manipulated this organization by shuffling the order and orientation of combs in the nest weekly. Shuffled colonies changed contents more often at the cell-level, tightened the comb-level organization, and lost their nest-level organization. Despite these organizational differences, we found no significant effect on colony-level performance between control and shuffled colonies. This provides a comprehensive look into the functional anatomy of a superorganism and the resilience it offers in the face of disturbance.

## Investigating drivers of variation in the paleognath wing

*Isabel Marzec, Sara Burch*

Palaeognathae is a group of flightless birds largely characterized by the absence of the keeled sternum. As they diverged from their flighted ancestors, most palaeognaths developed cursorial traits such as greater body mass and elongated hindlimbs, and concomitant with this was the reduction of the forelimbs, which were no longer needed for flight. This study investigates the forelimb variation within and between different paleognathous species to determine which behaviors and environmental pressures may have contributed most to the forelimb morphologies of extant taxa. Differences in the forelimb elements of males and females, indicating sexual dimorphism in the wing, would suggest variation results from sex-specific functions such as mating displays. Comparison between captive and wild populations could show variation resulting from presence of competition, predation, and other environmental factors. However, initial results suggest there is no clear pattern of sex-specific variability among Struthio camelus individuals. Using two-dimensional geometric morphometrics, principal component (PC) data for species representing all paleognath families were analyzed to investigate variation between forelimb elements and also test adherence to the hypothesized pattern of limb reduction in which reduction occurs distal to proximal. These methods allow us to contrast interspecies and intraspecies variation to quantify how functional demands on the wing affect morphological variation of the bones, and thus better understand the evolutionary relationship between form and function in cases of limb reduction.

## Why the long muscle? Bio-inspired exploration of muscle architecture in seahorse grasping tails

*Dries Marzougui, Riddhi Das, Barbara Mazzolai, Dominique Adriaens, Francis Wyffels*

Fish tails are typically powered and controlled by segmented muscles arranged in complex systems of conical connective tissue sheets, bridged by short muscle fibres. This allows an efficient force transfer onto the vertebral column during swimming. But what about fish that use their tail for something completely different, like grasping onto objects? Earlier research showed that seahorses are quite unique in having their ventral (hypaxial) muscles evolutionary re-arranged with elongated, parallel and flat sheets of connective tissue. In doing so, they may span up to 11 vertebrae, this in contrast to the usual 3 to 4 in fish with a conical system. To test whether these re-arrangements impact grasping performance in seahorses, hence reflecting adaptive evolution, a parameterised in-silico model as well as a physical model was developed to test the performance impact of muscle architectures with a variable number of segments being spanned. Using these tools traditionally used in robotics allowed addressing this elusive biological question, as testable biological data (seahorses with short myosepta) is non-existent. Results show that such a novel architecture with increased vertebral span at different levels does indeed result in a larger contraction force and thus torque needed to bend the tail. This opens up new perspectives for further testing of adaptive hypothesis in evolution, as well as improved design of a robotic system that bridges hard versus soft robotics.

## Biodiversity assessment of the metazoan communities of undisturbed and disturbed cenotes of the Yucatan Peninsula

*Muntadher Mashaan, Fernando Calderon Gutierrez, Danielle Bragg, Gabrielle Vaughn, Elizabeth Borda*

Karst aquifers are vital groundwater resources around the planet and house a unique fauna characterized by high endemism rates. Particularly, in the Yucatan Peninsula they can be accessed through sinkholes, locally called cenotes, allowing the study of this subterranean ecosystem. Most of the biodiversity assessments on cenotes have been conducted solely utilizing morphological methods, and several faunal lineages are not represented on molecular databases, even to order level. Our goal is to conduct a biodiversity assessment through the direct collection of adapted cave fauna, and through metagenomic analyses of environmental samples. This study was conducted in the Cenote Dzonot Miis located at the small village of Sotuta, Yucatan, Mexico, and Cenote Tres Rayos, located in an undeveloped jungle habitat nearby. Specimens of metazoans were morphologically identified and sequenced with COI & 16S to create a reference molecular library. Water and sediment samples were subject to environmental DNA extraction and processed using low-pass whole genome sequencing to evaluate and characterize the diversity of eukaryotes, emphasizing Metazoa. These data will serve as a baseline for the study of groundwater health of cenotes located near urban zones, agricultural and chemical processing plants, and other areas of human impact and pollution.

## Beak wiping stereotypies are not correlated with neophobia in captive house sparrows

*Danna Masri, Will Frazier, Melanie Kimball, Tosha Kelly, Christine Lattin*

Stereotypies—short, repetitive behaviors that seemingly serve no purpose—commonly arise in wild animals from the acute stress of captivity and captive conditions such as restricted cage size, fluorescent or LED lighting, frequent human contact, and novel foods. Further, stereotypies may increase over time in captivity. What is less well understood, however, is whether stereotypies are correlated with other types of anxiety-linked behaviors, such as neophobia, an animal's reluctance to approach or interact with novel stimuli. In this study, we assessed whether beak wiping, where birds wipe their beaks on a perch in a "windshield wiper" motion, was correlated with previously determined measures of neophobia in wild-caught house sparrows (Passer domesticus) in captivity. Sparrows may experience stress not only from the very act of captivity, but also from a lack of environmental enrichment. Therefore, we also predicted that adding rubber perches, manzanita branch perches, and pine branches to cages would decrease both the frequency and duration of beak wiping bouts in captive birds. Preliminary data show that neophobia was not correlated with beak wiping behavior within individual sparrows, suggesting these two behaviors arise due to different neurobiological mechanisms and that they do not form a "high anxiety" behavioral syndrome.

## Deconstructing Sex: Ungendering Sex Variables

*Megan Massa*

Though we scientists recognize "sex" as a contextual category composed of multiple physiologies, most basic scientific research treats this complex heuristic as a single, internally consistent, and binary variable. This "dimorphizing" can be viewed as the naturalization of societal gender on the body and can result in underspecified data, imprecise science, and a research field that inadvertently incorporates gender stereotypes into scientific practice. Using personal examples from the lab bench, I first demonstrate how the heuristic of discrete binary sex can occlude relevant biological physiologies and limit the scientific imaginary, and then I propose tangible steps to specify, ungender, and recontextualize the science of sex.

## Buzzed and Bothered: Investigating the Impact of Psychoactive Floral Alkaloids on Bumblebee Behavior

*Skylar Mathieson, Joshua Foley, Melissa Whitaker*

The relationship between plants and pollinators is often viewed as a strict food-for-service exchange in which plants provide nutritious rewards (nectar, pollen) for pollinators in exchange for the dispersal of plants' gametes (pollen). Yet in addition to provisioning key nutrients, the floral rewards of many plants contain diverse chemical compounds whose functions are mysterious or even puzzling. For example, many floral rewards contain plant secondary compounds that are traditionally classified as defensive toxins. Some of these "toxins" include neuroactive alkaloids that affect pollinator cognitive functions such as learning and motivation, suggesting dual roles for these phytochemicals. We are investigating the behavioral and physiological responses of generalist pollinators (Bombus impatiens bumblebees) to three psychoactive plant alkaloids – caffeine, nicotine, and morphine – using robotic flowers. Pollinator preference and performance assays are coupled with pollen transfer experiments to identify potential tradeoffs or conflicts in alkaloid-mediated plant-pollinator interactions and to assess the potential for hijacking of pollinator behaviors by plants. Investigations into plant manipulation of pollinator preference is particularly salient given that some pollinators have even been found to exhibit addictive behaviors to neonicotinoid insecticides. With a better understanding of how floral reward chemistry affects pollinator cognition, behavior, and foraging decisions, we hope to work towards reconciling the seemingly contradictory forces that shape plant–insect coevolution and drive plant chemo diversity.

## Bacterial upstream motility regulates multispecies niche construction in flow networks

*Arnold Mathijssen, Ran Tao*

Bacteria have the remarkable ability to swim upstream, causing the contamination of biomedical devices, urinary tract infections (UTIs), and respiratory diseases. Here, we study how this microbial motility against flows, called rheotaxis, regulates the navigation and multispecies niche construction in flow networks. First, we nanofabricated microfluidic devices composed of microchannels with branching and looping architectures. Subsequently, we inoculated these devices with E. coli bacteria and mapped out the spreading dynamics of single cells using holographic 3D tracking microscopy. We reveal that bacteria accumulate in specific areas of the flow network, governed by the currents in the surrounding network segments. By tuning these currents using flow network theory, we can control the bacterial motion and guide population dynamics. We then explore the ecology of multiple bacterial species in these flow networks and reveal how different architectures affect microbial coexistence, cooperation, and competition. Hence, we achieve programmable control for various functions, including species-specific depletion and accumulation, species sorting, and structured community biofilm formation.

## Springing into action: A click beetle-inspired robotic model organism

*Teagan Mathur, Liyuan Zhang, Soloman Khan, Josh Gibson, Marianne Alleyne, Aimy Wissa*

Click beetles utilize a latch-mediated spring-actuated (LaMSA) movement strategy to produce their ultrafast click. Their LaMSA mechanism involves several components: the peg and lip forming a geometric latch; the mesonotum, a saddle-shaped structure believed to act as the primary spring; and musculature serving as multiple actuators. This study presents a novel robotic model organism (RMO) inspired by the click beetle, including a biologically relevant body frame, a latch, spring, and an actuator. Micro-CT scans of the click beetle inform the body frame. The RMO's latching structure is modeled after the beetle's peg and lip using environmental scanning electron microscope (ESEM) images and micro-CT scans. The spring component is also modeled from micro-CT scans and informed by high-speed x-ray and finite element analysis of the mesonotum. Artificial muscles actuate the RMO, with muscle connection points based on micro-CT scans of the M2 and M4 muscles. The RMO is used to investigate two key questions: How does the muscle line of action affect peg dynamics during latching and mesonotum deformations during loading? Second, how does spring geometry impact elastic strain energy storage during loading? This RMO allows exploration of a broader range of parameters for muscle line of action and spring geometry than biology alone allows, extending these findings to other organisms and bioinspired systems employing LaMSA movement.

## Symbiotic sensory systems: The complex interactions that enable coral resilience

*Shayle Matsuda, Kelsey Johnston-Sapp, Olivia Williamson*

Corals, despite their simple sensory systems and limited mobility, are highly adapted to survive in diverse environments due to their intricate symbiotic relationships with various microorganisms. These relationships enable them to cope with stressors such as disease and climate change-induced ocean warming. Unlike traditional model organisms, corals rely on their symbionts for functions they cannot perform independently. Here, I will explore coral resilience under stress and how symbiotic microbial communities help them sense and respond to environmental changes and stressors. Corals and their algal symbionts display varying degrees of specificity in their associations, influencing responses to elevated sea temperatures, disease (e.g., Stony Coral Tissue Loss Disease), and environmental acclimatization (e.g., assisted gene flow). Responses vary widely among individuals, species, and conspecifics. By examining coral reactions to stress events like bleaching, we gain insights into how their symbiotic partners mediate their diverse responses. The concept of a sensory system in corals extends to their interactions with algal and bacterial symbionts, creating feedback loops that influence metabolism, physiology, stress response, nutrient cycling, and immunity. Each coral, therefore, is a unique holobiont, with its sensory system comprising both the coral and its associated microbial communities. Understanding these systems provides new perspectives on coral adaptability and survival in changing environments.

## Measuring heritability and genetic complexity of suction feeding performance in cichlid fishes

*David Matthews, Craig Albertson*

One fundamental goal of evolutionary biology is to understand how genetic variation leads to phenotypic variation. While great progress has been made in understanding the genetic basis of traits like morphology and development, the genetics of complex kinematic traits such as suction feeding are relatively unknown. The first step towards understanding how genes affect such performance traits is to analyze patterns of inheritance to estimate the underlying genetic architecture. We accomplish this by first crossing two Lake Malawi cichlids, a riverine foraging generalist (Astatotilapia calliptera) and a benthic specialist (Tropheops sp. “red cheek”). We then bred the resulting F1 generation to produce a recombinant F2 population. We used high speed videography and particle image velocimetry (PIV) to capture suction feeding events from individuals within each generation, measuring jaw kinematics and suction flow velocity in each video. Finally, we used classical quantitative genetic measures to estimate the genetic underpinnings of these traits, including their heritability and the number of genes that affect them. Our results demonstrate that there is a measurable genetic component to complex traits like suction feeding, and pave the way for genetic mapping experiments to reveal the precise genetic control of these traits.

## The Physiological Underpinning of a Range-Limiting Tradeoff in the Trinidadian Guppy

*Alex Mauro, Cameron Ghalambor*

When physical barriers and eco-physiological explanations fail to explain a species’ range limit, that limit represents a conundrum of evolvability: why can the species not adapt to a broader range of habitats and expand its range? We investigated this in the Trinidadian guppy, Poecilia reticulata, asking: why has it been unable to adapt to the brackish waters directly beyond its current range in Trinidad despite its ability to persist in brackish water elsewhere? We specifically investigated the hypothesis that a tradeoff between salinity tolerance and competitive ability with the competitor, Poecilia picta, contributes to P. reticulata’s range limit. Experiments in nature and in the lab found that brackish water only reduced P. reticulata fitness when combined with the presence of P. picta, the competitive interaction between P. reticulata and P. picta is context dependent on salinity, and there is a genetic basis for a tradeoff between salinity tolerance and competitive ability. Lastly, a network analysis of gene expression data of fish under different competitive and salinity conditions revealed that osmoregulation and aggression are linked via hormonal pleiotropy, which provides a potential physiological mechanism underlying this tradeoff. The consistent negative relationship between salinity tolerance and competitive ability across different levels of biological organization and ecological settings provides strong evidence that this tradeoff constrains evolution in P. reticulata and contributes to its range limit.

## Darkness startle-response in free flying mosquitoes and fruit flies

*Roni Maya, Noam Lerner, Tsevi Beatus*

Vision is a central sensory modality for locomotion in many animals, including flying insects. Characterizing the effects of a sudden loss of all visual cues in mid-air may inform us about an insect’s mechanisms for sensory integration and redundancy, ability to fly in total darkness, and highlight differences between diurnal and nocturnal insects. Yet, to the best of our knowledge, an experiment testing these behaviors has not been reported so far. Here, we use high-speed 3D videography to characterize and compare the response of diurnal D. melanogaster fruit flies and nocturnal C. pipiens mosquitoes to sudden and complete darkness during free flight. Both species exhibit a new type of startle response: after 30-40ms delay, they increase their wingbeat frequency, pitch up to brake their horizontal velocity, and then change course. Fruit flies fly backwards and mosquitoes fly vertically up or down. By controlling the duration of darkness, we show how both species return to nominal flight once the light turns back on. Overall, although both species typically do not takeoff in the dark, upon sudden mid-air darkness they perform a characteristic and well-controlled response while maintaining flight stability. These results indicate that gravity sensing in fruit flies and mosquitoes includes a non-visual input, and opens the way for further experiments to address the question: how do insects flying in total darkness know where down is?

## Regional heterogeneity in the EMG activity of extrinsic tongue muscles is critical to tongue functio

*Christopher Mayerl, Elska Kaczmarek, Maressa Kennedy, Ani Smith, Skyler Wallace, Hannah Shideler, Emily Volpe, Dylan Anderson, Thomas Stroud, Harlow Smith, Holly Sabato, Shanique Yazzie, Sarah Sheldon, Tobin Hieronymus, Rebecca German*

The muscular hydrostat of the mammalian tongue is a critical component of feeding function. This is especially true during infancy, when the tongue curls around a nipple to create a seal, acts as a pump to generate suction and draw milk into the mouth, and finally pushes the milk into the esophagus. While most work investigating the function of the tongue has evaluated it holistically as a single structure, it is made up of several extrinsic and intrinsic muscles, each of which have numerous motor units, resulting in high levels of regional heterogeneity, both within a single muscle and among different muscles. We systematically evaluated the functional impact of regional heterogeneity in tongue muscle activity by recording electromyographic (EMG) activity of the extrinsic muscles of the tongue along anteroposterior and dorsoventral axes with synchronous biplanar videofluoroscopy and fluoromicrometry during infant feeding. We also integrated previous work investigating the function of the jaw and hyoid musculature in the context of tongue movement. There was extensive variation across the extrinsic musculature, and that the tongue interacts with and depends on the supporting musculature outside of the muscular hydrostat. These results suggest that understanding this hydrostat relies on multiple scales of anatomy: within each muscle, the hydrostat as a whole, and the surrounding muscles that attach to the supports of the tongue, including the hyoid, palate, and pharynx.

## The effects of social relationships on flocking dynamics in homing pigeons (*Columba livia*)

*James Mayson, Jasper Chaplin, Steven Portugal*

Cluster flocking can have a higher energetic cost than flying alone, as individuals must avoid colliding with flock mates, match the pace of their conspecifics, and remain aware of movements of nearby birds in the flock. In Eurasian jackdaws (Corvus monedula), a strictly monogamous species, less energy is expended on the individual level when flying closer to their mate, and mates fly closer together than with any other birds in the flock. However, it is unclear if this relationship is ubiquitous amongst cluster flocking birds, or unique to strictly monogamous species. To determine this, we examined the relationship between social networks and flocking dynamics in free-flying homing pigeons (Columba livia), a less strictly monogamous species than jackdaws. We determined the social networks within pigeon flocks during local flights around their home loft before releasing birds from greater distances. Using biologging technology, we aimed to test (1) whether birds preferentially flew nearest to individuals close in their social network ('friends') over long flights, and then (2), using flap frequency as a proxy for energy expenditure, determine whether birds would expend less energy when flying close to 'friends'. By comparing these results to past research on Jackdaws, this study additionally provides insight into whether the effects of social relationship on flocking are conserved or unique across evolutionary and life history.

## Flocking dynamics and energy expenditure of cluster and V-formation species

*James Mayson, Hangjian Ling, Hana Merchant, Guillam McIvor, Alex Thornton, Steven Portugal*

In the collective motion of birds, there are two primary types of flocking: cluster (non-linear 3D flocks) and V-formation (linear and typically in a horizontal plane). Both forms of flocking impart both ultimate and proximate group living benefits, yet the aerodynamic interactions taking place between flock members are quite different. Cluster flocking includes energetic costs due to collision avoidance, while V-formations have aerodynamic advantages which decreases energetic costs. Flocking dynamics, such as the distance between birds, flock size, pairing of individuals, and individual flightpaths influences the flight of birds within both flock types, however, studying this in wild birds is challenging. We examined the flocking dynamics and energy expenditure of ring-necked parakeets (Psittacula krameria) and pink-footed geese (Anser brachyrhynchus) using a non-invasive camera-array system. We aimed to determine the factors that influence flight speed and flap frequency (a proxy for energy expenditure). Parakeets are a social, seasonally-mating, cluster-flocking species with a manoeuvrable and fast flight style. In contrast, pink-footed geese are lifetime monogamous social birds with less manoeuvrable flight. The camera array system allows for fine-scale collection of flap frequency and position, velocity, and acceleration in 3D for all birds passing through the array. By comparing these results from cluster and V-formation flocking species, we gain insight into factors influencing flocking dynamics and individual spacing and the comparative energy expenditure in these distinct flocking types.

## Weaving science into the lives of our neighbors

*Sarah McAnulty*

Science communication exists within an ecosystem of messaging. Every day, people experience messages from social media, traditional news sources, and conversations with their fellow community members. As science communicators, we need to break through a lot of noise to get accurate scientific information to as many people as possible. Online communicators are often fighting uphill battles against disinformation campaigns funded by fossil fuel companies, all amidst upheavals in social media. These challenges have underlined the importance of a diverse set of approaches in science communication to break through the noise.

Our recent projects in Philadelphia all begin with deep connection with local communities. These approaches circumvent siloed media structures to reach people across social media divides. We put science content directly in the paths of people's everyday lives via murals, street art, printed materials, and other unconventional approaches.

In this talk, I will cover the varied approaches we have taken in Philadelphia, and share a practical toolkit that scientists can use in their own communities.

## Impacts of Florida scrub jay management on the density and predation of Florida scrub lizards

*Lance McBrayer, Justin Sanclemente, Michael Brennan*

Management of imperiled habitats often focuses on charismatic target, or umbrella, species. Thus, management activities are conducted such that both target species and its habitat are enhanced. Resident non-target species may also benefit from greater area of habitat, or availability of key habitat characteristics, generated by management. Yet, target species may also be competitors or predators of non-targets which could lead to unexpected outcomes from species interactions. Ocala National Forest manages Florida scrub habitat via clear cutting, and for several target species including the endemic Florida Scrub Jay. Jays are known predators of another endemic, the Florida Scrub Lizard. We will present data comparing the density and abundance of scrub lizards in sites that are managed for jays and sites that are not. Also, we will present results from a clay model study that compared predation at sites managed for jays vs sites. that are not. Lizards are found in each management type, yet are at greater density at sites managed for jays. Interestingly, we found that models were depredated in each site type, but predation was highest in sites with jays. Thus, habitat management for jays for benefits this non-target lizard species broadly, but also results in greater predation on it.

## Rethinking enemy release: sex-specific infection risk and urban influences in House Sparrow populations

*Kailey McCain, Marty Martin, Aaron Schrey, Kevin Kohl, Elizabeth Sheldon, Gabriela Mansilla, Roi Dor, Henrik Jensen, Jorgen Soraker, Kim Mathot, Thinh Vu, Blanca Jimeno, Kate Buchanan, Massamba Thiam, Jim Briskie, Cédric Zimmer, Melissah Rowe, Ho Thu Phuong*

Enemy Release Theory suggests that introduced species experience reduced parasite pressure in novel environments, yet our study of House Sparrows (Passer domesticus) provides evidence to the contrary. Investigating the prevalence of enteric pathogens, Salmonella enterica and pathogenic Escherichia coli, across eight native and non-native populations, we found that pathogen prevalence varied significantly among populations but not consistently with invasion status. Contrary to the theory, invasion status alone did not predict pathogen prevalence.

Interestingly, a sex-specific effect emerged: non-native females were significantly more likely to be infected than native females, a pattern not observed in males. Additionally, we explored how body condition varied between infected and uninfected birds across invasion statuses and urbanization gradients. While invasion status alone did not influence body condition, urbanization played a significant role in modulating it.

These findings highlight the complex interplay between sex, urbanization, and invasion status in shaping host-pathogen interactions. This study emphasizes the need to consider ecological and demographic factors to fully understand disease risks in non-native species and urban ecosystems.

## Within arms reach: understanding the evolution of a cephalopod novelty

*Jennifer McCarthy-Taylor, Jenna Moor, Caroline Albertin*

Molluscs demonstrate a wide array of body plan diversity, making them an interesting group to study body plan evolution. Within this clade, the cephalopods have a striking and evolutionarily novel structure: prehensile limbs. While prehensile limbs are characteristic of several, diverse animal groups, they are not present in other molluscs. The same signaling molecules and transcription factors that govern limb formation and outgrowth in vertebrates and arthropods have been observed in cephalopods in a striking example of convergent evolution. In this study we aim to compare both leg gap genes (extradenticle, homothorax, dachshund, distalless, hedgehog, and engrailed) and the hox genes and their roles in limb placement, identity, and outgrowth in two squid species, Doryteuthis pealeii and Euprymna berryi. These squid diverged approximately 100 million years ago and have different life styles and modes of development: Doryteuthis pealeii are pelagic and hatch at a paralarval stage, while Euprymna. berryi are benthic and direct developers. To understand the interaction between body patterning genes that are expressed in the ancestral foot tissue, we employ in situ HCR and CRISPR/Cas9 knockouts, which are robust in both species. Going forward, we plan to compare these results to other molluscs without prehensile limbs to probe the evolutionary and developmental origins of these morphological novelties.

## Ballistic testing of extraoral teeth in scale-feeding fishes

*Kelsie McCorkle, Cassandra Donatelli, Jonathan Huie, Olivia Hawkins, Matthew Kolmann*

Many characiform fishes feed on the scales of other fishes and possess a remarkable adaptation for removing scales from their prey. These lepidophagous (scale-feeding) fishes often have extraoral teeth protruding from their upper jaw that help dislodge scales when they ram into a target fish. Scale-feeding fishes vary to what extent they rely on scales as a food source (obligate vs. facultative) and the size of their extraoral teeth, which may suggest morphological and ecological specialization. We predicted that obligate scale-feeding fishes have teeth more effective at removing scales than facultative lepidophages. We also hypothesized that scale-feeders have more robust vertebrae that reinforce the skeleton against forceful impacts during feeding. We first examined morphological differences among extraoral dentitions and vertebrae in three obligate and two facultative scale-feeding characiforms and two non-scale-feeding relatives using micro-computed tomography. We then assessed scale removal performance by filming 3D printed models of characiform skulls launched at dead fish with a spring-loaded railgun, simulating ram-feeding behavior. We find that obligate scale-feeders have larger extraoral teeth than facultative lepiodphages. We also find that models of obligate scale-feeders dislodged more scales than facultative and non-scale feeder models and that obligate scale-feeders have a more robust vertebral column. These findings indicate that obligate scale-feeding characiforms are equipped with a more effective feeding morphology for removing and feeding on scales.

## Population structure, local adaptation, and demography in the Texas tortoise (Gopherus berlandieri)

*Griffin McDaniels, Jacquelyn Tleimat, Sarah Baty, N. Jade Mellor, Paul Crump, Shawn McCracken, Kenro Kusumi, Greer Dolby*

The Texas tortoise (Gopherus berlandieri) is a dry-adapted species of conservation concern ranging from southern Texas along the Sierra Madre Oriental into the Mexican states of Coahuila, Nuevo Leon, and Tamaulipas. As ectotherms, they are sensitive to their environment, and their long lifespan and generation times may make them susceptible to demographic swings. Therefore, in addition to being relevant for conservation, they also offer an opportunity to study how populations of long-lived species have adapted to a dry landscape with variable trade wind patterns that may have changed historically. Previous work using microsatellite loci suggested weak divergence between northern and southern portions populations. However, development of genomic resources for the desert tortoise complex in the southwestern USA/MX (G. agassizii, G. morafkai, G. evgoodei) revealed extensive differential adaptation, conserved synteny, and demographic changes in those species. Here, we expand this study system by generating fully phased and annotated PacBio long-read and Hi-C scaffolded reference genomes for G. berlandieri as well as whole genome sequencing of 66 individuals across its Texas range. With these resources, we will test for evidence of population structure, local adaptation, and assess historical demography in G. berlandieri. Based on niche modeling and prior data, we expect to see signatures of population differentiation between northern and southern populations, potentially related to differences in precipitation associated with trade wind patterns.

## Fairy Knots — Unraveling the Biomechanics of Single-Strand Knot Formation in Curly Hair

*Christina McDonald, Thomas Jones, Ishant Tiwari, Saad Bhamla*

Fairy knots, or single-strand knots in hair, are a common issue for many people having textured hair with high degrees of curliness. The name evokes the knot's apparently spontaneous formation indicating that only a small fairy could tie such a tiny yet meticulous knot unnoticed. Typically forming towards the end of the hair shaft, these knots are difficult to remove once formed. Although the knots are suspected to form spontaneously from the stretching and recoiling of hair dur-

ing routine haircare practices, the root cause of their formation remains largely unconfirmed.

This research aims to identify the hair dynamics that lead to knotting, as well as key physical properties of knot-prone hair. Using high-speed videography and time-lapse imaging, we investigate the stretching and recoiling dynamics of textured hair under experimental mechanical (pulling and combing) and hydromechanical (wetting and drying) manipulations. Analysis of hair tip motion during these manipulations gives insights into potential mechanisms for knot formation. Understanding how fairy knots form can help develop targeted haircare solutions to prevent knots and reduce hair damage.

## Investigating the visual physiology of insect ocelli

*Marisa McDonald, Daniel Chappell, Grace Hickey, Martin (Ric) Wehling*

In insects most visual tasks are completed by the primary compound eyes. However, many groups also utilize a secondary visual system, the ocelli. The ocellar system is composed of two or three single lensed eye spots that reside on the head between the compound eyes, typically forming a triangle. While early studies suggested that ocelli were basic light sensors, with no focusing power, spatial detection, or specializations, we now know this is not the case. Ocelli are hypothesized to be used for a variety of visual tasks, the best described being flight stabilization and sky compass orientation. Because of the sophisticated compound eyes of insect systems, the ocelli are seemingly redundant; however, they may be used for quick decisions and rapid processing. It is likely that, much like the compound eyes, ocelli are specialized for specific functional requirements and therefore have distinct visual sensitivities compared to the compound eye. However, relatively few studies have been completed on the ocelli at this time. To better understand ocellar visual systems we used electroretinogram recordings to examine spectral sensitivity, flicker fusion frequency, and irradiance sensitivity of the ocelli in multiple insect species from the orders Hymenoptera, Diptera, and Odonata. Through this study, we aim to increase our understanding of ocellar function.

## Quit Monkeying Around: an anatomical study of hindlimb muscle architecture in primates

*Connor McDowell, Michael Deutsch, Alana DiMartino, Avarie Rembert, Anand Kanumuru, Ariba Islam, Alexandra Abrams, Aleksandra Ratkiewicz, Edwin Dickinson, Michael Granatosky*

Muscle architecture – an anatomical metric that describes force generating potential and excursion range of skeletal muscle – represents a key determinant to an animal's functional repertoire. While several studies have sought to describe these properties within primates' forelimb muscles, less is known about the structure and variation of hindlimb musculature. This study provides data on leg and intrinsic foot muscles from approximately forty primate species encompassing all major locomotor and substrate use categories found in strepsirrhines, platyrrhines, and catarrhines. Muscles were isolated and classified into functional groups: extrinsic ankle extensors and flexors, extrinsic digital extensors and flexors, and intrinsic foot muscles. Muscle mass, physiological cross-sectional area (PCSA), and fiber length were analyzed in relation to laterality, phylogeny, locomotor mode, and substrate preference. Results indicate that muscle mass and PCSA scaled with positive allometry, whereas fascicle length scaled with negative allometry or isometry. All variables strongly correlated with body mass. This suggests that larger primates are stronger than smaller species but have shorter leg muscle fibers. No significant correlations were found between muscle architecture, substrate or locomotor categories, and no significant bilateral differences were observed. These results indicate that while many aspects of muscle structure are conserved and influenced by scaling rather than ecological factors, certain elements of muscle anatomy may adapt to align with an animal's locomotor ecology.

## Changes in limb function with fatigue in two species of lizards

*Eric McElroy, Conner Entzminger*

Animals fatigue when they engage in high levels of activity for extended periods. One way that fatigue can be defined is a reduction in locomotor performance over time that occurs due to proximate changes in the physiology of the body systems underlying locomotion. This study examines changes in the three-dimensional limb and body kinematics and behavior of two species of lizards as they are fatigued due to repeated sprinting locomotion. Individual lizards were sprinted down a racetrack repeatedly in rapid succession to elicit degradation in sprinting performance. Limb and body three-dimensional kinematics and behavior were quantified and then compared for the first sprint (fresh, maximum performance) and the final sprint (fatigued, degraded performance).

## Widespread variation in retinochrome spectral absorbance across scallop phylogeny

*Kyle McElroy, Anna Ward, Jeanne Serb, Jorge Audino*

A major goal in evolutionary biology is connecting genotype to phonotype. Proteins with directly measurable properties, like light-absorption in opsins, are powerful settings to explore sequence-function relationships. Opsins are transmembrane protein receptors that bind to light sensitive chromophore molecules, forming photopigments capable of absorbing light at maximally sensitive wavelengths (λmax). In addition to initiating phototransduction for vision, opsins regulate numerous other light-dependent processes. An opsin's amino acid sequence influences its spectral properties by creating the biochemical environment surrounding the bound chromophore, which determines its light reactivity. Spectral tuning, or shifts in λmax towards shorter or longer wavelengths, can be achieved through amino acid substitutions, enabling natural selection to drive opsin functional change. Despite extensive research on the evolution of vertebrate visual opsin function, we know very little about spectral tuning for invertebrates or opsins with non-visual functions. Here, we expand on our previous work identifying spectral tuning sites in the retinochrome opsin from scallops. We compared retinochrome λmax among three pairs of closely related species to identify sites underlying spectral tuning. We found that scallop retinochrome has a wide spectral range of – based on our sampling – 486 nm to 525 nm. We then functionally investigated tuning sites via reciprocal mutagenesis between pairs of species with notably distinct λmax, Argopecten irradians vs. A. purpuratus (19 nm) and Chlamys farreri vs. Mizuhopecten yessoensis (15 nm).

## Sexually selected weapons can wear out, decreasing their effectiveness in combat

*Isaac McEvoy, Lana Daniels, Zachary Emberts*

Sexual selection has resulted in some of the most elaborate traits seen in animals, many of which are used as weapons. These weapons can be incredibly diverse, even within species. Such morphological variation has largely been attributed to the environment in which individuals are reared and their genetics. However, variation in weapon form could also be the result of a weapon wearing out from usage. This mechanism has received relatively little attention. In this study, we demonstrate that sexually selected weapons can wear out from repeated use, providing experimental evidence that weapon usage can contribute to the diversity of weapon shapes observed within species. In a second experiment, we demonstrate that having a worn-out weapon decreases an individual's fighting ability. This finding illustrates that the shape of a weapon can have an important role in determining contest outcomes. Overall, these results suggest that individuals are limited in the number of times they can effectively use their weapons, which may be one factor (among others) influencing how frequently an animal engages in a fight.

## Littoral Vegetation and Phytoplankton Primary Production in Laguna Bacalar, Mexico

*Jaclyn McFadden*

Laguna Bacalar, located in southern Yucatán, is known as the Lake of Seven Colors, with clear waters and a white carbonate limestone bottom, extensive modern stromatolites, and near several Mayan ruins. It has experienced increased tourism over the last few years and is predicted to become a key tourist destination. With the impending completion of the Mayan Train, including a designated stop in Bacalar, the town is only expected to grow. While this growth may benefit the economy, it could also negatively impact the health of the lake. It is imperative to determine a baseline of the primary production and respiration rates in the oligotrophic laguna before the impact of tourist development takes hold. The vegetation in the laguna has received little in-depth study. This research investigated the primary production and respiration rates of both the phytoplankton community and benthic macrophyte vegetation in Laguna Bacalar. This was done through a series of diel light and dark bottle experiments and through acrylic chambers deployed over 24 hours in situ on benthic littoral habitats in which oxygen concentrations were measured continuously (every minute). The phytoplankton findings indicate the laguna is phosphorus-limited, and baseline measurements were recorded for the respiration and production rates of the genera Eleocharis, Nymphaea, and Utricularia. There is still much to uncover regarding vegetation and primary production in Laguna Bacalar, requiring additional research.

## Muscle-tendon unit function in response to surface slope perturbations in hopping kangaroo rats

*Craig McGowan, Mary Pena, David Lin*

The natural terrains on which animals locomote present multiple types of perturbations, including changes in substrate properties, elevation, and slope. The mechanisms animals use to mitigate these perturbations are not well understood, and may include a combination of cortical control, spinal level reflexes, and intrinsic muscle-tendon properties. Kangaroo rats are an excellent model to explore these mechanisms because their bipedal hopping locomotion constrains ground contact to a small base of support and their relatively short stance phase limits the time for cortical input and perhaps even reflexes. In this study, we examine how changes in muscle mechanics of the ankle plantar flexors of desert kangaroo rats contribute to maintaining locomotor stability during a surface slope perturbation. Animals hopped at a steady speed (1.77m/s) on our custom-built variable terrain rotary treadmill that was instrumented with a 12 degree up-slope wedge. Using a combination of sonomicrometry, tendon force buckles, and electromyography, in the lateral gastrocnemius (LG) muscle, we examined changes in muscle dynamics in response to hitting the slope. Preliminary analysis showed that LG lengthening strain tended to increase during perturbed trials, relative to level hopping (0.19 vs. 0.11) but muscle-tendon unit force was not different (17.9 N vs 18.5 N). Further analysis is needed to determine if the PL muscle, which inserts on the toes, is more affected by the slope perturbations.

## Balancing risk and reward? State dependent neural responses to looming threats in *Manduca Sexta*

*Delaney McGowan, Varun Sharma, Leo Wood, Jordanna Sprayberry, Simon Sponberg, Emine Zeynep Ulutas*

Neural responses to looming stimuli as potential threats are common in animals across taxa. However, behavioral state can change how animals perceive and respond to threats. We hypothesized that when in a behavioral state triggered by perception of a high value resource, an organism might suppress its threat responses. The mechanisms of looming response have been studied extensively in model insects such as fruit flies and locusts. The adaptive neural coding of changes in behavioral response as reward changes is less explored

The tobacco hawkmoth, Manduca sexta, with its ability to actively hover feed for high-value nectar affords an opportunity to modulate the reward state of the behavior.

We built an electrophysiology setup that allows for flapping and olfactory stimulation while recording with multielectrode arrays. We tested loom-evoked responses from neck connective neurons of Manduca sexta when exposed to an innately attractive floral scent and with and without active flapping. We found collision time dependent looming responses in neck neurons in flapping and non-flapping trials. These first recordings with multichannel arrays in the neck connective during flapping shows that the looming response at this task-level representation is robust.

## The influence of hydrology on seasonal movement strategies of *Crocodylus acutus* in Costa Rica

*Maggie McGreal, Christopher Murray, Tyler Coleman*

Humans present significant challenges for large predators in shared landscapes, and the coexistence of humans and crocodiles in Guanacaste, Costa Rica poses an especially pressing issue. This study uses movement data to unravel the complex relationship between humans, hydrology, and American crocodiles (Crocodylus acutus) in the Lower Tempisque River Basin, where conservation efforts leading to population recovery have also created a situation of conflict. Seasonal variability in hydrology makes this an ideal system for studying the behavioral mechanisms by which crocodiles cope with environmental change and the implications these behaviors may have for human–crocodile relationships. Movement strategies arise in response to predictable changes in environmental conditions, and these strategies are reflected in the spatial and behavioral components of animal movement data. Crocodilians generate unique movement patterns often reflecting cryptic behaviors and prolonged periods of inactivity, presenting challenges that traditional methods of space-use estimation fail to overcome. To address this, we applied dynamic Brownian Bridge Movement Models (dBBMMs) to GPS data obtained from ten individual crocodiles to estimate movement parameters for modeling movement paths and inferring behavioral states. The findings reveal distinct seasonal movement strategies among individuals in response to changes in hydrology, providing valuable insights into the influence of environmental variability on the spatial and behavioral dynamics of crocodiles and constraints on movement that exacerbate conflict.

## Disruptions to the trait-environment relationships of African mammals

*Jenny McGuire, A. Michelle Lawing, Daniel Lauer, Leila Siciliano Martina, Julia Schap, Maria Hurtado Materon, Rachel Short*

We leverage relationships between mammalian functional traits and their environmental conditions to test whether extinctions degraded mammalian community function in eastern Africa since 7.4 Ma. We then predict where future climate change will disrupt trait-environmental relationships. We use an ecometric framework, which examines the alignment of community functional traits with environmental conditions.

We adapt ecometric methods to evaluate whether biodiversity losses since 7.4 Ma, when grasslands began expanding into eastern Africa, were coincident with disruptions to the functional link between communities of herbivorous megafauna and their environments. Although taxonomic, functional, and phylogenetic biodiversity shifted considerably from 7.4 to 1.9 Ma, trait-environment relationships were not disrupted until the early Pleistocene, with the advent of punctuated aridity and Acheulean tools. Even more extreme environmental disturbance is projected to occur soon, as climate change and human impacts intensify. Using a similar model, we identify communities whose trait-environment relationships will be disrupted under projected climate change. Over 50% of African communities exhibit weak future ecometric relationships for at least one trait, putting them at risk of depleted ecological function. The mammals comprising these communities will need to shift across space to realign trait-environment relationships. Evaluating the landscape connectivity across Africa, we identify where community reconfigurations will be impeded. Conservation efforts focused on movement routes are critical for conserving megafauna and essential ecological functions.

## The mechanics of soft skeletons: tube feet in sea stars

*Matt McHenry, Olaf Ellers, Theo Po, Amy Johnson*

Hydrostatic skeletons, such as an elephant trunk or a squid tentacle, permit the transmission of mechanical work through a soft body. Despite the ubiquity of these structures among animals, we lack a general understanding for how morphological differences affect the ability of soft skeletons to transmit muscular work. We have therefore developed a mathematical model of the tube foot in sea stars. Tube feet are relatively simple hydrostatic structures and therefore experimentally tractable. Our model explicitly considers the pressures and wall stresses in the two chambers of a tube foot on extension and retraction. We found that tube feet exhibit variable gearing, with changes in mechanical advantage generated by deformation of the skeleton and through the storage or dissipation of mechanical energy. We used this model and behavioral experiments to understand the locomotor mechanics of the juvenile six-rayed star (Leptasterias sp.). Our results suggest that tube feet primarily generate forces to overcome the submerged weight of the body, with a disproportionate amount of work generated by the feet at more proximal positions along each ray. These results demonstrate how the morphology of a hydrostatic skeleton can play a fundamental role in the mechanics of animal locomotion.

## Prevalence of assortative mating by larval type in a population of Streblospio benedicti

*Kayleigh McHugh, Christina Zakas*

The emerging model, Streblospio benedicti, offers the unique opportunity to explore the evolution of larval developmental strategies within a single species. This marine polychaete has both free-swimming, feeding larvae known as planktotrophs, and benthic, yolk-subsisting larvae known as lecithotrophs. S. benedicti populations typically contain only one larval mode. However, some populations are composed of both. Since larval mode is genetically determined and heritable, we aim to examine how patterns of assortative mating can contribute to population larval-type composition. We test if assortative mating occurs in a population with mixed larval-types collected from Baruch, South Carolina. We use a female-choice crossing scheme where females are simultaneously exposed to both planktotrophic and lecithotrophic males. We use a previously designed marker to assign paternity to the planktotrophic or lecithotrophic male. We compare this mixed population to previous studies that investigated female mate-choice across two different populations of lecithotrophic and planktotrophic S. benedicti. In these allopatric populations, females preferentially produced offspring from males with the same larval-type. Since the Baruch population is sympatric, we can test predictions of how assortative mating may be linked to larval development mode.

## Acclimation effects on cutaneous evaporative water loss in chameleons living in dynamic environments

*Madison McIntyre, Etti Cooper, Graham Alexander, Krystal Tolley, Christopher Anderson*

The underlying mechanisms by which organisms are capable of rapidly acclimating to their environments are of particular interest as the global climate becomes more extreme and unpredictable. Squamates are an ecologically diverse group, inhabiting a wide range of environments which fluctuate to varying extents over annual, seasonal, and daily shifts in aridity and temperature. Thermoregulation and hydroregulation are closely coupled mechanisms necessary for survival and both are dependent on the integument which drives transport of heat and water between internal and external environments. We measured acute changes in cutaneous evaporative water loss (CEWL) rates over a 12-hour period (day vs. night) in three chameleon (Bradypodion and Chamaeleo) taxa from diverse thermal and hydric environments. We evaluated differences in CEWL within and between species from measures taken across the body on field-fresh individuals. We found that some species experience greater shifts in CEWL rates due to daily shifts in temperature whereas others experience greater shifts due to humidity. After chameleons were acclimated to a controlled lab environment, there was reduced variation in CEWL rates based on temperature and humidity. Short-term acclimation effects over a 12-hour period illustrates the chameleon's ability to rapidly and reversibly change CEWL in response to environmental conditions. Longer-term acclimatization effects to a stable lab environment revealed species differences in CEWL rates which could be a result of phylogenetic, environmental, and physiological effects.

## Examining stress hormone fluctuations in green frogs (*Lithobates clamitans*) during the mating season

*Abby McIver, Joe Bidwell, Trevor Chapman*

With the global decline of amphibians, conservation efforts have become increasingly vital. Amphibians endure various stressors throughout their annual active periods including innate physiological and anthropogenic stress. An understanding of temporal trends in these stressors may facilitate conservation efforts. The goal of this study was to quantify corticosterone in green frogs (Lithobates clamitans) at baseline levels and in response to an acute stressor throughout the mating season. The project was conducted from May to September of 2024 at Bays Mountain Park in Kingsport, Tennessee. Samples collected throughout the season elucidated both the acute stress response and possible physiological responses to seasonal abiotic and biotic stressors. Corticosterone levels were determined from May to September using a non-invasive dermal swab technique. To measure the acute stress response, frogs were captured and swabbed every fifteen minutes for an hour with the swabs analyzed using enzyme-linked immunosorbent assay (ELISA) kits. It was expected that corticosterone levels will be greater in males throughout the season and both sexes will experience a peak in August.

## Genetic and structural similarities between apolipoproteins and two recently-describe stress respons

*Reagan McKee, Dustin Kolste, Randy Klabacka, Jeremy Bakelar*

Fr10 is a recently described stress response gene hypothesized to help the wood frog (Rana sylvatica) survive cold temperatures. Fr10 is upregulated in freezing conditions, reduces cellular damage from freezing, and causes in vitro reduction in the growth of ice crystals. Drp10 is another recently described stress response gene found in the African clawed frog (Xenopus laevis) identified as a possible structural homolog to fr10. Protein structure predictions have suggested structural conservation between fr10/drp10 and apolipoproteins. This suggested structural conservation has led to the hypothesis that fr10/drp10 may have independently evolved their novel stress response functions from an ancestral apolipoprotein gene. While structural homology of products from these genes with apolipoproteins has been suggested, genetic homology has not been explored. In this study, we explore the genetic relationship of fr10/drp10 with apolipoproteins. We hypothesize that genes homologous to fr10 and drp10 will be found in closely related species and will be members of the apolipoprotein gene family. To test this hypothesis, we searched genome databases for similar sequences, calculated phylogenetic distances between genes, estimated phylogenetic placement of these recently described genes among the apolipoprotein gene family, and examined the similarities of predicted structures using structural alignments. Our findings suggest genetic homology of ApoA-II with both fr10 and drp10.

## Turning and control of a tethered, Tuna-Inspired underwater vehicle *

*Owen McKenney, Joseph Zhu, Hilary Bart-Smith*

Current Tunabot models prioritize high speeds and have thus been mainly constrained to linear trajectories. In this study, we enhanced the maneuverability of an existing thunniform Tunabotvehicle by precise controlling of the vehicle's propulsion system. We developed a control algorithm that modulates the main propulsion motor at specific frequencies during key phases of the tail's sweeping motion. This resulted in a controllable asymmetric tail flapping, enabling the vehicle to perform turning maneuvers. This control method was tested using varying tailbeat frequencies ranging from 1-5 Hz with a difference of 1 Hz between the two frequencies. High-speed video was captured as the vehicle executed turns in an open water tank under various frequency combinations. The vehicle was tethered by slack electrical cables during testing, thus the effect was considered negligible. The minimum and maximum turning radii within this 1-5 Hz range and the turning speed were then determined.Additionally, these frequency combinations were also tested in a flow tank, allowing for the turning force of the asymmetric flapping to be quantified.

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## New & used: the exaptation of silk spinning systems in amphipods

*Siena McKim*

Novel functions have been pivotal in driving the evolution of complexity and biodiversity, but the degree to which these functions arise from pre-existing components and structures remains an open question. A prime example of this is the adaptation of silk-spinning systems, found in diverse arthropods such as arachnids, insects, and crustaceans. Amphipod crustaceans (Corophiida) use silk from their third and fourth legs to bind together sediment, algae, poop, and shell pieces to create diverse domiciles used for almost every aspect of their life. The function of silk is evident in these groups, but some corophioid amphipods do not produce conspicuous silk structures, seeming to have lost the ability to produce silk. These amphipods include skeleton shrimps (Caprellidae), whale lice (Cyamidae), and sea fleas (Podoceridae). In these groups, the role of potentially ancestral silk-spinning systems remains mysterious. Through histological staining and imaging techniques, I have examined the pereopodal gland morphologies within these taxa. Remarkably, I discovered that some species retain the entire silk-spinning system, similar to that of their silk-spinning relatives. In this work, I present my findings on these glandular systems, propose their potential functions, and discuss the evolution of the corophioid glandular system. Amphipod gland and silk systems provide an excellent model for studying the role of exaptation in the evolution of novel functions.

## The rhythm of love: investigating rhythm in bioluminescent ostracods

*Cheyenne McKinley, Todd Oakley*

Biological rhythms drive many physiological processes and behaviors using two main mechanisms, an endogenous clock or exogenous cues, such as light availability. Here, we begin to investigate the underlying mechanisms of biological rhythms in the bioluminescent courtship signals of ostracods. Luminous ostracods time their bioluminescent mating displays to the darkest periods of the night, when males swim into the water column and produce bioluminescent signals to attract mates. A previous study from field observations proposed that luminous ostracods respond directly to darkness as an external stimulus to determine when to produce mating signals, signaling when less than a third of the moon is visible. Under this hypothesis, we would expect luminous ostracods to signal at similar activity levels throughout the night when presented with constant darkness. To test this hypothesis, we conducted a pilot study, recording ostracod signal activity under constant darkness across several nights. Surprisingly, we found that signal activity occurs during a window of time early in the night and does not occur at similar activity levels throughout the night, suggesting the influence of an endogenous clock. This work challenges previous notions about the rhythm of bioluminescent displays in ostracods and lights the way for future investigation into the mechanisms of biological rhythms.

## Sublethal lead exposure impacts gene expression in the brain of developing songbirds

*Casey McLaughlin, Christopher Goodchild, Elizabeth Gilbert, Kendra Sewall*

Decades of research on lead pollution have focused on wildlife mortality, yielding important insights into acute lead toxicity. Yet many animals are also exposed to sublethal levels of lead, which can cause cognitive impairments. While the effects of acute lead toxicity are well documented, the underlying mechanisms driving impairment at sublethal doses remain unclear. Songbirds at lead-contaminated sites often have elevated blood lead levels. They do not typically exhibit acute lead poisoning, yet the exposure levels observed are associated with differences in behavior, cognition, and brain volume that implicate a neurological mechanism. To explore the mechanisms by which sublethal lead could impact the brains of songbirds, we dosed fledgling captive zebra finches with lead during a critical period of development. We measured the expression of genes associated with neural damage and cell death in the brain using qPCR. We found that a gene associated with apoptosis, caspase-9, was upregulated in lead-exposed birds compared to unexposed controls. Another gene encoding an antioxidant enzyme important in oxidative stress management, catalase, was downregulated in birds exposed to lead. These results suggest that sublethal lead exposure, even over a short timeframe, may induce apoptosis and oxidative stress in the developing songbird brain. Inappropriate cell death and oxidative stress, especially during the critical developmental window studied here, could contribute to disruptions in behavior and cognition that persist into adulthood.

## Fluctuating asymmetry and herbivory levels as indicators for stress in mangroves in Tampa Bay, FL

*Kate McLendon, Peter Stiling*

Mangroves are critical members of intertidal ecosystems, yet it is not fully understood how they will respond to the effects of climate change. Fluctuating asymmetry (FA), defined as the random deviations from perfect symmetry in organisms, is one way to measure the effects of stress and/or developmental instability in populations. Recent publications have been critical of the utilization of FA due to poor and inconsistent practices. Therefore, evaluating the efficacy of this simple and often non-invasive technique to measure population health becomes increasingly important as sea levels continue to rise and threaten coastal species with further inundation and salinity changes. Given that FA seems to be sensitive to environmental or genetic stress, we investigated the effect of salinity stress driven by climate change, measured as porewater salinity, on both leaf symmetry and leaf area removed by herbivores. This was achieved by removing leaves from all three mangrove species (Rhizophora mangle, Avicennia germinans, Laguncularia racemosa) at different sites in Tampa Bay, Florida and photographing and drying them for measurement and analysis, respectively. We looked for correlations between leaf symmetry and herbivory levels with leaf water content, tannin concentrations and porewater salinity. We hypothesize that as salinity increases, so will FA and leaf area removed by herbivores, and that less symmetrical leaves will have lower water content and tannin concentrations than those that are more symmetrical.

## Adult caudal fin shape is imprinted in the embryonic fin fold

*Sarah McMenamin, Eric Surette, Joan Donahue, Crisvely Soto Martinez, Nicolas Cumplido Salas*

The caudal fin is the primary appendage used for propulsion in most fish species, and the organ exhibits a range of distinct morphologies adapted for different swimming strategies, from a deeply forked shape (as in tuna and carp) to a truncate or rounded shape (medaka; clownfish). However, the molecular mechanisms responsible for generating these diverse shapes remain largely unknown. Zebrafish caudal fins are forked in shape, with longer supportive bony rays at the periphery and shortest rays at the center. We have demonstrated a premature, transient pulse of sonic hedgehog a (shha) overexpression during late embryonic development results in excess proliferation and growth of the central rays, causing the adult caudal fin to grow into a triangular, truncate shape. Both global and regional ectopic shha overexpression are sufficient to alter fin shape, and forked shape may be rescued by subsequent treatment with an antagonist of the canonical Shh pathway. The induced truncate fins show decreased fin ray number and fail to form the hypural diastema that normally separates the dorsal and ventral fin lobes. While forked fins regenerate their original forked morphology, truncate fins regenerate truncate, suggesting that positional memory of the fin rays may be permanently altered by a transient treatment during embryogenesis. Our work offers insights into the developmental mechanisms that may underlie caudal fin shape diversity across teleosts.

## Flapping wing insect inspired buckling joints for micro-robotic resilience

*Jenna McNally, Mark Jankauski*

The costal break is a sophisticated joint located along the leading-edge vein in yellow jacket wasps that buckles reversibly during wing collision events such as petal strikes during flight. Previous studies show this adaptation reduces wing wear and area loss during impact events, which is known to influence mortality in bees. Research also suggests that wing buckling mitigates reaction torques felt at the insect body, potentially stabilizing flight without need for active control. Still, the mechanical understanding of this joint and how it could be adapted into insect-inspired robots is poorly understood. We designed a robophysical experiment inspired by the costal break. The experiment involves a motor-driven beam assembly that includes a parallel-plate buckling joint. We used this experiment to investigate input and output reaction torques during high-speed collision events. The impact loading tests showed that the buckling beam had lower maximum reaction torques, impulse, and percent overshoot compared to a similar homogenous beam structure. This study provides insights into the design and optimization of insect-inspired buckling joints for future microbotic technologies.

## Genotype-to-morphology-to-performance mapping for tail shape in African cichlid fishes

*Sofia McNatton, Aldo Carmona Baez, Reade Roberts, Emily Moore*

Different life history strategies in aquatic environments require fine-tuning of morphology to optimize the ability to move in water. In fishes, tails have repeatedly convergently evolved similar shapes that follow swimming and foraging patterns, with forked tails hypothesized to minimize drag for endurance swimming and flat, truncate tails providing a broad surface area for bursts of speed. While the energetic properties of tail shapes have been modeled based on broad species comparisons, direct ties between gradations of tail shape and swimming performance have been little examined, as have the genetic loci that contribute to tail shape. The adaptive radiation of East African cichlid fishes in Lake Malawi recapitulates the broader morphological trend in tail shape between closely related species, where forked tails are common among the open water specialists, and truncate tails are prevalent at the rocky shore where quick bursts of speed may be advantageous. We generated an F2 cross between two species of cichlid that differ in life history strategy and tail shape (truncate tail, Metriaclima pyrsonotus; forked tail, Aulonocara baenschi). From photographs, we quantified tail shape with geometric morphometrics (R geomorph) and correlated shape with short burst swimming speed from video. We also performed genetic mapping to identify candidate regions that contribute to tail shape patterning. This genotype-to-morphology-to-performance framework provides real insight into the development and function of tail shape.

## Extracellular matrix shape change contributes to skeletal muscle passive force production

*Emily McParland, Thomas Roberts*

Vertebrate skeletal muscle extracellular matrix (ECM) consists of a hierarchy of collagen that surrounds all layers of the muscle. Epimysium wraps around the whole muscle and consists of dense, wavy collagen cables (organized bundles of fibrils). Endomysium is a thinner layer surrounding individual muscle fibers that is less organized with some cables. It has been hypothesized that the ECM plays roles in muscle shape change, passive force production, and lateral force transmission. Previous work has examined ECM orientation and its importance in muscle force production, but no studies have directly linked orientation with force development. Here, we visualized epimysial and endomysial cables and sarcomeres during lengthening of isolated bullfrog sartorius muscle using second harmonic generation (SHG) microscopy. Simultaneously, we measured passive force output to link ECM morphological change and its contribution to force production. Epimysial fibers uncrimp from their resting wavy state and straighten immediately upon lengthening. Endomysial cables also uncrimp during passive stretching, but only at longer lengths and when passive force begins to climb. Once endomysial cables uncrimp and the passive tension increases exponentially, their angle to the long axis of the muscle fiber decreases. These results provide evidence that skeletal muscle ECM orientation change contributes to passive force production in muscle lengthening.

## Genomic analyses suggest growth and development under selection across climates in a lizard species

*Matthew McTernan, Christopher Parkinson, Michael Sears*

Though many populations of widespread species adapt to local climates, we know little about the genetics underlying such adaptations. Genomic approaches can provide new insights into the genetic, cellular, and physiological pathways under selection. As a model system for climate adaptation, the Eastern fence lizard (Sceloporus undulatus) is ideal for such an investigation. Here, we use whole-genome sequences from 120 individuals across ten populations to identify genetic variants associated with climate. Because limits on activity are likely the primary selective pressure imposed by local climates for this species, we first use a biophysical model to calculate potential activity times for each population. Next, we use two genome-wide association models to identify variants putatively under selection: BayeScEnv and LFMM2. We input genes identified by both models into gene ontology enrichment analyses to identify putative biological functions under selection. BayeScEnv and LFMM2 identified 191 and 1,338 genes, respectively, with both models agreeing on 39 candidate genes. Gene ontology enrichment analyses on the three gene datasets identified enrichment for multiple growth and developmental processes, supporting the long-held notion that climate selects on life history variation across populations.

## The phylogeography and population genomics of the Eastern fence lizard (Sceloporus undulatus)

*Matthew McTernan, Michael Sears, Christopher Parkinson*

Climate cycles, geographic barriers, and the resulting range dynamics interact to determine the genetic landscape of widespread species. In North America, species have been subject to repeated glacial cycles, with interspersed mountain ranges potentially acting as geographic barriers to dispersal. Here we use the Eastern fence lizard (Sceloporus undulatus), a widespread species native to North America, to investigate how these past climate oscillations and geographic barriers dictate contemporary patterns of phylogenetic relatedness, admixture, and genomic variation. We sequenced 120 whole genomes of Sceloporus undulatus from across the species distribution to assess phylogenomic relatedness, admixture, migration rates, and patterns of runs of homozygosity. Additionally, we use climate niche modelling to assess range dynamics during the last glacial maximum. Four samples of Sceloporus woodi and five of Sceloporus olivaceus serve as outgroups. We hypothesize that climate oscillations have resulted in increased rates of admixture between northern and mid-latitude populations due to repeated bouts of range constriction and expansion along the northern extent of the species distribution. Furthermore, we hypothesize that the Appalachian Mountains pose as a barrier to gene flow, resulting the formation of eastern and western clades within this species. Our work serves to map out the phylogeography and population genomics of a model lizard species in North America and elucidate the forces driving those patterns.

## How songbirds maintain (oxidative) balance during migratory flights: does diet quality matter?

*Scott McWilliams, Kristen DeMoranville, Wales Carter, Liam Corcoran, Clara Cooper-Mullin, Barbara Pierce*

Little is known about how ecologically-relevant factors such as exercise and diet quality directly and interactively affect key components of the antioxidant system in multiple tissues of migratory songbirds. We tested 3 main hypotheses across three tissues in European Starlings fed diets with more or less antioxidants (anthocyanins) and long-chain polyunsaturated fats (18:2n6) while being flight-trained in a wind tunnel. Flight-training reduced plasma oxidative damage during a given acute flight, and antioxidant capacity and oxidative damage in plasma and tissues of flight-trained birds were similar to that of untrained birds. Flight-trained birds that expended more energy per unit time (kJ/min) during their longest, final flight decreased the non-enzymatic component of their antioxidant system the most during the final flight. Flight-trained birds that consumed more dietary anthocyanins had similar antioxidant capacity in liver and flight-muscle compared to untrained birds, and oxidative damage was prevented in the flight-muscle and reduced in the liver of flight-trained birds compared to untrained birds. Contrary to our predictions, dietary 18:2n-6 did not influence oxidative status even after flight training. In sum, the antioxidant system of songbirds flexibly responded to changes in availability of dietary antioxidants as well as increased flight time and effort, and such condition-dependent, individual-level, tissue-specific responses to the oxidative costs of long-duration flights apparently requires recovery periods for maintaining oxidative balance during migration.

## Inaugural class of Auburn University Gulf Scholars Program: introduction and research interests

*Ally Meadows, Alexander Gilray, Keegan Valentine, Aylsha McCall, Malorie Hayes, Becki Retzlaff*

The mission of the Auburn University Gulf Scholars Program, or AUGSP, is to prepare undergraduate students to become change agents for inclusive Gulf sustainability and resiliency. As change agents, our students learn to work across disciplines and engage diverse communities with cultural competence to solve the complex and multi-faceted problems impacting sustainability in the Gulf region. The GSP is funded by the National Academy of Sciences. The program supports Gulf of Mexico region colleges and universities in preparing undergraduate students as the next generation to address critical challenges in the region related to community health and resilience, environmental protection and stewardship, and offshore energy safety. This presentation introduces the inaugural class of scholars from AU-GSP and includes a research profile of the participating students at Southern Union State Community College. Each student will work with community partners to develop a research project focused on the sustainability of Alabama's Gulf region.

## It's the way your mucus smells: conspecific recognition in the sea slug *Doto chica*

*Melanie Medina, Don Levitan*

In marine invertebrates such as simultaneous hermaphroditic sea slugs with no secondary sexual traits or specific visual displays, mechanisms to communicate information related to the quality and fecundity status of a potential mate may be crucial for ensuring higher fitness outcomes. We show that the sea slug Doto chica is able to recognize conspecifics in absence of adult slugs via mucus trails, and that there are differences in the chemical composition of mucus based on quality of a partner. These results provide evidence of the presence of chemical components in the mucus that may aid in mate finding and choice in these hermaphrodites.

## Leveraging AI for the Identification of Aquatic Invertebrate Species

*Abigayle Mejia, Jordan Cruz, Elizabeth Borda, Jose Valdez, Ashley Teufel*

The identification of similar-looking aquatic invertebrate species is an especially difficult task due to their subtle morphological differences. To address this challenge, we developed a Roboflow model trained on a dataset that includes images from iNaturalist as well as images from our own collection. The model is designed to identify 15 distinct species of aquatic invertebrates native to the greater San Antonio region. Here, we evaluate the model's performance, in terms of its accuracy in detecting and correctly labeling each of these species. Additionally, we are working towards deploying this model in a mobile format such that it is accessible for field use, allowing for the identification of species in real-time. Ultimately, this tool benefits both researchers and students by enabling the accurate, efficient, and rapid identification of aquatic invertebrates.

## Impacts of developmental cold exposure on phenotype in tree swallows

*Nicole Mejia, Conor Taff, Daniel Ardia, Thomas Ryan, Maren Vitousek*

More frequent unpredictable climatic events are increasing the likelihood of exposure to thermal challenges during development for many species. Given the importance of temperature during development, thermal challenges may lead to phenotypic changes that affect how organisms cope with climate change. Previous research on tree swallows (Tachycineta bicolor) has suggested that cold exposure during incubation has lifelong effects on physiological stress responsiveness. This increased stress responsiveness could improve the capacity to cope with future thermoregulatory challenges. However, it is poorly understood how early developmental thermal challenges affect morphological or transcriptomic responses that are important for thermoregulation. Using comparative RNAseq analyses and hematoxylin- and eosin-stained slides of pectoral muscle tissue, a major site of thermoregulation, we investigated the effects of cold temperatures during late-stage incubation on gene expression and morphology in tree swallow nestlings. Natural nests were experimentally cooled for a five-day period during late incubation and a small sample of pectoral muscle was taken from nestlings on day 13 immediately after exposure to a 30-minute cold challenge. We predict that devepelomentally cold exposed chicks will show differences in muscle fiber morphology and expression levels of genes associated with muscle growth, as well as have higher thermogenic capacity. This study will provide insight into how climate change may be shaping individual variation in key thermoregulatory traits, and affecing survival in variable environments.

## Regulatory Divergences and Ecological Adaptation in Desert Tortoises

*N. Jade Mellor, Greer Dolby, Kenro Kusumi*

Mutations in different parts of genes can vary in effects on phenotypes and be important for understanding how species diverge and locally adapt. Changes in regulatory regions of genes can shape time-dependent cellular and behavioral processes that underly pre- and post-zygotic reinforcement and reproductive isolation mechanisms. Gopherus agassizii and G. morafkai are two recently speciated tortoise species, residing in adjoining but seasonally distinct deserts. The species have different egg-laying patterns, disease instances, and are differentially adapted to rainfall. We used sliding window Fst on whole genome sequencing of 21 individuals to characterize differences between the two species. Eighty percent of mutations found in the 1% most diverged portion of the genome mapped to intergenic regions. Mutations were found in promoter regions of genes associated with the circadian/circannual time-keeping and regulation of gene transcription. Regulatory changes in these genes could affect the timing of biological functions related to behaviors, reinforcing temporal isolation. Genomic regions with high exon divergence included respiratory mucus genes. Further investigation found extensive expansion of Mucin5 genes, differential duplication, and pseudogenization between the lineages. Mucosal genes are important in osmoregulation and host defense against bacterial pathogens. Overall, we show regulatory divergence could underlie transcriptional cascades and the offset of reproductive behaviors between the species; gene expansion that could play a role in the differential disease response among these species of conservation concern.

## Characterizing anthropogenic materials in cavity-nesting songbirds' nests in suburban and rural area

*Hailey Melvin, Jennifer Uehling*

Trash pollution has become a pressing wildlife issue that can negatively impact animals' fitness and populations. These harmful effects on wildlife health often occur when animals ingest trash or become entangled in it, as seen in many marine species including birds. Birds may use anthropogenic material when building their nests, putting both parents and offspring at risk. Anthropogenic material has been studied in marine bird nests, however, it is not as well-studied in terrestrial bird species. In this work, we characterize the anthropogenic material found in cavity-nesting bird nests in southeastern Pennsylvania, USA. We ask whether the amount and type of anthropogenic material in birds' nests in suburban and rural areas differ; and, whether different species use different quantities and types of trash in their nests. Nests were collected from five species: tree swallow (Tachycineta bicolor), eastern bluebird (Sialia sialis), house sparrow (Passer domesticus), house wren (Troglodytes aedon), and Carolina chickadee (Poecile carolinensis). We will dissect anthropogenic material from these nests and categorize it by type, size, and color. Additionally, we will weigh the trash and calculate the percentage of each nest composed of trash. Our findings will provide baseline information about trash pollutants in cavity-nesting songbird nests and may suggest whether certain bird species or birds nesting in specific habitats are more at risk of possible adverse effects of anthropogenic trash pollution.

## Leaping to glory: Characterizing the aquatic take-off of birds

*Laura Mendez, Tyson Hedrick*

One of the most explosive maneuvers in bird flight is taking off from a resting position. On land, take-off begins with a leg-powered jump followed by lift production by the wings. Aquatic birds taking off from water face additional challenges compared to birds on land given the different physical characteristics of water compared to solid surfaces. Aquatic birds initiate take-off by pushing the water away using their webbed feet resulting, in most cases, in a leap that brings the bird out of water followed by altitude gain via wing flapping. Aquatic birds differ widely in body mass and webbed feet area, all factors that affect the effort required for the movement and its effectiveness, leading to different take-off characteristics. We expect that birds with relatively bigger feet complete the take-off maneuver more effectively. Therefore, we hypothesize that larger bird species with smaller feet sizes relative to their mass will have a slower start and a lower force production at take-off than smaller species with relatively larger feet. We tested these ideas by using 3D field videography and kinematics to quantify the take-off performance of wild aquatic birds in their natural environment in the North Carolina piedmont and coast.

## TNF and N:L ratio changes in edge and core populations of invasive cane toads in Florida

*Mary Mendonca, Jennie Ha*

The Evolution of Increased Competitive Ability (EICA) hypothesis predicts invasive species reallocate resources towards physiological responses that enhance their fitness rather than costly aspects of host immunity (i.e. pro-inflammatory responses). Cane toads (Rhinella marina), were introduced to Miami, Florida in the 1930's and have been moving north, crossing at least two thermoclines. The EICA hypothesis predicts that harsher environment and increased stress due to rapid dispersal would have leading edge individuals exhibit a reduced proinflammatory response compared to core individuals.

Various studies have demonstrated that immune responses vary among invading populations in different locations, but few measured plasma pro-inflammatory cytokines due unavailability of assays for non-model species. In this study, we examined the suitability of dog TNFa and human IL6 kits for measuring these inflammatory cytokines in cane toads. We compared responses to a LPS challenge between core and edge populations by assessing N:L ratio and cytokines at 2h and 10h after LPS or saline injection. IL-6 was detected only in a few samples. TNFa levels, on the other hand, were detectable and elevated 2 hours post-injection in individuals from the northern edge population, while all other groups exhibited low levels (Two way ANOVA TREATMENT x SITE effect, $p=0.057$). TNFa levels were significantly lower at 10 hrs post injection. The pattern observed in the TNFa mirrored the response observed in the N:L ratio.

## Hot Spots of Evolution: Decoding the Spotted Lanternfly's Thermal Ecology

*Fallon(Fang) Meng, Valentina Alaasam, Kristin Winchell*

The spotted lanternfly (Lycorma delicatula, "SLF") invasion across the northeastern United States since 2014 offers a framework to explore the eco-evolutionary dynamics of invasions. Our previous studies have shown that SLFs in the U.S. experienced three significant population bottlenecks and possess low genetic diversity and differentiation. Despite these constraints, they have rapidly expanded over a decade. Thus, understanding the ecological and evolutionary mechanisms driving their success is crucial. Thermal tolerance is vital for species distribution and range expansion, especially in urban landscapes. Here, we measured metabolic rate, critical thermal maximum (CTmax), minimum (CTmin), and thermal plasticity across various sites and habitats (urban vs. rural) in both native (Shanghai, China) and invasive (northeastern U.S.) ranges under different thermal conditions. Our results suggest that SLF populations in the invasive range exhibit a broader thermal tolerance range than those in their native range. Additionally, urban SLFs show a broader thermal range and higher metabolic rates than rural ones in both ranges, reflecting their ability to cope with urban heat island challenges. Urban SLFs also demonstrate greater thermal plasticity, tolerating even higher temperatures than rural ones after heat acclimation. Our genomic analysis aims to uncover the genetic basis of these traits through differential gene expression across thermal environments. These findings illuminate how genetic and environmental interactions shape phenotypic traits, impacting the persistence and spread of invasive species.

## An insect-inspired soft antenna reveals the role of mechanics and contact speed in touch sensation

*Lingsheng Meng, Parker McDonnell, Kaushik Jayaram, Jean-Michel Mongeau*

Animals rely on touch information for decision-making. In particular, the American cockroach P. americana employs its soft antennae—endowed with ∼40,000 sensilla distributed along ∼150 segments—for anemotaxis, thigmotaxis, texture discrimination, etc. We hypothesize that soft antenna mechanics decompose tactile features into a sparse set of spatiotemporal patterns (motifs) to facilitate task-level decision-making. To test this hypothesis, we developed cockroach-inspired mechanical and robophysical models of the antenna. The mechanical model is composed of a series of rigid links interconnected by uniaxial hinge joints within the MuJoCo physics engine. The robotic model features a similar stack-laminate structure with embedded capacitive strain sensors at each joint. To determine how diverse tactile stimuli can be represented by a sparse set of motifs, we applied convolutive non-negative matrix factorization to spatiotemporal data generated from distinct classes of tactile stimuli. Our findings reveal that the mechanical properties of the cockroach-inspired models enhance feature classification compared to conventional sensor models. Further, the contact speed of tactile stimuli significantly influenced the feature classification rate, suggesting a speed-information tradeoff. Overall, our bio-inspired mechanical and robotic models reveal how mechanics decomposes tactile features into a lexicon of motifs. These motifs may play a crucial role in decision-making during slower tactile exploration and rapid maneuvering in insects. Our model also serves as an inspiration for the development of soft, distributed robotic sensors.

## Seasonal changes in toadfish vocalizations

*Allen Mensinger*

Male oyster toadfish, Opsanus tau, use boatwhistles throughout the mating season to acoustically attract females toadfish to the nest. Previous investigations have examined changes in frequency and calling rates for toadfish populations however few studies have tracked the vocalizations of single male toadfish throughout the breeding season. Using a passive acoustic array, the locations of male toadfish in Eel Pond, Woods Hole, Massachusetts were triangulated and the calls from individual males tracked throughout the season. Each toadfish produced a unique vocalization with the fundamental frequency of calls changing as expected with increasing water temperature. However, other aspects of the call continued to change with later season calls drastically different from early season calls. While individuality in male vocalization is not unique, the evolution of the call throughout the breeding season presents a moving target for females to select mates and it remains unlcear the functional significance of boatwhistle modulation on mate selection.

## Intraspecific variability in vertebral formulae in marsupials and monotremes

*Magdalen Mercado, Graham Slater*

The mammalian vertebral formula is a classic system for the study of developmental variability and constraint. The rule of seven cervical vertebrae and the few taxa that break it (e.g. Bradypus, Trichechus) have attracted considerable attention, but several key gaps in our understanding of mammalian vertebral formula evolution remain. For instance, large-scale comparative studies tend to be metanalytic, often utilizing historic datasets without addressing biases and shortcomings in sampling. Some detailed contemporary work focuses on Atlantagenata, presuming that early-diverging eutherians represent ancestral levels of variability and constraint in mammals, but this hypothesis has yet to be properly tested in marsupials and monotremes. In pursuit of solutions, here we assess the distribution of intraspecific and intrageneric variation in vertebral formulae across Marsupalia and Monotremata. We find levels of variability that challenge historic hypotheses about the presence and release of developmental constraints on numbers of cervical, thoracic, and lumbar vertebrae in Xenarthra and Afrotheria. We test these patterns across ecological, phylogenetic, and geographic diversity in crown mammals. Finally, we quantitatively test the relationship between morphological variation (vertebral formula, sacral ossification), and ecology (body size, metabolic rate, locomotor mode) and propose that the sacrum is a key developmental landmark in patterning the junction between the presacral and caudal regions of the vertebral column.

## The endocannabinoid 2-AG mediates seasonal life-history transitions in a wild reptile

*Lauren Merlino, Pauline Florence, Lin Lin, Faizy Ahmed, Daniele Piomelli, Deborah Lutterschmidt*

The mechanisms regulating seasonal changes in behavior are not well understood. Endocannabinoids modulate neuronal signaling in reproductive, metabolic and locomotive control centers and are widely distributed throughout the vertebrate nervous system, making them a strong candidate for facilitating seasonal transitions. Using red-sided garter snakes (Thamnophis sirtalis parietalis) we asked: (1) if brain endocannabinoid concentrations differ between male behavioral phenotypes associated with the transition from spring mating to summer feeding and (2) if brain endocannabinoid concentrations vary with migratory status or sex. We found that male snakes with a food-motivated phenotype displayed lower brain levels of 2-arachidonoylglycerol (2-AG) than those with a transitional phenotype. Similarly, within the reptilian homologue of the hippocampus, male and female snakes migrating to the feeding grounds had lower levels of 2-AG than snakes captured at the breeding grounds. To further evaluate if endocannabinoids mediate seasonal behavior, we manipulated endocannabinoid signaling. Blocking endocannabinoids with the cannabinoid receptor (CB1) antagonist AM251 significantly reduced male courtship behavior, but not locomotor activity. Moreover, increasing endogenous levels of 2-AG using JZL184, an indirect CB1 agonist, delayed the transition to feeding behavior in males. Our results support a role for 2-AG in the seasonal maintenance and termination of reproductive behavior. Because the endocannabinoid system is evolutionarily conserved across vertebrates, these data are broadly applicable to understanding the neuroendocrine mechanisms that mediate trade-offs between reproduction and self-maintenance.

## The genetic causes and behavioral consequences of glucocorticoid evolution in monogamous mice

*Jennifer Merritt*

Resilience to stress is in part controlled by the secretion and regulation of the levels of glucocorticoids. In mice of the genus Peromyscus, a pair of sister species have unprecedented divergence in the adrenal gland. Oldfield mice have a 9-fold larger adrenal cortex than deer mice, which corresponds with a 30-fold difference in the circulating CORT (corticosterone) – the primary rodent stress hormone. Further, oldfield mice provide more care for pups, and exhibit reduced anxiety-like behavior but increased susceptibility to infection relative to deer mice. To understand the genetic basis and phenotypic consequences of CORT levels, we generated 769 F2 hybrids and quantified parental behavior, anxiety-like behavior, and CORT levels in the hair. Quantitative genetic mapping revealed two loci centered on the glucocorticoid receptor (GR) and on the corticosteroid binding globulin (CBG) that together explain 29% of variation in CORT levels. To study these loci in detail, we generated backcross mice, and our preliminary findings indicate that CBG buffers the effects of GR. Oldfield GR has 4 amino acid substitutions and oldfield CBG has 10 substitutions relative to deer mice, some of which occur in functional domains of each protein, which we are now characterizing molecularly through reporter gene assays and surface plasmon resonance. Taken together, the genetic dissection of CORT levels offers new opportunities to understand the mechanisms by which behavioral diversity arises.

## The molecular underpinnings of phenotypic convergence in toucans and hornbills

*Jon Merwin, Lukas Musher, Anthony Geneva, Jason Weckstein*

Does phenotypic convergence arise due to parallel mutations on orthologous genes or does selection find different genomic routes to achieve similar outcomes? Convergent evolution is ubiquitous across the tree of life, and may be driven by selection on alternative genes, selection on the same genes, or molecular convergence due to mutational bias in regulatory or coding regions. We tested these alternate hypotheses in two large bodied, large billed, frugivorous tropical bird lineages, toucans and hornbills, a textbook example of phenotypic convergence. We compare positive selection and protein similarity in a set of well-annotated exons to identify the molecular underpinnings of phenotypic convergence in the avian clade Cavitaves. Using dN/dS ratios, we identified candidate genes under positive selection, and candidate genes with convergent protein structure. We identified genes that exhibit both convergent amino acid sequences and signatures of positive selection and mapped the functional relationship of these gene sets and their associated gene-ontology (GO) terms. We found that genes under parallel selection were part of functional networks related to bill and facial development, suggesting that convergence in toucans and hornbills may in part be driven by mutations on the same genes. We also suggest permutation and filtering methods to account for bias of exon sets in functional analyses.

## The contribution of a conserved secretory toolkit in the development of bioluminescent innovations

*Lisa Mesrop, Georg Brenneis, Jakob Krieger, Steffen Harzsch, Todd Oakley*

Secretory bioluminescent systems are evolutionary innovations with significant ecological impacts mediated through chemically secreted light displays. Like other novel secretory systems used for defense, predation and communication, secretory bioluminescence employs a shared 'genetic toolkit' for secretion, modified with new genes to produce bioluminescent compounds. This toolkit may not only be expressed in adult tissue but also during the developmental processes underlying the differentiation of the novel secretory tissue. Here, we examined the extent to which the secretory toolkit's expression is conserved during the development of a novel bioluminescent secretory system - the bioluminescent upper lip - in marine ostracods. First, we performed RNA-seq on bulk embryonic tissue across seven developmental stages, which include the development of the upper lip. Next, using microscopy techniques, we validated the developmental stages by identifying key developmental landmarks, including those specific to the upper lip. We show that secretory toolkit genes are co-expressed with novel enzymatic genes involved in bioluminescence during upper lip development, similar to co-expression patterns observed in adult upper lip tissue. In addition to the secretory function of the bioluminescent upper lip, our results thus suggest that the secretory toolkit may also play a role in the differentiation of the novel tissues involved in the synthesis and release of the bioluminescent mucus in the upper lip, shedding light on the evolutionary and developmental assembly of secretory innovations.

## Automated quantification of parental behaviors to uncover differences in two estrildid finch species

*Alex Meyers, Nicole Baran, Grace Smith-Vidaurre*

Parental care is crucial for reproductive success and is driven by evolutionary cost-benefit analyses. Both Zebra and Bengalese finches exhibit biparental care and social monogamy, though previous studies indicate differences in their extent of affiliative and parental behaviors. We hypothesize that zebra finches demonstrate coordinated roles in parental duties, characterized by synchronized trade-offs in feeding bouts and incubation periods, whereas Bengalese finches exhibit less overall synchrony and role-specific duties. To capture variation in parental behaviors, continuous monitoring systems that can capture and quantify rare behavioral events are required. We aim to develop systems to quantify these parental behaviors in order to interpret the differences between the two species, while revealing novel internal nest data. We deployed nine automated nest box tracking systems with motion detector cameras and beam breakers to streamline the process of automated data collection and interpretation across experimental replicates and over long developmental timescales. Additionally, we used temperature loggers to measure incubation temperature to uncover species-specific brooding patterns, and completed complementary focal observations to document affiliative behaviors. These methodologies enhance our understanding of avian parental care and offer a framework for investigating behavioral adaptations to environmental changes, contributing to broader discussions on conservation and population well-being.

## Evaluating water flow as an invasive bigheaded carp attractant in a model lock and dam

*Ellie Meythaler, Michael Frett, Allen Mensinger*

Bighead carp (Hypophthalmichthys nobilis) and silver carp (Hypophthalmichthys molitrix) are invasive fish species that threaten to establish populations in the Great Lakes region. Possible species-specific attractants could be used as a viable management strategy for invasive bigheaded carp. Positive rheotaxis has been observed in the wild, and empirical evidence of bighead and silver carp schools aligning within higher water velocities and turbulent water has been produced. Positive attraction to turbulence was evaluated to determine if bigheaded carp schools could be redirected outside of the lock chamber and remain downstream, effectively restricting passage upstream. Experimental trials were performed in a model lock and dam tank with recirculation modeling downstream water movement and underwater pumps to create flow. Schools of 10 bighead or silver carp were acclimated and 35 minute trials were recorded under four water flow levels (n=8). During trials, the downstream gate to the lock chamber was opened. At the end of the trial, the number of fish in the lock chamber were counted as upstream passages. Fish position was tracked, and the amount of time the school spent in flow, in the lock approach and lock chamber, and entrances into the lock approach and the lock chamber were measured. Standard downstream flow had more of an effect on carp behavior than additional turbulence from water pumps.

## Snapping shrimp utilize vision and olfaction to identify mutualistic goby partners

*Tanner Mierow, Alexandra Kingston*

Snapping shrimp are marine crustaceans in which some species engage in mutualisms. One such species is the tiger snapping shrimp, Alpheus bellulus, which engages in heterospecific partnerships with the yellow watchman goby, Cryptocentrus cinctus. In these partnerships, A. bellulus constructs and maintains a burrow that provides both partners with shelter, while C. cinctus warns of nearby predators and competitors. Once a partnership is formed, it is imperative that the partners identify each other or potentially face lethal consequences. We asked if snapping shrimp can identify their goby partner and what sensory modalities they use during identification. We hypothesize that A. bellulus identifies partner C. cinctus using vision and olfaction. To test this, we used a choice test where a snapping shrimp was allowed to freely choose between two gobies: its partner and a stranger. Next, we temporarily altered the sensory capabilities of A. bellulus by visually blinding, olfactory blinding, or both, and repeated the partner choice test. Unaltered snapping shrimp spend more time with their goby partner compared to strangers. We found that altered shrimp in all groups spend equal amounts of time with their partner and the stranger goby, indicating that both vision and olfaction are important in partner identification. We suggest that A. bellulus uses vision to identify a goby from a distance and olfaction to distinguish between their partner and stranger goby.

## Trend for Association Between Wing Morphology and Testes Mass in Male Jadera haematoloma

*Alva Mihalik, Amberlika Guruvadoo, Michael Forthman, Christine Miller*

Organisms are resource limited, and shifting investment between morphological traits is crucial to fitness. Male organisms invest and divest in various traits, including flight, which can impact ability to seek out mating opportunities. In Jadera haematoloma, there is an established relationship between wing polymorphism and egg production; long-winged females experience delayed and reduced fecundity in comparison with short-winged females. Despite numerous studies investigating this trade-off in females, we lack similar research for males, who also exhibit this same wing polymorphism. We tested whether males in J. haematoloma demonstrate variation in gonad investment between wing morphs. We hypothesized that testes mass is greater in short-winged males than in long-winged males. We also expected to confirm previous evidence indicating that egg production differs between wing morphs in females. We found a trend in testes mass variation between wing morphs in males. We also did affirm the relationship between wing dimorphism in females. This apparent trend may indicate the need for more investigation into males in wing polymorphic insects and whether other reproductive traits vary between wing morphs in males. By uncovering the details of this system, we illuminate whether and how traits which facilitate mate-seeking interact with other male copulatory traits.

## Biological effects of hydrostatic pressure

*Katelyn Mika, Alexandra Kingston*

As an organism descends into the ocean, light dims then disappears entirely, temperatures plummet, food becomes scarce, and pressure builds to such an intense level that even water is compressed. One of the greatest challenges of the marine habitat is the rapidly building and always present hydrostatic pressure (HP). HP is the pressure exerted on an object by a fluid. As an organism descends into the ocean, it experiences one additional atmosphere of pressure (1 atm = 0.101 MPa) for every 10 meters. Therefore, organisms living 30 meters underwater experience about four times as much pressure as those at the surface. How do organisms adapt to increased HP as they migrate deeper into the oceans? How widely shared are adaptations to HP among marine organisms? We are using innovative field and lab approaches to explore how vertebrates and invertebrates respond and adapt to changing HP. Transient and transgenerational genetic and physiological responses will be compared in gobies and snapping shrimp, a well-characterized mutualistic partnership. The responses of animals from the wild will be compared to those that experience simulated migration deeper into the oceans using a novel pressure chamber. Understanding the cellular, molecular, and physiological adaptations of fishes and invertebrates to changes in HP will reveal insights to how species may adapt to major habitat shifts, such as those brought on by global climate change.

## Venom-delivery systems in Asian and African rear-fanged snakes using diceCT imaging

*Kylie Miles, Ollie Safford, Kayla Hinnen, Jeffery Anderson, Kate Jackson*

Venom-delivery systems of rear-fanged snakes (opisthoglyph dentition) are less well studied than those of medically-relevant front-fanged (proteroglyph and solenoglyph dentition) taxa. We imaged and examined the venom-delivery systems and associated structures in African and Asian rear-fanged snakes. We used diceCT techniques to examine the cranial anatomy of Asian rear-fanged snakes of the genera Dendrelaphis, Ahaetulla, and Chrysopelea (family: Colubridae) and African rear-fanged snakes of the genera Psammophis (family: Lamprophiidae) and Toxicodryas (family: Colubridae) with emphasis on components of the venom-delivery system. We identified, imaged, and when possible quantified features of structures including: Duvernoy's gland and other oral glands, maxilla, associated teeth and fangs, and musculature of potential relevance to the venom-delivery system. We also compared morphological differences between the families Colubridae and Lamprophiidae, as lamprophiid rear-fanged snakes diverged from colubrids 54 million years ago.

## The influence of the microbiome on amphibian development and susceptibility to disease

*Abigail Miller, Douglas Woodhams, Jamie Voyles, Juli Petereit, Jennifer Rodriguez-Reynoso, Myungchul Jo*

The microbiome is necessary for the development of healthy immunity in many model systems. Early disruptions to the microbiome can have effects on immune function that persist into later life. Although much is known about the microbiome's role in development in model systems, little is known about its involvement in development of non-model systems, such as amphibians, especially in the context of infectious disease. Amphibians worldwide are experiencing population declines due to the pathogen Batrachochytrium dendrobatidis (Bd). The mechanisms that determine susceptibility to Bd have not been fully resolved. However, the microbiome has been implicated in interspecific differences in response to infection. Here, we established a gnotobiotic system in tadpoles to investigate the roles of both microbial disruption and microbial rescue in amphibian development and susceptibility to disease. We found that a disruption to the microbiome in early life led to differences in growth, developmental time, and survival of tadpoles. We also found some of these developmental effects could be rescued with administration of a probiotic. We challenged froglets with Bd to determine any differences in susceptibility but did not detect significant differences in infection patterns. These findings suggest the microbiome plays an important role in the development of amphibians but did not alter susceptibility to Bd in later life stages. This system can now be used to investigate questions on the microbiome and immunity.

## Assessing trophic interactions in freshwater communities under the effects of salinization

*Cole Miller, Maya Mylott, Alex Barron, Allison Welch*

With climatological, geological, and anthropogenic stressors on the rise, various freshwater ecosystems are at risk of changes in community and trophic structure. Salinization due to sea level rise, storm surge, and subsidence is a threat to coastal, freshwater wetlands. However, community and ecosystem level impacts of salinization are poorly understood. In this study, we investigated impacts of freshwater salinization at multiple, interacting trophic levels within experimental mesocosms. Algae, zooplankton, herbivorous amphibian tadpoles, and predatory odonate nymphs were used as a model coastal wetland trophic system to quantify impacts of salinization on biomass at each trophic level. We employed three salinity treatments as well as variation in tadpole density and nymph presence to isolate effects of salinization, competition, and predation. We will analyze the data to examine changes in biomass at each trophic level through time and interactions among trophic levels. The findings of this study will help provide a framework for understanding the impacts of salinization on trophic dynamics in vulnerable coastal systems.

## Visualizaing the anatomy of imperfect tail regeneration in Sphenodon punctatus using DiceμCT

*Jordan Miller, Yara Haridy, Matteo Fabbri, Neil Shubin*

Fish and amphibians regenerate large portions of their anatomy, whereas regeneration is generally less ubiquitous and less successful in replicating original tissue composition in lizards, mammals, and other amniotes. While regeneration has been a topic of intense research in teleosts, amphibians, mammals, and squamates, little is known about other groups of amniotes. Here, we present a three-dimensional atlas of soft and hard tissues for tail regeneration in the only living representative of Rhynchocephalia and most basal living amniote Sphenodon puctatus (tuatara) by performing dice μCT followed by a digital reconstruction of a historical adult tuatara specimen with a regenerated tail. This allowed for the three-dimensional reconstruction of the innervation, vasculature and musculoskeletal system following a caudal amputation and subsequent partial regeneration. Our data fill an important evolutionary gap in the life history of regeneration, as previous studies were mainly restricted to two-dimensional histological visualization. Our results confirm previous findings in squamates and tuatara, such as the generation of a cartilage rod and a lack of osteological regeneration. Additionally, our 3D data allowed for the visualization of innervation and musculature in the regenerated tail exceeding what has been reported in the literature for tuatara. This work serves to further our understanding of the evolutionary history of regeneration in amniotes broadly, emphasizing the value of tuatara's status as an extant early diverging amniote.

## Tidepool tales: ecological insights from Yellow Island

*Kai Miller, Camille Gaynus, Tiara Moore, Christine Mantegna*

Intertidal zones are dynamic environments characterized by extreme environmental fluctuations. Organisms inhabiting this ecosystem are known for their resilience, but climate change drivers are pushing them beyond their limits. Understanding the species richness and diversity of the intertidal community on Yellow Island, a nature and marine preserve in the San Juan Island archipelago, allows us to interrogate the unique geographic and ecological factors that shape the intertidal habitat on this island. Through comprehensive surveys of macroinvertebrates and algae, we aim to clarify the community structure and identify potential patterns in species distribution. The 2024 data was analyzed across tidal zones and as a result, analyses of common marine invertebrates are highly resolved on this island. We expect the highest species diversity and richness within the lower-middle and lowest tidal zones, with differences in community composition between the North and South sides of the island due to wave action and nutrient fluctuation differences. Identifying the factors driving diversity in this isolated ecosystem will inform conservation efforts as the health of the intertidal habitat is a window into the health of the greater water body. Subject both to warming air and warming oceans, understanding community dynamics of the intertidal ecosystem is vital to clarifying how change will continue to affect tidal ecosystem dynamics.

## Quantifying and mathematically modeling gait asymmetries in horses

*Laura Miller*

In this study, we quantify and model gait asymmetries and irregularities in horses, with a focus on understanding how previous injuries impact locomotion. We measured movement at the walk, trot, and canter using a combination of the EquiPro Inertial Measurement System and high-speed videography for 20 horses of various breeds and ages. These measurements allow us to capture detailed kinematic data, providing insights into the variations in footfall patterns and the impact of asymmetries on overall gait. To complement this empirical work, we present mathematical models of gait that incorporate these asymmetries and variations, moving beyond more traditional models that assume symmetry. The motivation behind this research is to enhance our understanding of equine biomechanics, which could lead to improved diagnostics, more effective training techniques, and better rehabilitation practices for horses affected by gait abnormalities.

## Prenatal corticosterone impacts nestling condition and immunity in Eastern bluebirds

*Taylor Miller, Kristen Navara*

Exposure of avian mothers to stressful conditions permanently programs offspring behavior and physiology. Yet, the impacts of maternal stress on the development of offspring immunity in birds remains unclear, particularly in wild species. We injected Eastern bluebird (Sialia sialis) eggs with either a corticosterone or control solution, then measured the impacts on nestling morphology and two measures of immunity, bactericidal capacity and swelling responses to phytohemagglutinin. Nestlings from corticosterone-treated eggs had lower condition indices at hatch, but quickly caught up to their control counterparts by day 5 post-hatch and until fledging. Corticosterone-exposed nestlings also mounted smaller swelling responses to phytohemagglutinin, while there were no effects on bactericidal capacity. These results indicate that maternal stress can program the offspring immune response, but more work must be done to test the effects on additional aspects of immune function

## How to model the evolution of transcriptomes to understand neural sex differences

*Isaac Miller-Crews, Sara Lipshutz, Ben Fulton, Jason Bertran, Mathew Hahn, Kimberly Rosvall*

The degree of sex differences varies among species, especially in relation to social and reproductive behavior. As we seek to understand how these behaviors evolve, we naturally turn to the brain, yet it is unclear how neuromolecular sex differences evolve over macroevolutionary time. We address this question via new algorithms in the software, CAGEE (Computational Analysis of Gene Expression Evolution). We measure gene expression in the ventromedial telencephalon in 10 songbird species, half of which have convergently evolved obligate cavity-nesting, a reproductive strategy that is associated with multiple behavioral phenotypes. We focus on the sex ratio of gene expression in the brain (male:female), and model how it varies in its rate of evolution. In cavity-nesting lineages, there are more genes shifting in their sex ratio, suggesting that gene expression changes more so in one sex than the other. Sex ratios also evolve more quickly on the sex chromosome (Z) compared to the autosomes. Taken together, our results imply that, as behavior evolves, sex differences in brain gene expression change too.

## The stress response of the American alligator in aquacultural facilities

*Lani Milstead, Christopher Murray, Jorge Lopez-Perez*

The effects of light- based circadian rhythm deviations and density variation have been documented among wild vertebrates in the context of behavior, health, and survivorship. However, agricultural and aquacultural practices producing vertebrate resources that manipulate these two variables have been minimally evaluated for their physiological ramifications. Disruption in circadian rhythm via light manipulation and variation in stocking density, for example, can be associated with changes in physiological responses. I aimed to evaluate the effects of light availability and stocking density on American alligator (Alligator mississippiensis) leukocyte profiles (proxy for stress) and scarring in a farm setting. Specifically, I compared alligator leukocyte profiles among light treatments (total darkness, partial light, full diel cycle sun), and manipulated densities (1.0, 1.6, and 2.3 animal ft per ft3). Blood samples were obtained, and scarring was quantified. I hypothesized that alligators kept in partial light and crowded stocking densities would exhibit elevated H:L ratios and higher frequency of conspecific conflict that would lead to scarring.

## Determining the impacts of resource acquisition mode on wound recovery in *Astrangia poculata*

*Emma Min, Jane Doyle, Liz Burmester, Justin McAlister*

Corals are routinely exposed to non-lethal predation and other physical intrusions which force colonies to rebuild lost tissue. Directing energetic resources toward wound recovery directly impacts coral health as it reduces energy for other tasks, e.g. growth, metabolism, and reproduction. While many corals harbor photosynthetic algal symbionts and can use both autotrophy and heterotrophy to meet relative energetic requirements, the interactions between the mode of energetic resource acquisition, environmental stressors, and wound recovery are intricately associated with coral health and yet are difficult to disentangle in tropical corals that bleach when stressed. In order to better understand the relative contributions of energy provided by coral host and algal symbiont towards wound recovery, we examined polyp regeneration and stress tolerance of a temperate and facultatively symbiotic coral, Astrangia poculata. Although colonies of A. poculata exhibit a spectrum of symbiotic states (symbiotic, aposymbiotic, and mixed/mottled) in nature, our study focuses primarily on mixed/mottled coral. By closely examining the pattern and rate of wound recovery of individual polyps nested within mixed/mottled colonies, we aim to tease out how resource acquisition mode can impact within-coral energy dynamics and overall coral health.

## Tickled Zinc: Characterizing A-to-I RNA Edits in O. Rubescens in response to ocean acidification

*Meg Mindlin, Ricky Wright, Kirt Onthank*

Octopuses appear to adapt to low pH environments more readily than other marine taxa do. Does RNA editing contribute to octopus acclimation to lower pH environments? RNA editing can diversify mRNA expression. Adenosine deaminases that act on RNA (ADARs) edit single bases in mRNA transcripts from adenosine to inosine, which is then read as guanosine by ribosomes. Selectivity for this reaction is not well understood, but the role of RNA editing in adaptation to environmental conditions has been demonstrated in multiple sites in cold water octopus species, such as modifications of K+-channel, altered kinase motility, and changes in binding affinity in synaptotagmin. Transcriptome-wide RNA editing patterns of six Octopus rubescens exposed to higher acidity environments revealed extensive editing to zinc finger genes, hinting at possible mechanisms of low pH adaptation in octopuses.

## Phagocytic Activity of Cassiopea mesogleal cells

*Cody Miner, Mark Q. Martindale, Charlotte Kahn*

Cnidarians, like many other invertebrates, rely on innate immunity for protection against invading pathogens. One potential cytological component of this system in the scyphozoan jellyfish Cassiopea are the amoebocytes, or mesenchymal cells that reside in the mesoglea between the two main tissue layers. Through a selective dissociation technique, we are able to isolate these cells, and the mesoglea that contains them, from live polyps. The cells contained in the mesoglea are highly diverse in size and morphology, and many possess dynamic filopodial projections, as shown through live imaging. We have also obtained evidence of phagocytic activity in cellular suspension using pH-sensitive pHrodo heat-killed E. coli bioparticles, potentially facilitated through those filopodial projections. We also show the impacts of the actin polymerization inhibitor cytochalasin D on this phagocytic activity. Through these experiments, we aim gain insight into these potential immunologically active cells in an early-diverging metazoan lineage.

## Big fish can't jump? Allometry of terrestrial jumping in cyprinodontiform fishes

*Michael Minicozzi, Alice Gibb*

Teleosts that emerge onto land must produce effective movements to return to the water. We used Cyprinodontiformes (killifishes) to quantify the relationship between size (mass) and terrestrial jumping performance and examined the tail-flip jump across a size-range of individuals representing three aquatic species (Gambusia affinis, Poecilia mexicana, Jordanella floridae) and two amphibious species (Kryptolebias marmoratus, Fundulus heteroclitus). Individuals representing each category spanned an order of magnitude in mass and were recorded (600fps) jumping on land. We found no differences in takeoff angle with mass or across species. However, aquatic killifishes decrease jump distance as mass increases, while amphibious killifishes increase jump distance. Similarly, aquatic killifishes show a decline in the ability to accelerate at larger body sizes, but amphibious killifishes maintain similar accelerations. Consequently, amphibious killifishes can maintain high takeoff-velocities as mass increases. In contrast, the negative scaling relationship for mass vs. displacement in aquatic killifishes suggests there is a size-limit for terrestrial jumping in fishes that only infrequently encounter the terrestrial environment. We also measured mass distribution to test the hypothesis that subtle morphological changes contribute to jump performance differences. Aquatic killifishes have a fusiform body shape (more anterior mass) while amphibious killifishes have a more uniform mass distribution (less anterior mass), likely reducing the inertial effects of lifting the anterior body from the surface during the tail-flip jump.

## A total evidence approach to dating the cetacean phylogenetic tree using quantitative characters

*Joe Minus, Anjali Goswami, Sandra Alvarez-Carretero, Ellen Coombs, Morgan Churchill, Mario dos Reis Barros*

Combining phylogenomic and discrete morphological data in Total Evidence Dating (TED) analyses has been used to infer species divergence times for numerous taxonomic groups. Nevertheless, discrete data possess several limitations such as subjective character choice. Additionally, incorporating intraspecific morphological variation and trait correlations, which highly impact timetree inference, can be computationally expensive under the Mk model (a basic model for discrete character evolution). Many of these restrictions can be avoided by using quantitative morphological data. In addition, character correlation and intraspecific variation can be efficiently accounted for under a Bayesian approach. Despite these advantages, only small datasets with quantitative morphological and molecular data have been used within a TED framework (Alvarez-Carretero et al., 2019). In this study, we extend and test the scalability of such an approach with a larger dataset. We assembled molecular data from 68 species and combined this dataset with 123 3D landmarks and 124 curves gathered from the crania of 202 species of extant and extinct cetaceans. Intraspecific variation was estimated using a sample of Delphinus delphis. We modelled morphological evolution under Brownian diffusion, with preliminary results analysed under the independent-rates model indicating a divergence time between Cetacea and Hippopotamidae at 58 Ma. Overall, our extended approach can be used to assess the efficacy of Bayesian phylogenetic methods with high-dimensional morphometric data for large, comprehensively sampled datasets.

## Evolution and structure-function relationships of pollical unguis types in Rodentia

*Rafaela Missagia, Anderson Feijo, Lauren Johnson, Maximilian Allen, Bruce Patterson, Paula Jenkins, Gordon Shepherd*

The unguis of the first digit (D1) of tetrapod hands exhibits numerous adaptations to catch, cling, climb, and dig but its evolutionary association with ecological diversity was never examined across a large group. We estimated the D1 unguis types across the Rodentia tree and found that most extant genera and ancestral lineages bear a nail, while claws and no D1-unguis arose multiple independent times and are dominant only in a few lineages. Exploring the correlation of unguis type with two hand-dependent behaviors—food handling and life mode—showed clear structure-function relationships such as the gain of D1 claws with subterraneality and the loss of D1 unguis in oral-only feeders, which evolved intimately coordinated multiple times. We hypothesize the close association between D1 unguis and manually dexterous food handling is linked to the early acquisition of diprotodonty and gnawing in Rodentia that enabled them to exploit hard nuts and seeds, an energy-rich niche dominated by rodents after the multituberculates extinction. Our study presents a new way to conceptualize rodent evolution and uncovers a novel morphological trait underlying its successful radiation.

## A comparison of reptile and mammal embryonic curvature and organ growth during early development

*Tiya Mistry, Katherine Starr, Suzannah Williams, Paul Trainor, Thomas Sanger, Antonia Weberling*

Early reptile embryogenesis is often modelled using the Hamburger-Hamilton stages of chicken development due to the limited availability of non-avian reptile staging series. The novel pre-oviposition staging of the brown anole (A. sagrei) suggests significant variation in reptile morphogenesis. Despite the divergence of avian and non-avian reptiles over 250 million years ago, only few comparative embryological studies have been carried out. Our comparison of mammal (H. sapiens, M. musculus), avian reptile (G. gallus) and non-avian reptile (A. sagrei) embryogenesis reveals stark differences across the vertebrate subphylum and within the reptile and mammal clades. We analysed the craniocaudal axial curvature and organ growth rate using brightfield images and found significant variation in craniocaudal curvature across the four species. Additionally, analysis of head, heart, and eye growth rates revealed species-specific tendencies related to post-birth development and behaviour, especially the altricial nature of H. sapiens and M. musculus in comparison to G. gallus and A. sagrei neonates. The trends observed in this study provide a deeper understanding of the morphological dynamics of reptile versus mammal development. Moreover, our data also highlights the differences between model organisms and their representative species, suggesting a need for a more diverse database of animal models.

## Elderly *Aplysia* have trouble escape-galloping and start losing the ability to remember recent attack

*Viral Mistry, Daniel Martinez, William Frost*

Aplysia californica has provided major advances in our understanding of the cellular basis of behavior and learning. One insufficiently understood topic is how neural networks lose function with aging. Our laboratory has previously used large-scale imaging to discover principles of operation of Aplysia's locomotion network in healthy young adults. Here we take our first steps to investigate a major problem for all species: how network-level functioning degrades as behavioral vigor and learning decline with aging. When testing young (5-7mo) and elderly (12-13mo) adult Aplysia under both naive conditions and after a 5-trial non-associative learning protocol, we found that elderly Aplysia showed reduced capacity to gallop (vigorously locomote), and lost their ability to sensitize locomotion initiation with repeated stimulation. Notably, some elderly Aplysia were initially unresponsive to a naive stimulus, but could marginally improve their escape response with successive stimuli. Using large-scale voltage-sensitive dye imaging of isolated brains from both young and elderly Aplysia, we identified similar deficits in multiple network features of elderly animals' locomotion motor programs, including a loss of galloping and failure to sensitize locomotion network initiation, as compared with young adults. These findings represent a first step toward using Aplysia's escape locomotion network to investigate how behavioral networks lose function with aging, why some brains age better than others, and explore treatments that might maintain function during otherwise inevitable age-related decline.

## Leonardo, Murray, and Hack: A Computational Investigation of Flow Distribution in Branching Networks

*Yash Mistry, Morgan Nunez, Zubin Mistry, Chad Westover, Puneet Achpal, Dhruv Bhate*

Branching networks have received significant interest from mathematicians, biologists and physicists. Yet there is no capability that merges ideas from these domains in the generation of branching forms for engineering applications. This research aims to address this gap by developing a novel computational design approach that integrates mathematical, physical, and biological laws within the context of fluid flow in branching channels. We demonstrate the effectiveness of this approach by examining three laws proposed for branching in natural system by Leonardo, Murray and Hack. Originating from tree architecture, vascular systems, and river deltas respectively, these three laws represent distinct approaches to specifying the geometric relationships that constrain the design of a branching structure. We use computational modeling and additive manufacturing to enable simulation-driven and experimental studies of fluid flow in different branching designs, elucidating the underlying principles of each law and their implications for the uniformity of flow distribution. Our findings suggest that Murray's Law optimizes flow resistance, while Leonardo's Law exhibits a closer approximation to uniform flow distribution. More generally, our work demonstrates the potential of converging mathematics, biology and physics towards enabling innovative computational design both towards bioinspired design for engineering applications as well as for offering new insights into the design strategies employed by natural and engineered systems.

## The effect of temperature on the morphology and innate immunity of eastern bluebird nestlings

*Sophia Mita, Sarah Knutie, Jennifer Houtz*

Temperature is an important environmental factor that can have negative and positive effects on organisms. Global temperatures are also rising, which are causing more frequent temperature extremes. Animals are particularly susceptible to variable temperatures during development, which can determine the overall body size and influence the innate immune response.

Nestling birds experience a wide range of temperatures throughout development but few studies have causally tested whether temperatures during egg incubation has lasting effects on morphological and immune phenotypes in wild populations. For our study, we experimentally manipulated nest temperature (colder, control, warmer) during the egg incubation stage of Eastern Bluebirds (Sialia sialis) in western Pennsylvania. We then measured the morphology (i.e., body mass and wing, feather, bill, and tarsus length) and innate immunity (i.e., bacterial killing assays) of 13 day old nestlings. We hypothesized that early-life egg incubation temperatures determine nestling phenotype after they hatch because development of the innate immune system starts inside the egg. We predicted that cold and warm temperature treatments would result in smaller nestlings and lower innate immune responses. Temperature treatments did not significantly affect nestling morphology. The results of the innate immune assays will also be discussed.

## The anemone *Exaiptasia diaphana* actively limits phosphate sharing with its symbionts

*Geoffrey Mitchell, Sterling Embury*

Corals depend on symbiosis with photosynthetic algae that reside within their cells. This relationship, however, is delicate as rising sea temperatures are causing corals to bleach, expelling their symbionts. Little is known about how coral-algal cell divisions are coordinated to maintain healthy symbiosis. Control of nutrient exchange is one likely mechanism. Both nitrogen and phosphate are necessary for dividing cells, and while nitrogen enrichment is known to increase symbiont density in the host, the consequences of phosphate enrichment are poorly understood. Previously, we examined the effects of phosphate depletion on symbiont growth in culture and compared the physiology of phosphate-starved symbionts in culture to symbionts that were freshly isolated from a host. We found that limited access to phosphate controls algal proliferation within a host. To follow up, we investigated whether anemone hosts actively limit sharing of phosphate with their symbionts. To test this, we exposed model anemones to excess dissolved inorganic phosphate for two weeks and measured the amount of phosphate (organic and inorganic) within anemone tissue and symbionts. We found that while anemone tissue had higher phosphate levels are exposure, symbiont phosphate remained constant, suggesting that the host is actively limiting how much phosphates is shared with the symbionts.

## Heat evolution of the bacterial microbiome found in heat evolved *Cladocopium* C1acro

*Geoffrey Mitchell, Nathan Krueger*

Mass coral bleaching events are affecting our coral reefs. One approach to minimizing bleaching has been experimental evolution of the coral endosymbiont Cladocopium C1acro with the goal of developing heat-tolerant symbiont strains. While previous work investigated how experimental evolution affected the composition of the bacterial communities associated with these strains, nothing is known about how individual bacterial species were affected. To begin addressing this question, we isolated five bacterial genera associated with both a wild-type (WT10) and heat-tolerant strain (SS8) of Cladocopium C1acro. We then compared the growth of WT10-derived bacteria with SS8-derived bacteria at low (27°C) and high (31°C) temperature. Interestingly, not all SS8-derived bacteria grew better at 31°C. For bacteria in monoculture, decreased doubling time at higher temperature would indicate successful adaptation to those conditions. As part of the symbiont-associated microbiome, however, adaptations in other traits, such as nutrient exchange may be more important than decreased generation time.

## Symbiont density impacts bleaching susceptibility in the model anemone *Exaiptasia diaphana*

*Geoffrey Mitchell, Katie Watson*

Corals are threatened by rising sea temperatures, which cause them to expel their algal symbionts (bleach). Without these symbionts, corals can't harvest energy from sunlight and struggle to survive. To solve this, it is necessary to understand the cellular events underpinning bleaching. Indeed, little is known about how corals and symbionts coordinate cell divisions to maintain healthy symbiosis. Remarkably, uncoupling of coral-algal cell division has been implicated in bleaching. One study found that symbionts expelled during heat stress have a higher mitotic rate than symbionts remaining in the host. There are two explanations: 1) when expelled, symbiont proliferation is no longer inhibited, so symbionts begin to divide or 2) symbionts that began dividing within the host are preferentially expelled. Our attempts to address this directly have been unsuccessful. Instead, to evaluate the link between heat stress and symbiont proliferation in a model anemone, we assessed whether anemones that have been freshly inoculated with symbionts are more susceptible to bleaching than anemones that have well-established symbionts. When aposymbiotic anemones are inoculated, symbionts will undergo proliferation to fill host tissue. Once established proliferation will slow as symbionts then maintain a stable population. Because symbiont proliferation is higher in freshly inoculated anemones, we expected those anemones to be most susceptible to heat stress. Instead, results indicate that anemones with established symbionts are more susceptible to heat-induced bleaching.

## Traits for conservation: using phenotype to determine extinction risk and recovery in birds

*Matthew Mitchell, Ryan Felice, John Ewen, Amanda Trask*

As vertebrate biodiversity continues to decline, understanding how to determine extinction risk for species is becoming ever more important. Specific traits such as size and island endemism can be linked to extinction. However little is known about how ecological and morphological traits more widely interact to influence population decline and/or recovery and extinction risk. Here, we use the IUCN Red List in conjunction with the AVONET database to link bird species population size and IUCN threat status to phenotypic traits. We use hypervolume analysis to investigate the functional similarity among species that have declined, recovered or remained in the same Red List population bracket since 1950. We find more functional similarity between recovering species and those that remain at the same risk, and that specific traits are associated with a decline in numbers and increased threat status. Aquatic and insectivorous lifestyles are linked to population decline, as well as morphological traits such as short beak length. In the most at-risk species, we find that since 1950, 21% have demonstrated recovery in numbers, 39% have remained in the same population bracket and 40% have declined. Our results show that birds that exhibit certain ecological and morphological traits are more at risk and less likely to recover, enabling focussed conservation planning to take place.

## Investigating the role of the transcription factor Cut in the development of insect camera-type eyes

*Amartya Mitra, Elke Buschbeck, Shubham Rathore*

Eyes are among the most complex sensory organs and have been the subject of extensive evo-devo research. What remains understudied however, is how one elaborate eye-type, such as a compound eye, might evolve into another, such as a camera-type eye. This is a phenomenon observed repeatedly in arthropods and exemplified by stemmata, the camera-type eyes of larval holometabolous insects. A particular gene of interest in this system is Cut, a homeodomain transcription factor restricted in its expression to compound eye Semper cells, which are support cells that develop immediately after photoreceptors. cut knockdown results in disruption of the ommatidial array and fusion of neighbouring ommatidia in the structurally distinct adult compound eyes of Thermonectus marmoratus diving beetles and D. melanogaster flies. As ommatidial fusion is a proposed pathway for the development of certain stemmata, we posit that the regulation of Cut expression may play an important role in mediating fusion during the evolutionary transition from compound to camera eyes. Here we explore the expression and function of Cut during the embryonic development of eyes in T. marmoratus. Aligning with our expectations, in T. marmoratus larval camera-type eyes, Cut is expressed in the proximal corneagenous cells and preliminary data shows that embryonic knockdown leads to the fusion of neighbouring eye units. We expect these results to shed light on the ontogeny and evolution of arthropod camera-type eyes while providing novel insights into organogenesis.

## Salient features: tail anatomy in the bipedal jumping jerboa compared to quadrupedal rodents

*Juri Miyamae, Talia Moore*

Bipedality in rodents has evolved independently in multiple lineages, and has often been accompanied by the presence of a long tail. The Lesser Egyptian Jerboa (Jaculus jaculus; Family Dipodidae) represents one of these lineages, possessing remarkably fast and agile jumping locomotion as well as a tail length exceeding 1.5x its body length. Rapid swings of the tail and the formation of complex 3D curvatures are hypothesized to aid in inertial maneuvering that enhances quick directional changes during the jerboa's escape trajectory. Currently, the skeletomuscular features that make a tail specialized for different biomechanical tasks are not well understood. In an effort to identify key anatomical features that augment inertial maneuvering, we compared the tails of jerboas with several quadrupedal rodent species. Specifically, we examined muscle differentiation, patterns of tendon attachments on caudal vertebrae, integration with the hindlimb musculature, and changes in relative tail dimensions. By identifying the salient features that make the jerboa tail an integral part of its unique saltatorial locomotion, we can better understand the neuromuscular control of tail motion, the adaptive evolution of tail anatomy, and the use of tails for inertial maneuvering.

## Evolution of extrinsic eye muscles in vertebrates

*Tetsuto Miyashita, Philippe Janvier, Kristen Tietjen, Michael Coates*

Extraocular muscles form a virtual constant in vertebrate anatomy because all living vertebrates have six of them. However, lampreys and gnathostomes exhibit different patterns in innervation and organization of the six muscles. Placoderms are inferred to have seven muscles. Therefore, the current transformation scenario is that: 1) lampreys represent the primitive pattern; 2) placoderms evolved one extra muscle; and 3) innervation and spatial organization were modified prior to crown gnathostomes.

Here we present an alternative hypothesis based on new reconstruction of the orbital cavity in a jawless stem gnathostome, the osteostracan Norselaspis glacialis. Osteological correlates in Norselaspis resemble the placoderm pattern, once more indicating the presence of seven extraocular muscles. Two rectus muscles received the innervation by the abducens nerve in Norselaspis as in lampreys and placoderms. The trochlear-innervated oblique muscle sat in the posterodorsal corner of the orbit, which is intermediate between lampreys and crown gnathostomes. The oculomotor nerve penetrates an attachment scar for the dorsal rectus.

Given this new evidence, we argue that the seven extraocular muscles as identified in both stem gnathostome lineages represents a primitive condition for all vertebrates. From this ground pattern, lampreys and crown gnathostomes lost one muscle each independently. As an alternative to the previously proposed homology that requires elaborate changes, our new scenario offers a simpler solution where the relationships between nerves and muscles remain conserved.

## Mercury Concentration in the Blood of Juvenile Sharks of the Tampa Bay Coast

*Aleu Moana, Jasmin Graham*

Though Mercury does occur naturally in low levels around the world, human activities such as the burning of fossil fuels have increased mercury concentrations in the atmosphere by about 450 percent. Mercury in the atmosphere eventually makes its way into the ocean or other large bodies of water where it is then converted into the highly toxic methylmercury and passed through the food chain from phytoplankton to zooplankton to fish (and eventually to humans). Previous research has shown very high methylmercury levels in the muscle tissue of larger, predatory fish such as sharks, swordfish and tuna. We would like to test the blood levels of specific species of sharks to compare Mercury absorption in the muscles versus the blood, and the Mercury absorption of different species in the same habitat. Using the Attogene Mercury Detection Kit, we will test the Mercury levels in the blood of 15 juvenile Blacktip sharks (Carcharhinus limbatus) and Blacknose sharks (Carcharhinus acronotus) and compare the data to the Mercury concentration in the muscle tissue of the same species. We hope to find reasons for the differentiation in Mercury concentrations across species in the same environment and evaluate the health of the ocean in the Tampa Bay area.

## Changes to neuromechanical coordination of energy production in the legs after neuromuscular fatigue

*Melody Modarressi, Joelle Dick, Gregory Sawicki, Young-Hui Chang*

Neuromuscular fatigue can have profound implications for understanding mechanisms of injury and recovery of performance in animals. The sensorimotor system is able to leverage motor redundancies to compensate for such acute changes to maintain task performance. During single-legged jumps (SLJs), a common task in terrestrial human locomotion, coordination of the lower limb joints is necessary to generate sufficient force to propel the body upward and also to stabilize the landing to minimize impact loads. This locomotor task requires a balance between positive and negative mechanical energy generation and absorption. Failure to meet power generation and absorption demands during lift-off and landing phases can result in instability and injury about the impacted joint(s). We hypothesized that pelvic limb joints experiencing varying degrees of fatigue after strenuous exercise will alter the joint contributions to the whole limb mechanical work production and absorption required to safely perform a SLJ. We observed changes in joint motor coordination with strenuous activity. Notably, subjects with fatigue reorganize their motor coordination strategy to rely less on the knee and more on the ankle during both lift-off (+6% ankle contribution) and landing (+8% ankle contribution, -9% knee contribution) phases of the SLJ, indicating a statistically significant preference for an ankle power strategy that might prioritize safety of the knee joint following fatiguing activity ($n = 9$; p-value $< 0.05$).

## Collective behavior and emergent fluid dynamics during vertical migration

*Nina Mohebbi, Nina Mohebbi, Matthew Fu, John Dabiri*

Collective swimming and flying can generate complex fluid flows on the aggregation scale. Using brine shrimp (Artemia salina) as a model organism, we explore the hydrodynamics of vertical migration within a $20 \times 20 \times 11$ cm observation volume inside a larger

3000-liter tank. We induce collective upward movement using the positive phototaxis of brine shrimp and employ a combination of Particle Tracking Velocimetry (PTV) and Particle Image Velocimetry (PIV) using a single camera and a scanning laser sheet, which allows simultaneous tracking of the 1 cm swimmers and measurement of the surrounding fluid flow. This integrated approach provides information on how collective behavior influences the emergent fluid dynamics as well as how fluid dynamics influences both individual and collective swimmer behavior. Therefore, this method is used to investigate the interplay between the behavior of collective swimmers and the dynamics of their aquatic environments.

## Swollen-thorn acacias invested more in their defending ants during El Niño 2023

*Cristian Molina, Yorlenis González, Maikol Guevara, Jonah Naugle, Emmy Zeilstra, Sabrina Amador-Vargas*

Species interactions are frequently context-specific. Extreme climate events such as droughts potentially inflict stress on individuals, inducing plasticity in their behavior or resource allocation. Obligate mutualisms may be particularly sensitive to such events if this plasticity influences the quality, quantity, or proper timing of investments between partners. In Panama, Pseudomyrmex ant colonies defend swollen-thorn acacias (Vachellia collinsii) in exchange for hollow spines to nest in as well as food in the form of extrafloral nectar and amino acid-rich Beltian bodies. The production of these structures for associated ants is plastic both temporally and dependent on ant partner identity. We studied how an El Niño-associated drought in Panama impacted the investment of these plants in their ant colonies. Hence, during an El Niño event in 2023, we resampled swollen-thorn acacias which were measured for food and housing traits in 2019, and in plants that have mutualist, facultative, or weaker ant colonies. We found that swollen-thorn acacias invested more resources in ants overall, with some variability depending on the resident ant species. The observed results may be explained by increases in herbivore activity, increases in light availability, decreases in precipitation, or a combination of factors. This work thereby inspires further questions about how complex biotic and abiotic factors may influence species interactions.

## Characterization of leukocyte differentials in a hantavirus reservoir host species

*Xander Molina, Richard Dolman, Michelle Haynie, Christopher Goodchild*

Hantaviruses are an emerging global public health threat and can cause severe respiratory illness in humans. Unlike many infectious diseases, hantavirus (specifically Sin Nombre Virus [SNV] in the United States) is not vector-borne but is transmitted from mammalian reservoir host species to humans through human contact with animal excreta and secreta. However, the disease dynamics and pathology in reservoir host species remain unclear. In this study, we conducted a survey of free-living deer mice (Peromyscus maniculatus) in northwest Oklahoma. We prepared blood smears for leukocyte differentials and collected whole blood to measure for the presence of SNV RNA. These data will advance understanding of immune responses to hantavirus carriers in a natural hantavirus reservoir host population.

## Quantifying muscle architecture in embryos using DiceCT and algorithmic fiber tracking

*Julia Molnar, Cassidy Davis, Edwin Dickinson, Akinobu Watanabe*

Muscle contraction during embryonic development is an important factor in shaping the mechanical environment in which tissues are formed. However, muscle architecture in embryos is poorly known due to the technical challenge of taking measurements manually from very small specimens. Using contrast-enhanced nano-CT and algorithmic fiber tracing, we measured volume, fascicle length, and fascicle orientation in 10 jaw muscles from a late-stage chick embryo. Algorithmically tracked muscle fibers closely matched manually tracked fibers from the same muscle in mean length, range of lengths, and orientation, indicating that the algorithm was able to track a representative sample of fibers. These parameters also were very similar between left and right sides, supporting the method's repeatability. Three muscles – depressor mandibulae and two of the pterygoids – had relatively large potential for force generation, as quantified by cross sectional area (>3.5mm2 versus 1-3mm2). Overall fiber orientations were similar to adult chickens, but some of the temporal muscles had smaller mediolateral components – potentially due to a relatively narrower mandible – supporting the idea that fiber orientation and muscle vectors in the jaw change across ontogeny. This method, used here for the first time on embryos, has the potential to greatly increase the number of species and stages for which muscle architecture is known, allowing us to compare muscle development across multiple species and model interactions between muscle and bone during embryonic development.

## Darwin's finch jaw muscle architecture and gearing properties in relation to biting specialization

*Irene Montanez, Anthony Herrel, Sam Van Wassenbergh*

It is assumed that the force-velocity trade-off of beak movement had implications for song divergence, mating dynamics and ultimately the process of speciation in Darwin's finches. Species with higher bite forces to crack larger seeds have evolved songs characterized by slower beak movements, while finches with slender beaks produce more complex songs involving more rapid movements. However, quantitative data on the geometrical characteristics of their jaw muscles is needed to advance our insight into the biomechanical principles behind this trade-off. Here we used contrast-enhanced CT scans to measure fiber lengths, pennation structure, cross-sectional areas, and moment arms with respect to the quadrato-mandibular joint in four finch species with a tenfold range in bite force: the warbler finch, small tree finch, small ground finch, and medium ground finch. We found that pennation structure was fairly conserved, but moment arms increased by $>10\%$ for both the adductors and depressors in our sample. This, in addition to a greater imbalance in the force capacity between beak closing and opening muscles, likely contributes to reduced beak movement frequencies and hence trill rates during singing. These data will eventually be integrated with biomechanical model simulations to provide new insights into the biomechanics behind the divergence in beak movement capacity in Darwin's finches.

## The thermal sensitivity of parental effects on offspring survival in a model ectotherm

*Kristi Montooth, Maathir Basi, Hamdiya Mumade, John DeLong, Ibrahim ElShesheny, Ian Keesey*

Early development is a particularly thermally sensitive life stage in ectotherms as temperature speeds up the molecular processes of development but also compromises the cellular structures that support these processes. Our prior work in the fruit fly Drosophila melanogaster demonstrated that acute heat exposures early in embryogenesis before zygotic transcription begins have lasting effects later in development and that maternal provisioning of small heat-shock proteins can buffer this thermal effect (Lockwood, Julick, Montooth, JEB (2017) 220, 4492-4501). I will present data sets showing additional ways that temperature-mediated parental effects impact offspring survivorship in outbred Drosophila melanogaster from Lincoln, Nebraska. We found that the function that relates decreasing offspring survivorship to parental age is thermally sensitive, with an intermediate temperature of 17C maintaining higher offspring survivorship as parents age. This effect scales up to shape the thermal performance curves of fecundity and population growth. In addition to these physiological parental effects, we are investigating how oviposition preference impacts offspring survival in the context of multiple ecological factors. I will present data testing the hypothesis that females lay eggs on cooler substrates when there is ethanol in the environment to offset ethanol's fluidizing effect on cellular membranes. Through this research we hope to illuminate how behavioral and physiological parental effects are integrated to impact offspring survivorship in heterogeneous environments, particularly in the early stages of embryogenesis.

## An empirical bayes approach to study the phenotypic evolution from high-dimensional data

*Paola Montoya Valencia, Hélène Morlon, Julien Clavel*

The fast increase of multivariate data describing phenotypes is extending our capacity to understand their evolution. Today, we are not limited to characterize complex phenotypes from linear measurements but from multivariate quantifications describing complete and detailed shapes. Even though current approaches allow to make evolutionary inferences from multivariate data, this complex phenotypes in high-dimension, still being challenging and even restrictive when the number of variables is around thousands. To overcome the limitations given by the dimensionality, we propose a new regularized approach using an empirical bayes framework, to infer evolutionary parameters through a maximum likelihood estimation. Using simulations, we found a high accuracy in the estimation of evolutionary parameters from the proposed approach, even when the number of traits surpass the number of species for more than 30 times. Likewise, for parameters as the covariance matrices, the regularized matrix obtained in our approach is more similar to the true one as the difference between the number of species and traits increases, presenting a similar performance than other approaches handling high-dimensional datasets. However, in contrast with current approaches, our approach reduces the performance time, being up to 200 times faster. The proposed approach provides an accurate and fast alternative to deal with high-dimensional datasets for testing multiple evolutionary hypothesis of phenotypic evolution along the tree of life.

## The jaw joint, mandibular symphysis, and hemimandibular movements during chewing in Carnivorans

*Stephane Montuelle, Rachel Olson, Susan Williams*

Previous studies of the anatomy and morphology of the carnivoran jaw have suggested that the temporomandibular joint (TMJ) configuration may restrict 3D movement at the joint, while a patent, or unfused, mandibular symphysis may allow the hemimandibles to roll around their long axes to facilitate tooth occlusion during chewing and biting. However, previous studies also suggest that differences in symphyseal morphology between species within the group may contribute to interspecific variation in symphyseal movement. We leverage X-ray Reconstruction Of Moving Morphology (XROMM) to explore in vivo motion of each hemimandible during chewing in skunks (Mephitis mephitis) and raccoons (Procyon lotor), which differ in symphyseal morphology. A joint coordinate system (JCS) at each TMJ measured hemimandibular rotations and translations relative to the skull, and a JCS at the symphysis measured motion of one hemimandible relative to the other. We also used locators on the teeth (e.g., canines, carnassials) to visualize the 3D dynamics of tooth trajectories in relation to jaw and symphyseal motion during chewing. Our data show marked independent hemimandibular mobility at the TMJ which involves yaw, roll, and condylar translations (anteroposterior and mediolateral) in both species. These combine to produce complex movements at the symphyseal joint, including separation and apposition of the symphysis along its posterior and ventral borders, all resulting in controlled 3D tooth trajectories. This project was funded by NSF-IOS 1456810.

## Social mates dynamically coordinate aggressive behavior to produce flexible territorial strategies

*Nicole Moody (they/them), Matthew Fuxjager*

Adopting a systems approach to study complex behavioral patterns reveals contextual variation in how resident pairs deploy behaviors to defend breeding territories. Downy woodpeckers (Dryobates pubescens) are most well known for their characteristic acoustic signal, the "drum" produced by rapidly hammering their beaks on hard substrates. The drum is a distinctly woodpecker signal, but it is not the only type of territorial behavior these birds use in defense. Here, we describe the complex suites of behaviors resident pairs generated to defend their space from a simulated intruder. We use correlation networks, spectral clustering, and behavioral transition analysis to capture and quantify the dynamic strategies deployed by this species. We find that the type of territorial threat determines the specifics of how birds construct their strategies. Specifically, pair coordination is a prominent feature of defense in this species, and residents are more likely to coordinate their efforts with a mate when facing higher threat intruders. Overall, we demonstrate the power of systems thinking for analyzing multiagent behavioral dynamics.

## When the lung invades: new perspectives on avian postcranial skeletal pneumaticity

*Andrew Moore, Karl Bates, Stephanie Baumgart, Emma Schachner*

Birds are unique among extant tetrapods in exhibiting pneumatic (i.e., air-filled) postcranial bones that result from invasive diverticula of the gas-exchanging lung and its ventilatory air sacs. Despite a long history of study, postcranial skeletal pneumaticity remains poorly understood. We leverage new data and anatomical, developmental, and biomechanical insights to evaluate the functional and evolutionary significance of pneumaticity, yielding several novel conclusions. First, contrary to previous claims, ontogenetic pneumatization patterns are not conserved across birds, and the well-resolved sequence for Gallus cannot be cited as evidence for developmental recapitulation of evolutionary patterns observed in non-avian dinosaurs. Second, despite their superficially lightweight appearance, the skeletons of pneumatic birds are not less heavy for their body mass than those of apneumatic birds. Pneumatic skeletons may nonetheless be lightweight with respect to body volume, but this hypothesis requires testing. Third, although pneumatic skeletons are sometimes argued to be equally good or better than apneumatic skeletons at resisting biomechanical forces, this hypothesis requires that pneumatic skeletons increase in mass to avoid the risks of buckling, and is therefore antagonistic to the better-substantiated notion that pneumaticity offers energetic savings by reducing mass. Finally, we apply deep learning-based segmentation to microcomputed tomography scans to produce a pilot model of the pneumatized spaces in the neck of a Mallard, a step towards building a scalable workflow for large, comparative studies of pneumaticity.

## One fish, two fish, red fish, blue fish: deep learning tracks social dynamics in cichlid fish

*Erika Moore, Andrew Yuan, Veronica Britton, Tessa Solomon-Lane*

From neural networks to social networks, information is propagated through individual connections. Understanding the mechanisms that shape these interactions is crucial for disciplines ranging from computer science to behavioral neuroscience. Yet, despite recent advancements in computer vision, limited research thus far has leveraged machine learning to model the effect of group size on social network dynamics. Such an approach offers deeper insight into the factors that underlie individual influence and social cohesion. We used automated tracking to investigate the impact of group size on behavior in the highly social African cichlid fish Astatotilapia burtoni. Multiple replicates (n=8) of 1, 2, 3, and 4 fish were filmed 24 hrs or 48 hrs following group formation. The deep learning framework Social Leap Estimates Animal Poses (SLEAP) was used to train a neural network and track individual identities. Velocities, distances traveled, and spatial preferences were calculated using coordinate data. Our findings suggest there was a nuanced effect of group size on social interaction, with larger groups displaying more intricate, varied behaviors. We expect that group size influences network dynamics in a non-linear manner. Revealing these hidden layers of social complexity through computational approaches deepens our understanding of biological systems, such as the elements of social experience that shape development in A. burtoni and other organisms alike.

## What is biological sex?

*Ignacio Moore*

Gender is often described as a social construct and thus dependent on culture. In contrast, biological sex is often described as fixed and determinant. But what is biological sex and is there a definition that is useful? Sex determination is complicated and many factors, including genetics and hormones, determine phenotype and ultimately behavior. In this talk I will explore different aspects of biological sex and how they are useful and what are their limitations.

## Exploring variations in bobcat (*Lynx rufus*) locomotion across varied environmental conditions

*Katrina Moore, Megan Steen, Primrose Thavornthon, Brinda Garikapati, Monica Daley*

Wildlife movement is influenced by environmental factors including climate, terrain, energy expenditure, and the risk of injury, prompting animals to adapt their behavior and locomotor patterns to balance changing demands. Bobcats (Lynx rufus) inhabit regions with varied terrains and levels of human impact and thus offer valuable insights into such adaptations. Using trail cameras, we collected video data of bobcats across diverse landscapes in Southern California, tracking gait, posture, and locomotor intermittency (whether movement is continuous or interrupted by other behaviors). We hypothesized that, in high-risk environments (i.e., increased temperatures, rocky terrain), bobcats reduce locomotor intermittency and maintain more upright posture to minimize energy expenditure and time spent in these areas. We found that bobcats exhibited less intermittent locomotion at lower temperatures, on rocky terrain (compared to flat terrain), and during dawn or dusk (compared to daytime or nighttime). Additionally, bobcats adopted a more upright posture at higher temperatures and showed a greater variation in posture at night compared to during the day or dawn/dusk. Bobcat gait choice appears largely unaffected by environmental variables, with a lateral walk used consistently across landscapes and times of day. These findings enhance our understanding of bobcat movement patterns and can inform habitat restoration and wildlife corridor design to support populations and reduce human-wildlife conflict. NSF DBI-2319710.

## Aerobic constraints limit the territorial behavior of dragonflies at high elevations

*Michael Moore, Allison Pierce*

High-elevation environments present animals with severe metabolic challenges. Prior work has shown that the hypoxic conditions in montane habitats can hinder essential activities related to growth and survival, like thermogenesis and resource competition. Although territorial and courtship behaviors are often species' most aerobically demanding activities, little is known about if or how elevation affects these mating activities. Here, we show that high-elevation habitats constrain the territorial activity of dragonflies and may restrict species' mating activities in the future. Our field observations of $>1000$ territorial contests across 16 species and $>1600$ m of elevation show that male fighting ability declines by 75% for each kilometer gained above sea level. By contrast, these observations also show that fighting ability declines by 41% for each 10C increase in air temperature. Subsequent experimental manipulations reveal that locomotor endurance is reduced by the low $O_2$ found at high elevations. Moreover, field collections of territorial males show no intra- or interspecific body condition differences across the elevational gradient. Finally, under climate change scenarios, our projections indicate that territorial performance will decline by 52% if species disperse upslope to maintain their preferred temperatures but only decline by 10% if they experience the forecasted warming in their current elevational position. These findings highlight how the aerobic challenges of high elevations restrict mating activities and could impede upslope migration in response to climate change.

## Migratory monarchs only use magnetic cues for orientation with orientation recalibrated by coldness

*Samuel Moore, Steve Matter, Patrick Guerra*

Each fall, eastern North American monarch butterflies (Danaus plexippus) leave their northern range and migrate to overwintering sites in central Mexico. Although monarchs primarily rely on a bidirectional time-compensated sun compass for southwards directionality en route to Mexico, when directional daylight cues are unavailable, monarchs can use a magnetic compass to maintain proper directionality. As compass cues can only be used for directionality, monarchs must use other mechanisms for locating their overwintering sites. Although previous work found no evidence that monarchs use a fine-scale magnetic map, monarchs possibly use magnetic cues in a general sense for knowing their location, such as when they have overshot their destination. In this work, we use righting response orientation trials to show that fall monarchs maintain southwards orientation even when tested under artificially generated magnetic field conditions consistent with locations geographically south of the overwintering sites. Monarchs also keep orienting southwards when tested with magnetic conditions representing either the overwintering sites or locations geographically north of them. We also found that monarchs prematurely exposed to overwintering-like coldness reverse their orientation northwards, indicating that the monarch magnetic compass is also recalibrated by overwintering-like temperature, as shown with the sun compass. Monarchs therefore use other cues for locating the overwintering sites. As coldness recalibrates multiple compass mechanisms, this underscores the threat of climate change on multiple facets of monarch migratory biology.

## Hands-on approaches for mammal tails

*Talia Moore, Margaret Zhang, Juri Miyamae*

One of the many privileges of studying in the Biewener lab has been exposure to a diversity of outstanding research concepts and approaches. More than anyone I know, Andy is excited to personally surmount technical challenges to tackle questions across many subfields of biology. This can-do attitude empowered us students to explore cutting-edge concepts and even develop novel techniques. Throughout my time as Andy's student, I was lucky to read about, observe, and sometimes assist with several unique experiments taking place in the lab that continue to inspire my current research program. Recently, Andy hosted a visit by myself and my postdoc, Juri Miyamae, to dissect a tree kangaroo, which revealed unexpected morphologies. Andy encouraged us to seek out the function of this unique architecture and look for similarities with other species. These conversations prompted us to branch out and examine 12 more species and build a robotic physical model. Both have been significant undertakings, but will ultimately help us understand how tail morphology and function coevolve. Working with Andy made me realize how beneficial having a hands-on advisor can be to a student's research, and motivates me to take on this role in my own lab. I feel most like I am following Andy's footsteps when I am working side-by-side with my students, reassuring them that their big, risky ideas are worth trying.

## Effects of temperature and seasons on microbial growth of nasal bacteria in Mojave Desert tortoises

*Jenna Morales, Daniela Ramirez, William Fikan, Mariah Painter, Holly Nelson, Franziska Sandmeier*

Thermal environment plays an important role in the regulation of body temperature in ectotherms. These thermal regimes may also impact the growth of microbial communities. We sampled the nasal cavities of 18 captive Mojave Desert tortoises (Gopherus agassizii) and incubated the samples at seven different temperatures (13-40 degrees Celsius) across 24-72 hours in non-selective, liquid media. We repeatedly measured turbidity of nasal lavage samples to quantify microbial growth and generate thermally-dependent growth curves. We sampled animals across all seasons (spring, summer, fall, and winter). We used DNA extracted from these nasal lavage samples to quantify levels of Pasteurella testudinis, a bacteria commonly found in the tortoise respiratory tract. We sought to understand the impact of season and incubation temperature on overall microbial growth and species-specific growth of P. testudinis. We hypothesized that the in vitro microbial growth of nasal bacteria and quantified levels of P. testudinis will vary across seasons and incubation temperatures. Although the temperature of maximum bacterial growth did not shift across the seasons, winter did have less overall growth when compared to other seasons.

## Relevance of fruits for understanding morphological change of Araceae in the fossil record

*Jeronimo Morales Toledo, Selena Smith*

The plant fossil record is essential for understanding macroevolutionary patterns in plant lineages, offering direct evidence of past diversity. However, interpreting the relationships between extant and extinct species requires comprehensive documentation of current diversity. This study focuses on the Araceae family, a diverse group of angiosperms with a rich fossil record, where some fossils are difficult to interpret due to limited comparative data on modern fruit structures. Using X-ray microcomputed tomography, we analyzed fruits from various extant Araceae species, creating a novel morphological dataset to enhance our understanding of past aroid diversity. Non-Metric Multidimensional Scaling (NMDS) was employed to visualize morphological complexity and identify key traits shaping evolutionary patterns. Three analyses were conducted to explore how morphological data are lost during fossilization, affecting our interpretation of macroevolutionary patterns. The study identified oxalate crystals and epistase as significant in extant fruits but less likely to be preserved in fossils. Traits like seed shape, stylar region characteristics, and zonation of scleretic cells were found to be crucial in both extant and fossil records. This research advances our understanding of aroid fruit structure and provides a framework for integrating fossil data into macroevolutionary studies.

## Age, growth, diet and reproduction of African pompano

*Clinton Moran, Hunter Bramley*

African pompano (Alectis ciliaris) is an important species in commercial markets and can fetch up to $25/pound. Despite this, nothing is known about their basic biology which is often used when making management decisions. We sought to fill this gap and describe the age, growth, diet and reproduction of the African pompano from Georgia, South Carolina and North Carolina. Following collection by fishermen, basic morphological variables were measured and gonads, guts and otoliths were removed. We found that this species is a rapidly growing fish reaching 5.5 kg in their first two years. The oldest individual analyzed here (9 years) weighed 17.7 kg. Though most stomachs were empty, we found that this species feeds primarily on cephalopods including squid and octopus. Fish parts were infrequently found inside the guts. Finally, reproductive capacity was highly variable among individuals. We found a positive relationship between the relative weight made up by the gonads and total weight. Furthermore, we found a positive relationship between female fecundity and age. Surprisingly, there was no relationship between fecundity/egg condition and date collected suggesting that these fish spawn all summer rather than preparing for a massive spawning event. With this research we reveal some important basic biological features of the African pompano. Additionally, this information can be used by managers worldwide to create science backed management policies.

## Gene adaptation and response to hydrostatic pressure in adult zebrafish

*Jaralynn Tammi Morellano, Katelyn Mika*

Hydrostatic pressure is the main limiting factor of marine organisms' ability to vertically traverse the ocean, and information regarding shallow-water fish's tolerance and response to this stress is sparse. Prior studies have shown that zebrafish exhibited upregulated and down-regulated differentially expressed genes (DEGs) when they were exposed to increased hydrostatic pressure. To further investigate this area of genetic adaptation, we are studying the genetic responses of adult zebrafish to increased hydrostatic pressure via RNA sequencing. Transcriptome data collected will be compared to available data to further our understanding of adaptive mechanisms in deep-sea fish. Current experimentation will occur from 0 mPA to a max of 0.4 mPa, with plans to increase the pressure further and observe how the increased stress affects the regulation of genes. Beyond comparing responses across pressures, we are investigating potential correlations to age and sex. Tissue samples focus on the brain and sexual organs, both of which were shown to have the least and most stable response to hydrostatic stress, respectively. However, we are also taking several other samples to see how zebrafish physiology is affected overall.

## Cattle regenerative grazing effects on bat foraging activity in Southern Appalachia

*Seth Morelock, Richard Carter*

Agriculture is one of the predominant forms of land use change taking place globally, with reports of cultivated croplands and permanent pastures occupying up to 40% of the terrestrial land surface. Livestock farming, being expected to double by 2050, is indirectly and directly affiliated with 70% of all agricultural affairs and takes up 30% of the Earth's terrestrial surface. This brings a major concern for the substantial loss of biodiversity livestock can cause if not managed properly. Bats in North America are declining due to white-nose syndrome and habitat loss, resulting in a need to understand how bats respond to intensive land use changes, such as agriculture. It has been observed that cattle presence correlates with an increase in bat activity within agroecosystems. This study investigates how cattle regenerative grazing affects bat activity and species-specific bat activity. Passive acoustic sampling recorded bat activity for pre-, during, and post-cattle presence within pens of eight farms that performed cattle regenerative grazing in 2024 from May to September. The findings from this study resulted in a significant difference in both overall bat activity and species-specific bat activity for pre-, during, and post-cattle presence within the pens. This information can contribute to better livestock management practices, creating healthy agroecosystems, and determining suitable habitat preferences for bat species.

## Optomotor experiments reveal variation in summer flounder (Paralichthys dentatus) visual acuity

*Vanessa Moreno, Lorian Schweikert*

Visual acuity (i.e., capacity to resolve spatial detail) can be assessed for many animals using behavioral methods such as an optomotor reflex test, where an animal's innate visual responses (i.e., optokinetic responses; OKRs) to a set of rotating visual stimuli are observed. One challenge of this approach is optimizing the optomotor setup for a given animal's behavior, particularly in defining the criteria of a stimulus detection or positive OKR. Typically, for a positive OKR to be achieved by eye tracking alone, the animal must continuously track the stimulus until it leaves their field-of-view. This definition however, does not apply to every species due to differences in the motor behavior of their visual performance. Here we describe our approach to an optomotor assessment of visual acuity in the summer flounder (Paralichthys dentatus), which moves its two eyes independently and thus, requires custom definitions for a positive OKR. Here, we tested a range of five stimuli corresponding to the summer flounder's morphologically-predicted visual acuity, along with a gray control. We found intraspecific variation in summer flounder visual acuity, ranging between 3.6 to 4.6 cycles per degree (CPD) across eight animals, with a mean value of 4.06 CPD $\pm$ 0.4 (s.d.). These data align with known visual acuity in other flatfishes and offer valuable insights for future optomotor experiments with animals showing nonstandard OKRs.

## Understanding the ecomorphology effects of lumbar vertebrae in Soricidae

*Tyler Morgan, Stephanie Smith*

Shrews are a morphologically and ecologically diverse group of small-bodied mammals, ranging in body mass from under 2 grams to around 100 grams. Their diversity and size makes them an excellent model for investigating the effects of small body size on the ecomorphology of the skeleton. We want to investigate if there is ecologically informative variation in skeletal morphology of these tiny mammals, and if so, does the relationship between shape and ecology vary across body size? Using µCT scans of skeletons from the Field Museum of Natural History, we quantified morphology of the middle lumbar vertebra in 25 species of shrews via 3D geometric morphometrics. Because the lumbar spine is heavily involved in mammalian locomotion, we analyzed the correlation between locomotor mode and vertebral shape, as well as between centroid size and vertebral shape,. We found no statistically significant association between centroid size and locomotor group, or between size and shape. However, we found variation in vertebral morphology across locomotor groups, with notable shape differences in centrum aspect ratio, height of the neural arch, and location of the transverse processes. Fossorial and scansorial species diverge the most from the overall mean shape. We also recovered phylogenetic signals associated with shape. Future work will refine the relationship between shape and bone performance under various loading scenarios and enable us to better separate functional from phylogenetic effects.

## Battle of the sexes: sexual dimorphism in the brain of the smooth butterfly ray, *Gymnura micrura*

*Haley Morman, Kara Yopak*

Cartilaginous fishes (sharks, batoids, chimaerids) can experience indeterminate growth, where body and brain continue to grow throughout their lifetime. Thus, brain size and brain organization can change over ontogeny, potentially providing insight into sensory or behavioral shifts. However, very limited data is available on intraspecific variation in the brain between males and females at key life stages, especially at or around sexual maturity. This study assessed brain size and brain organization, or the relative size of seven major brain regions (olfactory bulbs, telencephalon, diencephalon, optic tectum, tegmentum, cerebellum, and medulla oblongata) in 22 individuals (9 males, 13 females) of the smooth butterfly ray, Gymnura micrura, in late ontogeny. The brain continues to increase significantly with body mass after sexual maturity in G. micrura, but male rays show a significantly higher intercept (ANCOVA, $F_{1,18} = 8.157$, $p = 0.01$), suggesting that mature males are more encephalized than mature females. Patterns of brain region scaling similarly show continued growth of all brain regions in both males and females. However, there are significant differences in the relative size (residuals) of major brain regions between the sexes. Mature males have significantly larger olfactory bulbs and telencephalons, while mature females have significantly larger diencephalons, cerebellums, and medullas. These differences may reflect sensory or behavioral specializations and/or differences in reproductive investment in males versus female rays after sexual maturity.

## The paraphyly of Pisauridae and restoration of the family Dolomedidae (Arachnida: Araneae)

*Sarah Morris, Nicolas Hazzi, Gustavo Hormiga*

Pisauridae, or the nursery web spiders, is a speciose family with a worldwide distribution and a variety of prey capture strategies. Recent phylogenetic studies have called the monophyly of the family into question, and no morphological synapomorphies currently exist that circumscribe Pisauridae as a clade. Despite being named for their nursery webs, similar structures are built by members of Oxyopidae and Ctenidae. In a preliminary study, we used maximum likelihood methods to build a phylogeny with eight genetic markers and found that the placement of Dolomedes and Bradystichus outside of Pisauridae renders the family paraphyletic. Dolomedidae, described by Simon (1989), could be used to circumscribe these two genera, but it was rejected by Sierwald (1990) on the basis of unclear character coding. We have now expanded our dataset to nine marker genes as well as Ultraconserved Elements to reconstruct the evolutionary relationships of Pisauridae. Our results, obtained through both maximum likelihood and multispecies coalescent approaches, corroborate our preliminary findings. Thus, we propose the resurrection of Dolomedidae to maintain the monophyly of Pisauridae. We offer several synapomorphies for Dolomedidae, as well as directions for future studies concerning other pisaurid genera.

## Behavioral and molecular mechanisms of sex-reversed parental care in poison frogs

*Jeanette (Jen) Moss, Eva Fischer*

Flexible parental care strategies are widespread in nature and factor prominently into conflict between the sexes and the realization of sex roles. While one sex is typically the primary caregiver, the other sex may retain caregiving capabilities but limit their involvement to a compensatory capacity. While adaptive explanations abound, the mechanisms that underlie flexible ‘sex-reversal’ of care are not always clear. Here, I enlist a biparental frog (Ranitomeya imitator) with flexible sex-reversal of tadpole transport to investigate the extrinsic and intrinsic mechanisms underpinning transport decisions. Using standard mate removal experiments in the laboratory, I show that members of the flexible sex (females) express greater variation in transport behavior than members of the primary transporting sex (males), and that transport propensity is somewhat affected by extrinsic partner cues (i.e., visual and acoustic stimuli). Conversely, individual repeatability of transport behavior is high, with success significantly predicted by behavior on the day before eggs hatch. To understand whether differences in transport propensity are underpinned by differences in brain gene expression, I sequenced RNA from whole brains of transporting and non-transporting frogs. While transporting females showed minimal differential gene expression compared to transporting males, females that failed to transport showed distinct patterns of gene expression. These patterns offer an initial glimpse into the genetic regulation of flexible sex-reversal.

## Bend, don’t break! Using sloths to evaluate bone loading and properties in a suspensory mammal

*Angela Mossor, Andrew McKamy, Melody Young, Aaron Rochté, Judy Avey-Arroyo, Edwin Dickinson, Michael Granatosky, Michael Butcher, Jesse Young*

Sloths are the only mammals that utilize obligatory suspensory locomotion as part of their arboreal lifestyle. Their limb bones are therefore subjected to increased tensile loading, despite mammalian bone being ∼400% stronger in compression than tension. The objective of this study is to evaluate long bone loading and material properties in sloth bones to investigate possible modifications for extreme tensile loading. We tested the hypothesis that sloth limb bones experience a relatively high degree of tensile loading but are nonetheless optimized to withstand greater tensile loads via a greater degree of parallel collagen fiber orientation. We tested this by conducting a suite of experiments in Bradypus and Choloepus consisting of inverse dynamic estimates of bone loading during suspensory locomotion in living animals, in vitro bone strains on cadaveric specimens, material testing (three-point bending and axial tension) on isolated long bones, and polarized light microscopy (collagen fiber orientation) on long bone sections. Results show that sloths display predominately axial loading during locomotion, increased bone extensibility ex vivo, and more parallel collagen fiber orientation in their cortical bone. These findings suggest that obligate suspensory locomotion in sloths has necessitated limb loading patterns and bone properties that are divergent from upright mammalian taxa.

## Rough but not so tough: impact of surface roughness and loading orientation on sea urchin adhesion

*Andrew Moura, Carla Narvaez Diaz, Austin Garner*

Sea urchins are prominent herbivores in coastal marine habitats that, by grazing on foundational species, have profound effects on marine ecosystems. Habitats occupied by sea urchins are frequently subjected to hydrodynamic loading (i.e. applied force) from waves and currents. Sea urchins use tube feet to resist dislodgment from these forces. Tube feet consist of an extensible stalk and terminal adhesive disc containing a duo-gland adhesive system that enacts strong, reversible adhesion on different substrates. Variation in substrate roughness has been shown to influence sea urchin attachment in both natural and laboratory experiments. However, tests of adhesive performance of tube feet on rough surfaces have been limited by 1) the inability to separate the influence of surface chemistry from roughness and 2) comparisons restricted to two roughness extremes (smooth vs rough). Additionally, the impact of loading orientation (application of perpendicular or parallel loads) has not been investigated in echinoderm tube feet. We assessed the effect of surface roughness and loading orientation on tube foot adhesive performance using a gradient of surface roughness in the sea urchin Strongylocentrotus purpuratus. Foraging and survival of sea urchins are strongly influenced by their ability to attach, thus understanding how tube feet perform in variable surfaces is needed to better understand ecological interactions between sea urchins and foundational species.

## Spatial covariance in GxE interactions influences local adaptation in green anole lizards

*Morgan Muell, Kendall Jackson, Daniel Warner*

Genotype by environment interactions (GxE) are hypothesized to enable local adaptation across environmental clines. However, spatial covariance in GxE (CovGE) can evolve to alter the relationship between genotype and environmental effects based on population, causing phenotypic variation to mismatch theoretical predictions about the influence of the environment on genotypes. Yet, the influence of CovGE on phenotypic variation is rarely quantified in natural systems, which can hinder interpretation of the adaptive significance of phenotypic variation across clines. We tested for spatial CovGE using a reciprocal transplant design in seven populations of green anoles (Anolis carolinensis) from southeast USA to interrogate the role CovGE may play in local adaptation to temperature seasonality. We incubated eggs from all populations under three incubation treatments that represent variation in natural nest temperatures at collection sites, measured offspring traits, and estimated CovGE and GxE. We also test for effects of local climates on maternal life-history traits. After controlling for egg size, we find moderately strong evidence of countergradient variation for incubation period and no evidence of CovGE in hatchling morphology. We find no evidence of GxE for any phenotypes. Together, our results show latitudinal variation in key life history traits that may reflect local adaptation to seasonality. We demonstrate the influence of spatial CovGE on the evolution of fitness-relevant traits and the importance of CovGE in characterizing patterns of local adaptation.

## Host and microbiome response to a two-month heat gradient in the cnidarian model *Exaiptasia*

*Kaden Muffett, Emilia Sogin, Mara Schwiesow*

Increasing temperatures associated with global climate change impact the symbiotic interactions between cnidarians, their algal symbionts and the diverse consortia of microorganisms living within their tissues. However, the directionality of these interactions, including the magnitude of change and overall impacts on symbiotic function are poorly understood. Here, we exposed the model sea anemone Exaiptasia diaphana to a thermal stress gradient for two months. Over 1300 anemones from heat-tolerant (CC7) and heat-sensitive (H2) clonal lines were followed across each temperature condition (26.5C, 29.0C, 31.5C) in 24 individual populations. Thermal stress impacted reproductive output in heat-tolerant and heat-sensitive anemones unevenly. Heat-tolerant Exaiptasia created more asexual clones in higher temperatures, while heat-sensitive Exaiptasia experienced reproductive declines. In addition to reproductive changes, Exaiptasia populations held at high temperatures began producing offspring capable of surviving extreme heat shocks (38C) within three months. We also found marked shifts in the anemone's microbial community as measured by 16S rDNA analysis across over 400 samples. Our results showed that the microbial community shifted in all 24 Exaiptasia populations and that key microbial strains associated with coral-algal symbioses collapsed under long-term and short-term heat stress. With this dataset, we are able to describe the host and microbiome response to a heat gradient in the cnidarian model Exaiptasia.

## The root microbiome as a source of antibiotic resistance genes

*Aijalon Muhammad, Tobias Hoffmann, Mentewab Ayalew*

Understanding the dynamics of bacterial resistance to antibiotics is crucial for developing effective strategies to combat infections and safeguard public health, given the growing prevalence of multidrug-resistant pathogens. We chose soil and plant roots as the focus of this study because they house a reservoir of diverse bacteria species. Bacteria in/on plant roots represent a subset of bacteria present in soil. However, the density of bacteria is much higher due to energy-rich compounds being released by roots. We hypothesize that bacteria in/on roots may have higher antibiotic resistance due to the density and competition among bacteria to occupy this niche. Soil and plant material was sourced from Spelman College, and 10 bacterial isolates from soil and 10 isolates from roots were tested for resistance to a panel of antibiotics. The isolates were also sequenced and identified. The abundance of each isolate was also examined in soil and root metagenomic data sets. It is expected that isolates abundant in roots will have increased resistance levels to antibiotics. These results can potentially indicate that plant roots represent an important environment for the selection of bacteria harboring antibiotic resistance genes.

## Energetics and continuous shifts of leader position in a wild carangid fish school

*Ishani Mukherjee, James Liao*

In fish schools, individuals occupying forefront positions have been shown to bear greater energetic costs than individuals who follow. We investigated the impact of water flow on leadership and energy expenditure in a wild, schooling carangid fish the Atlantic Bumper (Chloroscombrus chrysurus). A school of 20 fish (mean standard length of individuals = 4.61 ±0.30cm; mean weight of individuals =1.45±0.25g) was exposed to three different flow speeds in a 185-litre flow tank with a large working section (80cm × 25cm × 25cm). Two synchronized Basler cameras (100 fps) recorded individuals in the school continuously for 20 minutes. The school was tested at 3 flow speeds, each repeated three times. We hypothesize that in higher flow leaders swap positions more often to decrease the energy expenditure of any one fish. However, we found that the number of leadership events (18.3/minute, duration = 4 s) were comparable across flow speeds. Oxygen consumption was assessed at each flow speed for 20 minutes, revealing a linear decrease with time at each speed (slope of regression= -6; $R2 = 0.68$; $p < 0 .001$), but no differences across flow speeds. Analysis is underway to reconstruct 3D trajectories to calculate nearest neighbor distances, tail beat frequency, and turn angles. These findings suggest that schools adapt their energetic demands behaviorally at different flow speeds to maintain constant oxygen consumption rates.

## Novel antimicrobial peptides and peptide-microbiome crosstalk in Appalachian salamander skin

*Carly Muletz-Wolz, Julian Urrutia-Carter, Owen Osborne, Steve Kutos, Jose Meneses Montano, Joseph Madison, Brian Gratwicke, Ratanachat Racharaks, Randall Jimenez, Amy Ellison, Timothy Cleland*

Host antimicrobial peptides (AMPs) act as barriers to pathogenic microbes, while allowing beneficial or commensal microbes to remain. We used multi-omics and mathematical tools to discover new AMPs and examine AMP-microbial relationships in three Appalachian salamander species (Plethodon cinereus, Eurycea bislineata and Notophthalmus viridescens). We conducted skin transcriptomics ($n = 13$), proteomics ($n = 91$) and AMP database querying to identify candidate AMPs. With candidate AMPs, we identified correlations with the skin microbiome (16S rRNA amplicon) and synthesized 20 peptides to use in challenge assays with pathogens of amphibians (Batrachochytrium dendrobatidis: Bd) and humans (ESKAPEE pathogen panel). Using transcriptomics, transcriptionally active candidate AMP genes (30-67 genes) were detected in all individuals with Cathelidicin-like peptides being most common. Using proteomics, detectable AMPs were only found in a subset of salamanders (31/91) – predominately E. bislineata – with Kinin-like peptides being most common. Candidate AMPs showed both positive and negative correlations with abundant bacteria in the skin microbiome suggesting both pro-microbial and anti-microbial activity by AMPs. Crude and synthesized peptides showed limited activity against Bd. However, two synthesized Cathelicidin-like peptides (from P. cinereus) showed moderate to strong killing activity against human pathogens, Acinetobacter baumannii and Escherichia coli. We show that mining understudied taxa and using multi-omics fuels AMPs discovery, reveals dynamic AMPs-microbial relationships, and informs the therapeutic potential of AMPs usage in conservation and translational applications.

## How to use biological collections in course-based research to address coloniality and equity issues

*Ulrike Muller, Sharndeep Kaur, Viridiana Rivera Flores, Alexandria Hansen*

Many universities use their natural history collections for research and education. These collections often contain specimens that have been collected over a long period of time and therefore they are also valuable historical records to study change over time, addressing evolutionary and ecological questions. These collections are also a historic record of coloniality and equity in academia. Many collections share information in online databases, making them a readily accessible and free resource for students to use in course-based research. Students build valuable disciplinary and transferable skills, including developing and executing their own research projects. Projects on coloniality and equity issues are particularly impactful because the topic presents a low entry threshold in terms of concepts and research techniques, and often provides opportunities for students to bring their own activism, expertise, and experiences into the project design. Research projects can focus on the specimens themselves (taxonomic representation, sex representation, geographic representation), or metadata (collector identities such as apparent gender and geographic ancestry). These projects produce data that can be presented at professional meetings and can reach publication quality. They also allow students to gain experience with interdisciplinary research through collaborations with, for example, anthropology, sociology, gender studies, data management, and computer science experts.

## Modularity and rate of phenotypic evolution among Appalachian salamanders (Plethodontidae)

*Dartagnan Mullins, Edward Burress*

Modularity is a pattern whereby functionally related traits evolve as interrelated systems, resulting in lower covariation between modules and higher covariation within. This organizational system permits traits to independently adapt for different purposes such as feeding and locomotion. The Appalachian Mountains are a biodiversity hotspot for lungless salamanders (Plethodontidae). We measured 30 linear traits that characterize various aspects of body shape across 380 individuals representing 77 species. We test whether (i) Appalachian salamanders express signals of modularity in functionally related morphological characters and (ii) if the rate of evolution – a fundamental macroevolutionary signal of ecological opportunity – of these modules are coupled or decoupled. We find that Appalachian salamanders exhibit significant modularity in which their head, trunk, limbs, and tail act as different modules. These modules vary in how decoupled they are based on their evolutionary rates. The rate of head evolution is correlated with all other modules, while the rate of tail evolution is uncorrelated with most other modules. These results suggest that modularity may underlie much of the morphological diversity of Appalachian salamanders by permitting an array of trait combinations. We also find that the rate of evolution of well supported modules can be highly correlated, suggesting that although the phenotype may exhibit modularity, modules may respond similarly to ecological opportunity.

## Deep learning for 3D image segmentation and analysis of evolution in planktic foraminifera

*James Mulqueeney, Anieke Brombacher, Alex Searle-Barnes, Yichen He, Anjali Goswami, Thomas H. G. Ezard*

Three-dimensional imaging techniques, such as x-ray micro-computed tomography (micro-CT), have revolutionized the ability to visualize and quantify intricate internal and external structures across a wide range of objects. These techniques provide high-resolution insights, but the manual segmentation needed to extract and compare features across numerous individuals presents significant challenges, particularly as trait complexity increases. To address this issue, deep learning offers a promising solution for automating image segmentation in three-dimensional biological images. In this study, we employ convolutional neural networks (CNNs) to automate the extraction of volumetric data from 1,714 CT-scanned specimens of planktonic foraminifera, representing four species within the Menardella lineage. Our initial investigations, focused on percentage calcite and total body size, reveal distinct species-level differences, with more recently evolved species exhibiting significantly thinner shells compared to their ancestors. These findings support a punctuated equilibrium model of evolution for this lineage, with periods of stasis followed by rapid expansions in morphospace. Ongoing work using regional growth algorithms to explore the developmental trajectories of these organisms will uncover how morphological changes during ontogeny interact with environmental and functional constraints to produce these evolutionary patterns. The results provide significant insights into the factors driving the micro- to macroevolutionary transition and the dynamics of speciation and demonstrate the capacity of deep learning to allow phenomics of vast datasets bridging micro and macroevolutionary scales of analysis.

## Detection and depuration of microplastics in American oyster collected from Gulf of Mexico coast

*Rebecca Muniz, MD Rahman*

Microplastics have invaded the aquatic environment and its inhabitants, causing significant disturbances. Bivalves are among the main organisms impacted by microplastics due to their unique filter-feeding technique. Their important ecological roles make them key species for ecotoxicological research. In this study, we used a Nile red staining technique to quantify microplastics in American oyster (Crassostrea virginica, an ecologically and commercially important marine mollusk). We compared gill and digestive gland tissue samples from 30 oysters collected from two polluted sites on the Southern Gulf of Mexico coast, as well as tissue samples from oysters after a depuration study, to identify differences in the quantity, shape, and size of microplastics in oysters. The depuration study lasted two weeks under controlled laboratory conditions with running filtered seawater and aeration. The field results showed a significant number of microplastics, with an abundance of microfibers and varying sizes, while the laboratory results showed a significant decrease in both the quantity and size of microplastics in the gills and digestive glands of oysters. Our findings suggest that microplastics are disrupting the tissue architecture which may lead to increased oxidative stress and subsequently inhibit the physiological functions of oysters.

## Neural and molecular regulation of social subordination by androgen receptors in an african cichlid

*Kathleen Munley, Sakuni Rankothgedera, Shiyanth Thevasagayampillai, Amy Hoang, Preethi Gunaratne, Beau Alward*

Androgens are critical in controlling physiological mechanisms and behaviors associated with social rank. Previous research from our lab has shown that the two androgen receptors present in teleost fishes, AR$\alpha$ and AR$\beta$, regulate distinct aspects of dominant social status in male Astatotilpia burtoni, a highly social African cichlid. AR$\alpha$ is required for the expression of dominant-typical behaviors (e.g., aggression, mating), whereas AR$\beta$ is required for the expression of dominant-typical physiological characteristics (e.g., testes growth, bright coloration). It is unclear, however, how androgenic signaling modulates subordinate social status. Here, we characterized the neural and molecular regulation of social subordination by androgen receptors in male A. burtoni using AR$\alpha$ and AR$\beta$ knockout fish. We determined that subordinate AR$\alpha$ and AR$\beta$ mutants show different deficits in reproductive physiology: AR$\alpha$ mutants have a higher gonadosomatic index (GSI), while AR$\beta$ mutants have a lower GSI than wild-type fish. Moreover, our preliminary data suggest that AR$\alpha$ and AR$\beta$ have distinct roles in controlling subordinate-typical behaviors: AR$\alpha$ mutants display more fleeing, grazing, and freezing, whereas AR$\beta$ mutants show less fleeing, grazing, and freezing relative to wild-type fish. In ongoing work, we are identifying cell type-specific gene programs in the hypothalamus of subordinate males that are perturbed by AR genetic deletion via single-nucleus RNA sequencing. Taken together, these findings will enhance our understanding of the mechanisms that govern subordination in group-living species.

## Kinematic evaluation of descent slowing behavior during falls in lizards

*Victor Munteanu, Savannah Swisher, Amanda Kellerhals, Trevor Brewington, Richard Blob*

Animals living in arboreal (tree-based) habitats encounter numerous discontinuities in their environment. These discontinuities expose arboreal animals to a significant risk of falling. In this context, such species may be expected to adjust their body and limb positions during falls to reduce potential impact forces upon landing. However, species with different limb and body configurations may have different abilities to make such adjustments. We constructed a custom-built apparatus that can release animals for an aerial drop onto a cushioned landing pad 150 cm below, simulating an event possible in nature. We compared trials for each of three arboreal lizard species that varied in body height and tail proportions: Chamaeleo calyptratus (tall-bodied), Gastropholis prasina (low-bodied, long tail), and Anolis equestris (low-bodied, shorter tail). Using high-speed video from multiple perspectives, we tested whether differences across taxa in body, limb, and tail movements during falls were correlated with differences in morphology. Overall, despite body configuration differences, each species sprawled the limbs out laterally and slightly dorsally during falls, with the anterior part of the body pitched forward. These results suggest a common method of reducing falling velocity in arboreal lizards. This indicates a decoupling between morphological and behavioral specializations; despite different body configurations, falling kinematics across these species are more comparable than predicted.

## Marine and terrestrial sediment on algal turf limits herbivory pressure and species richness

*Zuri Murph, Amarie Strong, TaVon Palmer*

Herbivory on coral reefs provides strong top-down control that maintains turf algae in a short healthy state after disturbance kills coral. While it is well known that marine sediment deters herbivory, what remains unknown is the effect of terrestrial sediment that is increasing on coral reefs due to climate change and coastal development mobilizing soils in developed watersheds. We evaluated the effect of marine and terrestrial sediment on herbivory rate on algal turf in three sites in Mo'orea, French Polynesia. We confirmed that turf height (LME, $p<0.001$) and sediment depth ($p<0.0001$) varied across sites ($n=10$ per site). Total herbivory rates quantified from video recordings of bite rates on replicate experimental plots did not vary between sites (Kruskal-Wallis, $p>0.05$). Rather, bite rates for individual species and the species richness of the fish taking bites differed across sites. Richness and herbivory rates were highest where sediment and turf were lowest. Both herbivory and fish diversity declined at the site with marine sediment and long turf and were lowest by far at the site with terrestrial sediment and long turf. Overall, we found that terrestrial sediment deterred herbivory more than marine sediment. Thus, increases in sedimentation, particularly of terrestrial sediments, associated with climate change could further degrade coral reefs by decreasing total herbivory and the species richness of the herbivore community, ultimately inhibiting coral recovery.

## Assessing Tradeoffs Between Tail-Flip Jump Distance and Critical Swimming Speed in Fish

*Corvus Murphy, Michael Minicozzi*

Terrestrial locomotion is observed in a wide variety of teleost fish species. Many of these species display a specialized and highly stereotyped behavior called a tail-flip jump. Little is known about potential tradeoffs in a fish's locomotor ability in terrestrial and aquatic realms. Thus, we asked if tradeoffs exist between tail-flip jump distance and sustained swimming performance across many different fish species. Fish were prompted to jump and recorded using a high-speed camera at 600 FPS for kinematic variables and an overhead camera to record jump distance. The kinematic variables measured were jump time, takeoff angle, and curvature coefficient. Critical swim speed was calculated using a flume and a critical swimming procedure where fish were acclimated for 20 minutes with no flow, followed by 20 minutes at 7.5 cm/s. After the acclimation period, the flow was turned up by 1 cm/s every 3 minutes until the fish could not sustain the swim speed and was swept against the downstream barrier. The maximum jump distance was measured by placing the fish in a arena and prompting them to jump continuously for 30 seconds. We found that fish species fell into three categories, with some species exhibiting a tradeoff between critical swim speed and jump distance, some showing a correlation between high critical swim speed and high jump distance, and some exhibiting no relationship between these variables.

## How do tiny insects fly? Measurements of the flow generated by a freely flying sub-mm scale insect

*David Murphy, Evan Williams, John Murray-Bruce*

Flying sub-millimeter insects implement kinematic and aerodynamic mechanisms distinct from those of larger insects. Kinematically, these tiny insects are obligate users of the clap and fling mechanism and incorporate deep U-shaped wing-tip trajectories to generate lift. However, our prior understanding of their aerodynamics was based solely on numerical simulations and dynamically scaled models. Here we present time-resolved (10kHz) measurements, acquired by our novel brightfield micro-PIV system, of the flow generated by a freely flying tobacco whitefly (Bemisia tabaci). A novel inverse problems approach to preprocessing the images significantly improves signal-to-noise ratio. We simultaneously measured the 3D wing and body kinematics with two additional orthogonal cameras. The whitefly has a body length of 0.85 mm, forewing length of 0.85 mm, hindwing length of 0.75 mm, stroke amplitude of 123°, beat frequency of 178 Hz and chordwise Reynolds number of 14. In addition, the whitefly oscillates its abdomen at 178 Hz. The forewing and hindwing have distinct wing trajectories and non-synchronized Euler angles throughout the stroke. The measured flow fields reveal a downwards jet ejected from between the wings with flow speeds up to 500 mm s-1, a medial spanwise flow during the fling mechanism as the wings create a V-shaped gap, well-developed flows attached to the wing during the power stroke, and recirculation occurring during stroke reversal that may indicate a novel form of wake capture.

## Snake skin lipids and fungal-bacterial interactions influence the growth of Ophidiomyces ophidiicola

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The integration of data from different biological scales (i.e., microbial to whole-organism) into studies of host-microbiome-pathogen interactions is essential for identifying factors contributing to host health and enabling the development of more reliable predictive models for disease spread and management of wildlife epidemics. Within the host-microbiome-pathogen system, host microenvironment and extracellular chemical composition are often overlooked. For example, reptilian skin possesses a complex lipid matrix rich in cholesterol that likely influences the skin microbiome community composition and pathogen performance. In this study, we test the hypothesis that the intricate relationships between host skin chemistry and the bacterial microbiome affect growth of the fungal pathogen responsible for snake fungal disease (Ophidiomyces ophidiicola). Analyses of culture dependent and independent methods suggest that host skin chemistry, particularly the presence of specific long-chain organic molecules (e.g., oleic acid, squalene) and bacteria isolated from wild snake skins influence the growth of O. ophidiicola. The O. ophidiicola genome contains biosynthetic gene clusters that, when expressed, may produce enzymes that suppress host lipid production, thereby facilitating fungal colonization of snake skin. Our results emphasize the diverse lipid milieu of snake skin as a powerful source of chemical defense against pathogens that require a unique microbial community, interactions and growth environments.

## Survey of the sensory organs and setae of the esophagus of *Metacarcinus magister*

*James Murray, Lee Morris*

Decapods have an unusual method for rejecting distasteful foods. Like many animals, they ingest foods based on signals from the mouthparts, but unlike most animals, they reject distasteful foods based on esophageal receptors post-ingestion, but before or near the transition from the esophagus to the cardiac sac. The Dungeness crab is a predator and scavenger that coexists with toxic prey such as soft corals and sea slugs. How they learn to avoid such prey is largely unknown. We have surveyed the internal cuticle of the esophagus and ventral area of the cardiac sac with light and scanning electron microscopy and have identified numerous types of setae and setules, some of which may be chemosensory. We have focused our attention on a pair of finger-like structures distal to the cardiac sac that are covered with both long setae and short stubs with a central pore. Our longer-term goal is to record from the nerves serving these setae to determine if they respond to distasteful chemical stimuli such as denatonium and sea slug tissue.

## Costs of gestation in intrauterine milk secreting rays

*Annais Muschett-Bonilla, Dean Grubbs*

The diverse reproductive strategies of elasmobranchs pose an unknown amount of risk to pregnant females from the distribution of nutrients from mother to embryos during embryonic development. This study aims to investigate the potential costs associated with matrotrophic lipid histotroph secreting species during gestation. While these species do not provide parental care post-parturition, they are assumed to invest greatly into the post-fertilization and pre-parturition period. Hypanus sabinus, a dersmal and abundant species collected along the Florida gulf coast, was the studies model organisms when investigating energetic expendature throughout gestation. These organisms were collected shortly after ovulation and kept at 26.0 C throughout their 4 to 4.5 month gestational period. Every 2 to 3 weeks 24-hour respirometry trials were conducted to calculate standard metabolic rate at various gestation stages, including shortly following parturition and a month post parturition. Further studies hope to utilize this research to compare the potential costs of gestation between reproductive modes in elasmobranchs and assess the variation in costs and strategies that exists between individuals and closely related species utilizing the same mode of reproduction.

## Light-dependent flight dynamics in Damselflies (*Ischnura ramburii*)

*Veronica Muzio Crego, Elina Barredo, Jamie Theobald*

Insect activity is closely correlated with light niche, and flying insects rely on vision for vital activities, such as foraging and mate selection. This require them to efficiently collect available light, while also acclimating their navigation strategies to seasonal brightness variations. For aerial predators like damselflies, brighter environments help with contrast perception, but may make them more visible to predators. Thus, damselflies typically rest on perches in highly busy visual environments, then carefully glean prey from cluttered vegetation. To explore how light level affects typical damselfly flight, we filmed local male Ischnura ramburii using high-speed videography, then reconstructed 3D flight paths. We looked at specific patterns of flight dynamics (speed, acceleration and curvature) across bright and overcast conditions, then estimated the photons reaching a defined area using the Environmental Light Field (ELF) method. We report characteristic flight differences that vary with brightness, which hint at the environmental tradeoffs for an animal that functions as both predator and prey. These results add to the current knowledge of this widely abundant but largely understudied insect.

## You are what you eat: diet and the gut microbial community and health

*Amelie Mwilambwe, Benjamin Sadd, Logan Sauers*

Gut microbial communities (microbiota) play crucial roles for host health, yet the composition of these communities varies. Understanding factors that influence microbiota membership and function is essential to appreciate underlying causes and consequences. There is a clear connection between a host's diet and its gut microbiota, but diet diversity and its relationship to the microbiota and host health is relatively understudied in pollinating insects. Bumble bees are naturally and agriculturally important pollinators, but land use changes can have consequences for their diet. We investigate how pollen diet influences the bumble bee gut microbiota and health, hypothesizing that diet nutrition and diversity will affect microbiota structure and host health. Adult bees were given one of five diet treatments, including no pollen, one of three individual nutritionally variable pollen types, or a diverse mix of the three pollen types. These bees were sampled for their gut microbiota composition or survival under stressful conditions, with the latter being found to decrease as pollen diversity was reduced. Microbiota results are still being analyzed, but we predict a diverse pollen diet leads to healthy microbiota establishment and single pollen diets will differ depending on their nutritional profiles. This work increases our knowledge of the link between diet, gut microbiota and host health, and how pollen availability may affect health and conservation of a key pollinator through effects on its microbiota.

## Defying trends: a range-wide assessment of variation in the northernmost Heliconius species

*Tanner Myers, Angelo Ruggieri, Marysol Trujano-Ortega, Nicolas Miranda Díaz, Camilo Salazar, Carolina Pardo Díaz, Riccardo Papa, Brian Counterman*

The formation of new species depends on extrinsic (e.g., geographic isolation) and intrinsic (e.g., genetic incompatibility) processes that result in reproductive isolation. Heliconius butterflies have emerged as a model for the study of speciation due to the radiation of mimetic wing color patterns acting as warnings to potential predators. Wing color patterns are often important for mate choice and influence reproductive isolation. Despite extensive speciation research, there remain lineages of Heliconius that are largely unexamined. One example, Heliconius charithonia, has a large distribution, but does not exhibit wing color pattern divergence. In addition, H. charithonia is the only Heliconius species with an island distribution, which spans much of the Caribbean. We hypothesize there has been species-level divergence among H. charithonia populations, despite the lack of divergence in wing coloration. Using whole genome sequences and phenotypic analyses, we explicitly test (i) the extent of variation of divergence of wing color patterns in the visual and ultraviolet spectra, (ii) the impact of island isolation on genome divergence, and (iii) competing diversification hypotheses. Initial analyses support concordant patterns of wing pattern and genome divergence in H. charithonia. The degree of population differentiation between mainland and island populations reflects species-level genomic divergence seen among other Heliconius lineages, supporting potential cryptic speciation. Further sampling and analysis will be conducted to further resolve the evolutionary history of H. charithonia diversification.

## Freshwater salinization and biomass transfer from algae to amphibians

*Maya Mylott, Alex Barron, Cole Miller, Allison Welch*

The influx of salt into freshwater habitats has become a rising concern due to increased storm surges, sea level rise, climate change, and other anthropogenic practices. Amphibians, which are ecologically important organisms due to their ability to facilitate biomass transfer, can be greatly affected by salinization of their freshwater habitats. Due to their permeable skin, elevated salinity increases the demands of osmoregulation and maintaining homeostasis. Salinity in freshwater habitats may affect not only amphibians, but also their interactions with primary producers. This study investigates the effects of freshwater salinization on the trophic relationships between amphibians (tadpoles) and their food source (algae) within experimental mesocosms of differing salinities. We predict that algal biomass will be negatively correlated with tadpole density, reflecting consumption of algae by tadpoles. In addition, we predict that algal biomass will be greater in the elevated salinity treatments due to negative effects on tadpoles and thus less biomass transferred to the next trophic level. By investigating the effects of elevated salinity on the food webs of the tadpoles, this work contributes to a better understanding of the impacts of freshwater salinization on trophic interactions and ecosystem function as a whole.

## Characterizing run-and-tumble behavior of the Ripple Bug, Rhagovelia oriander

*Nithil Nagappan, Ishant Tiwari, Jacob Harrison, Saad Bhamla*

Ripple bugs (Rhagovelia) are known for their unique ability among neustons (air-water interface dwelling animals) to move along the surface of fast-flowing streams [Santos et al., Science 358, 386-390]. Their movement along the interface is a rapid series of gliding and pivoting, which appear similar to the "run-and-tumble" motion observed in various bacteria and protists. Run and tumble motion is characterized by darts or "runs" separated by random reorientations or "tumbles." Previous studies show that this seemingly random pattern of motion has been utilized by multiple microorganisms for effectively executing chemotaxis and phototaxis. In this study, we collected Rhagovelia oriander from local streams in Georgia and recorded their body dynamics moving on a custom-designed flow mill ($n = 30$, $N = 30$). We determine whether R. oriander uses run-and-tumble motion and how its body dynamics change in response to increasing flow rates. Regardless of flow rate, R. oriander prefers turning either left or right ($\pm 90^\circ$ w.r.t. the head) rather than maintaining their direction or turning $180^\circ$. Additionally, partially obstructing water flow revealed a preference for R. oriander to be in areas of flow rather than behind obstruction. Our results yield important insights into how the environment affects the run-and-tumble motion in ripple bugs and inform how run-and-tumble motion is expressed across orders of magnitude.

## The evolution of insect metamorphosis: A study on the heterochronic role of the gene, *chinmo*

*Hana Nagata, Yuichiro Suzuki*

How holometabolous insects evolved is a highly speculated area of study among entomologists, where the origin of the larva and the pupa have been heavily debated. Various aspects of metamorphosis seem to favor different theories, but one factor that has recently been in focus is the proposed juvenile stage regulator gene, chronologically inappropriate morphogenesis (chinmo). Previous studies have suggested that in holometabolous insects, Chinmo dictates the juvenile stage since its reduction gives rise to precocious pupal characteristics in the larva. Here, we examined the function of Chinmo in the hemimetabolous milkweed bug, Oncopeltus fasciatus, to better understand the developmental differences between holometabolous and hemimetabolous insects. chinmo knockdown of these insects resulted in accelerated development and the skipping of nymphal instars, accompanied by a rise in expression of the adult stage specifier gene, Ecdysone-induced protein 93F. The obtained results suggest that, rather than being a juvenile stage specifier as previously described, chinmo may be a heterochronic regulator that controls the timing of progression to the next life stage. Our work suggests that the nymphal instars can be condensed into fewer instars and supports the idea that the hemimetabolous nymphs were compressed to give rise to a single, holometabolous pupal stage.

## Large leg spines serve as mechanosensilla in Hawaiian spiders (Tetragnatha)

*Kathryn Nagel, Carsten Müller, Gabriele Uhl, Rosemary Gillespie*

Organisms rely on a variety of sensory organs to survive and navigate complex environments. Arthropods utilize a multitude of cuticular sensilla, and spiders (Araneae) use hair- or peg-like sensilla to detect mechanical stimuli, cuticular strain, vibrations, humidity, temperature, and chemicals. Web-building spiders use silk as an enhancement and extension of their sensilla. However, cursorial spiders lack this extrasensory network, and may compensate using cuticular sensilla. Large, extended leg spines are observed across multiple spider families, and are present on both web-building and cursorial species. Using two clades of Hawaiian long-jawed orb weaver spiders (genus Tetragnatha), I compared the external and internal structure of these spines in species from web-building and cursorial clades to test my hypothesis that the leg spines function as mechanosensilla. In cursorial species, these spines are longer and higher in number. SEM images show the external structure of the leg spine follicle and shaft closely resemble the smaller mechanosensory hairs present on the legs in both clades. TEM cross sections confirm the characteristic structures of a large mechanoreceptive sensillum, including a hollow spine shaft lacking sensory cells, and the presence of two to three dendrites terminating in large tubular bodies at the base of the shaft-wall cuticle in the socket. These results suggest that leg spines function as mechanosensory sensilla, and differences in external and internal structure may indicate lifestyle-specific adaptations.

## Development and evolution of mechanosensory hair cells in Cnidaria

*Nagayasu Nakanishi*

In parallel with bilaterians, cnidarians evolved structurally and functionally diverse mechanosensory structures that range from filiform tentacles of hydroids to statocysts of jellyfishes. In these mechanoreceptors, the primary sensory neuron responsible for transducing mechanical stimuli is the concentric hair cell, which is characterized by the apical mechanosensory apparatus consisting of a single cilium surrounded by one or multiple rings of stereovilli/microvilli. However, little is known about developmental biology and evolutionary histories of this fundamental sensory cell type of Cnidaria, limiting our ability to understand how cnidarian mechanoreceptors diversified. Here, I will summarize recent and ongoing efforts to address this problem, highlighting emerging data on developmental genetics and cell type diversity of concentric hair cells in Cnidaria.

## Variation in passerine size and physiological aging across environmental gradients

*Gabrielle Names, Frédéric Angelier, Lindsey Willingham, Anuj Ghimire, Heather Mathewson, Jennifer Grindstaff, Cécile Ribout, David Westneat, Britt Heidinger*

Climate change is influencing the phenotypes of wildlife worldwide. Bergmann's rule states that smaller individuals are favored in warmer environments because they are better able to dissipate heat, while larger individuals are favored in cooler environments because they retain heat better. Bergmann's rule has been described across taxa, but the underlying physiological mechanisms and consequences remain largely unknown. To help fill this gap, we investigated relationships between body size and physiological aging across environmental gradients. We hypothesized that temperature variation has selected for differences in body size across environmental gradients, and that these body size differences influence physiological aging. We predicted that individual body size would be larger in cooler compared to warmer habitats. Due to trade-offs between growth and longevity, we also predicted that physiological aging would be greater in larger individuals and those in cooler habitats compared to smaller individuals and those in warmer habitats. To test our hypothesis, we collected morphological measurements from 1) Hawaii Amakihi juveniles and adults across an elevational gradient on Hawaii Island from 2016-2018, and 2) House Sparrow nestlings across a latitudinal gradient in the central USA (North Dakota to Texas) from 2022-2023. To measure physiological aging, we collected blood samples to quantify erythrocyte telomere length in a subset of measured juvenile Amakihi, and erythrocyte telomere length and loss in House Sparrows across the nestling period.

## Foul Play? Do bio-foulers reduce compressive strength of Ostrea lurida shells in San Diego Bay, CA?

*Taylor Naquin, EW Misty Paig-Tran, Danielle Zacherl*

Oyster reefs are complex assemblages of live oysters, interstitial space, and dead shell. Bio-fouling organisms can increase shell degradation rate and might compromise shell compressive strength. Decreases in compressive strength, an adaptation to environmental stressors, can, by proxy, estimate reef degradation rates. We measured percent cover of bio-foulers and compressive strength as max load (i.e. maximum amount of force (N) applied before shell failure) of Ostrea lurida (N = 237 live oysters) to test if more heavily fouled shells have weaker compressive strengths than less fouled shells. We sampled two seawalls in San Diego Bay, CA, USA. Grande Caribe has an east-facing seawall and is parallel to the waterline. Cesar Chavez seawall is northwest-facing, perpendicular to the waterline, and has a history of industrial pollution. Compressive strength of O. lurida shells increased with bio-fouler cover (p=0.0146), contradicting previous studies suggesting bio-foulers would weaken shells. Small shells (30 mm) or in the upper intertidal. Overall, multiple factors interacted to affect shell strength, weakening shells at Cesar Chavez relative to Grand Caribe. These data illuminate how bio-fouler effects on shell budget and carbon storage within oyster reefs in the face of climate change.

## Mechanisms and functions of collective behavior in diverse neotropical *Lepidoptera* larvae

*Avaneesh Narla, Thalia Corahua-Espinoza, Jacob Harrison, Suraj Shankar, Saad Bhamla*

In the Peruvian Amazon, we observed diverse species of Lepidoptera in immature stages exhibiting a wide range of previously undescribed collective behaviors. These behaviors include coordinated foraging, group defense, trail-marking, resting-site selection, and pupation and demonstrate high levels of synchronization among groups of a dozen up to hundreds of individuals. Our research encompassed twenty groups over ten Lepidoptera species, and employed field monitoring/observations and controlled experiments. The behaviors observed are complex and metabolically expensive as they require interaction between many individuals and significant movement. For example, a group of 320 individuals performed a ∼40-minute "milling" motion before hour-long foraging bouts involving synchronized processionary travel for ∼25 meters (∼500 body lengths). The prevalence of these behaviors across multiple taxa suggests they may confer a fitness advantage, leading to its repeated emergence in Lepidoptera. Notably, while individual behaviors such as movement patterns, feeding habits, and chronotypes are highly species-specific, group behaviors like self-organized synchronization and distributed foraging show remarkable conservation across taxa. Our observations expand our understanding of social complexity in insects and the evolution of collective behavior while potentially revealing novel strategies for pest management in ecologically and agriculturally important Lepidoptera species. Furthermore, these principles of self-organization may have broader applications in fields such as swarm robotics and collective decision-making algorithms.

## Impacts of hyposalinity and marine heatwaves on juveniles of the purple sea urchin

*Carla Narvaez Diaz, Fleur Anteau, Jason Hodin*

Sea urchins are herbivores that play critical ecological roles in many marine habitats. Understanding how environmental changes associated with climate change, such as increased rainfall leading to hyposalinity events and more frequent marine heatwaves, impact sea urchin populations is crucial for predicting ecosystem responses. Like many marine invertebrates, sea urchins have a biphasic life cycle with pelagic larval and benthic juvenile/adult stages. Although the larvae and adults of many urchin species are relatively well studied, the susceptibility of their newly-settled juveniles to environmental stressors is poorly understood, due to challenges in locating and culturing early post-settlement individuals. This study evaluated the effects of two environmental stressors - hyposalinity (30, 26, 22 ppt) and elevated temperature (11, 15, 19°C) - on newly-settled (5 days post settlement) Strongylocentrotus purpuratus juveniles using a fully crossed factorial design. We assessed growth, survival, and adhesive performance during exposure and 2 days post-exposure. Results indicated that higher water temperatures decreased adhesive performance and post-exposure survival. Responses to hyposalinity were variable, but overall 22 ppt reduced performance across metrics. This research provides critical insights into how newly settled sea urchins may respond to increasingly common environmental fluctuations driven by climate change. Understanding impacts on this key transitional life stage can help predict population-level and ecosystem effects of altered environmental conditions in coastal marine ecosystems

## The Other Blue Zone: Trait diversity and biogeography of coral reef fishes across Okinawa, Japan

*Chloe Nash, Samuel Coatham, Lauren Sallan*

Investigating community structuring can reveal how historical and current biogeographical processes impact species distribution and evolution. Okinawa-jima, the largest of the Ryukyu Islands, is ideal for this study due to its rich marine biodiversity, high endemism, and resilience. The Ryukyu Islands, or Nansei Islands, are located at Japan's southern tip and mark the northern boundary of the Coral Triangle. Spanning 1,200 km from southern Japan to Taiwan, this archipelago formed from convergent plate boundaries and was recently isolated from mainland Asia after the last glacial maximum. These islands have experienced frequent environmental and human-induced disturbances. This study examines how benthic habitat availability influences the morphological, life history, and behavioral traits of coral reef fishes in Okinawa-jima. Using 2D/3D morphometrics from market specimens, static video surveys of various reef substrates, and a comprehensive trait database, we test hypotheses about fish community associations with benthic habitats and geographic patterns of trait variation. We hypothesize that distinct fish communities will be associated with each substrate type and that more complex habitats will support communities with greater trait diversity. This research will provide insights into biodiversity patterns on the island and set the stage for future studies on fish population connectivity, dispersal, and the effects of historical disturbances on community structuring across the Ryukyu Islands.

## Sensory neuroanatomy of bluegill dorsal fins

*Jillian Nash, Amanda Torick, Anabela Maia*

The dorsal fin of bluegill sunfish (Lepomis macrochirus) is theorized to have an essential role in swimming stability. Previous research has demonstrated that interfering with the sensory input of dorsal fin negatively impacts coordinated movement and recovery. Our hypothesis is that the spiny dorsal fin in bluegill is capable of detecting flow through the presence of mechanoreceptors, likely akin to Meissner's corpuscles. Samples from spiny and soft portions of dorsal fin were collected, preserved using 4% PFA, and incubated in primary antibodies anti-acetylated tubulin, calcitonin gene related peptide and cytokeratin 20 followed by secondary antibody incubation and imaging. Fin spines show high innervation with branching throughout, nerve fibers wrapping around the spines, especially towards the tip and ending sensory structures with a round shape. More cranial spines have denser innervation and more nerve endings than the caudal spines. Meanwhile, the soft dorsal fin rays are less innervated and have a lower density of mechanosensors. Our current results suggest that afferent neurons are less densely packed leading to the base of the fin. The broader goal of this study is to understand capability of fish to sense their environment.

## The functional morphology of dermal photoreception in the skin of a color-changing fish

*Lydia Naughton, Lorian Schweikert*

Dermal photoreception, or the ability of skin tissue to sense light, is a trait commonly evidenced in animals that are capable of color change via the dispersion and aggregation of pigment granules within cells called chromatophores. It remains unclear how dermal photoreception is incorporated into the functional organization of color-changing skin, especially as it relates to the vertical arrangement of chromatophore layers. Previously, we found that a short-wavelength-light-sensitive opsin (SWS1) is localized in cells beneath pigmentary chromatophores in the skin of the hogfish (Lachnolaimus maximus), a rapidly color-changing fish. Further, we demonstrated that black and red-colored chromatophores differentially transmit light depending on whether their pigment is dispersed or aggregated. We hypothesized that the underlying opsin may detect these changes in light transmittance to monitor the state of chromatophores. To investigate this, we performed anti-SWS1 immunolabeling of skin whole mounts to visualize SWS1-positive cells relative to the chromatophore cell field. Next, we measured cell areas to test whether a significant portion of the underlying SWS1-positive cell is occluded by the dispersed versus aggregated pigment states. We then used transmission electron microscopy to identify other chromatophore types that contribute to the arrangement of cell layers affecting light detection by dermal opsins. This work provides insight into the optical mechanisms and functional significance of dermal photoreception in a fish that achieves rapid color changes.

## Evaluating historical and contemporary rates of black-spot disease in fishes in an Arkansas stream

*Thomas Naylor, Austin Bailey, Brook Fluker*

Black-spot disease is often observed in freshwater fishes and is the result of trematode larvae that encyst themselves into the skin and fins of host fishes. Little is known about the impact of these trematodes on small stream fishes, but the fish serves as an intermediate host in the trematode life cycle. The immune response from the host fish is to deposit melanin around the trematode, causing a black spot to appear resulting in the name black-spot disease. This project focuses on understanding aspects of black-spot infection for three mid-water dwelling fishes in a northeast Arkansas stream: Northern Studfish (Fundulus catenatus), Ozark Minnow (Miniellus nubilus), and Bleeding Shiner (Luxilus zonatus) over a 50-year period. Specimens of these species collected in 1975 were obtained from the Arkansas State University Museum of Zoology (ASUMZ) and modern samples were collected from the same stream sites in May 2024. Specimens were weighed, measured for standard length, and quantified for black spots to compare the relationship between body condition and prevalence of black spots among species and between time periods. Our results will provide baseline information on black-spot disease for these three species and will provide a unique opportunity to test for differences or similarities in infection rate over a 50-year period.

## Filtering is Rough: Quantifying Surface Morphology of Filtering Structures in the Megamouth Shark

*Jordyn Neal, Dylan Wainwright, EW Misty Paig-Tran*

In filter-feeding sharks, separating plankton from water requires specialized modifications to the gill rakers to prevent prey from exiting the gills, yet all three filter-feeding shark species have different raker morphologies. Here we focus on the morphology of the gill rakers and filtering structures of the megamouth shark (Megachasma pelagios). We used gel-based profilometry and microscopy to describe the three-dimensional morphology and surface features of megamouth rakers, and quanitified these surface features using metrics such as: surface roughness, skew, kurtosis, denticle density. We imaged 20 to 30 areas along the gill raker to explore variation in denticle morphology across eight sharks. In addition, we imaged the epithelial tissue from the gill arch and tongue from three individuals to compare the surface morphology with gill rakers. Denticle morphology and surface texture varied across structures (e.g., gill arch, tongue, gill rakers) and among individuals. For example, gill rakers were smoother than surfaces along the gill arch and tongue. The gill raker denticles were densely packed and highly imbricated, whereas denticles along the tongue were angled upright and were less densely packed. We predict that the denticles along the filtering structures could be used a protection against particle impaction during feeding and may help to direct flow during feeding.

## Examining biogeographic variation in a bioluminescent fish-bacteria symbiosis

*Emily Neff, Alison Gould*

The genus Siphamia is comprised of 25 cardinalfish species, which are characterized by their light organ and large geographic range spanning the Indo-Pacific. Based on previous studies, S. tubifer, appears to have high specificity for their bioluminescent symbiont, Photobacterium mandapamensis located from a small region of Japan. However, it remains unknown whether this specificity is upheld throughout other parts of their range and among other Siphamia species, and whether this relationship persists through time. To further characterize the specificity of this symbiotic association, we analyzed genetic variation in S. tubifer and its bioluminescent symbiont from two locations in Okinawa, Japan and Caubyan, Philippines. We compared the genetic variability of the symbionts of S. tubifer to that of S. fuscolineata from Verde Island, Philippines and S. mossambica from Zanzibar, Tanzania. Shotgun DNA sequencing from fish light organs recovered whole genome information for both the host and symbiont. We then characterized symbiont diversity within and between host species and found all symbionts were identified as P. mandapamensis. Additionally, all three Siphamia populations revealed that symbiotic specificity extends across host species. Overall, this reduced-complexity system can help us understand how specificity and stability of host-microbe associations are maintained over space and time, even in highly connected marine environments.

## Sexual pelvic thrusting in mammals

*Joseph Nehme-Haily, Ling Yuping, David Hu*

In many mammals, copulation is characterized by vigorous pelvic thrusting by the male. The copulatory process can be so exhausting that some mammals, like the mouse-like marsupial Antechinus, die after mating. One reason for the tiring nature of copulation is the high rate of pelvic thrusting. In this study, we analyze films of copulating mammals, from mice to elephants. We report a power law for pelvic thrusting, indicating that smaller mammals thrust up to six times per second, while other mammals such as the rhino thrust just once. We rationalize the power law in terms of the transfer of forces from the leg to the inertia of the body. Our findings may help improve breeding strategies for domestic mammals and correct undesirable behaviors such as humping in dogs.

## Thermally-dependent phagocytosis in Mojave Desert tortoise lymphocytes, heterophils, and monocytes

*Holly Nelson, William Fikan, Rylee Conklin, Jenna Morales, Mariah Painter, Franziska Sandmeier*

Climate change can have drastic effects on many species, but ectotherms, whose physiology is heavily influenced by temperature, may be particularly vulnerable. How their immune systems may thermally acclimate, is an important research question, with broad applications for their conservation. Phagocytosis is an important process in the immune functions of all animals. In phagocytosis, cells consume exogenous particles to eliminate them. The Mojave Desert tortoise (Gopherus agassizii) is an ideal organism for investigating the phagocytic function of B1 lymphocytes, in comparison to other phagocytic cells. Our goal was to quantify how different types of phagocytic cells function across a wide range of temperatures and seasons. We took blood samples across the tortoise's active seasons and incubated samples with fluorescent beads at seven different temperatures (13 - 40°C) for four hours. We hypothesized that the thermal performance of phagocytosis will vary by season, incubation temperature, and the leukocyte subpopulations. We found that lymphocyte ($p=0.0251$) and heterophil ($p=0.0148$) populations vary significantly across active seasons. We also found that lymphocyte reactivity with the fluorescent beads varies significantly across active seasons ($p<0.0001$) and across incubation temperatures ($p=0.0137$). Heterophil reactivity also varies significantly across seasons ($p<0.0001$) but not across incubation temperatures ($p=0.4531$). Monocyte reactivity varied significantly across seasons ($p=0.0014$) and across incubation temperatures ($p=0.0461$). Overall, different cell types are regulated in different ways across seasons.

## Endocrine regulation in the diploid-tetraploid gray treefrog complex

*Elizabeth Neslund, Christopher Leary*

Circulating levels of adrenal glucocorticoids (GCs) and gonadal steroids, and interactions between these hormones, are remarkably variable across vertebrates. Although the environmental and ecological correlates of this diversity are well studied, the potential genetic underpinnings giving rise to this diversity remain poorly understood. We are studying endocrine regulation in polyploids to understand how associated changes in gene copy number (i.e., gene dosage) may contribute to this diversity. Polyploidization is expected to promote modifications in endocrine regulation because increased gene dosage can introduce novel gene expression patterns and/or increase rates of mutation that alter the expression of gene products (i.e., receptors and binding proteins) governing the hormonal phenotype. Examination of endocrine regulation in extant polyploids may provide insight into diverse hormonal phenotypes given that comparative genomics data suggest that polyploidization is a historical feature of vertebrate evolution and a major source of variation in gene copy number in extant diploid species. Our work examines regulation of GCs and gonadal steroids in natural tetraploid gray treefrog lineages and their diploid ancestor to understand how polyploidization impacts endocrine control. We will present results describing how circulating hormone levels and crosstalk between the hypothalamic-pituitary-adrenal/interrenal (HPA/I) and -gonadal (HPG) axes are modified in polyploids and the approaches we are currently taking to understand how polyploidization impacts the various endocrine elements governing the hormonal phenotype.

## Developmental polyphenism shapes juvenile behaviors and glucocorticoid regulation in spadefoot toads

*Dante Nesta, Kate Millar, Daniel Woods, Lia Castro-Sauer, Cris Ledón-Rettig*

Early life environments experienced during development often have lasting effects on later life phenotypes. Such "carryover effects" are expected to emerge in systems that display marked developmental plasticity, where environmental variability can induce discrete, alternative phenotypes (i.e., polyphenism). However, few studies have empirically tested carryover effects that arise from developmental polyphenism, and none have evaluated how developmental polyphenism impacts later life behaviors, hormonal regulation, and their interplay. We fill this empirical gap with our study using tadpoles of the genus Spea. These tadpoles display a resource polyphenism during early development, resulting in the production of two ecomorphs: smaller detritus-consuming omnivores and larger predatory carnivores. Here, we use field-collected omnivore and carnivore Spea multiplicata tadpoles from replicate ponds across two populations and reared individuals under common conditions through metamorphosis to determine whether polyphenism affects later life phenotypes. We find that tadpole morph influences juvenile body condition, locomotor and prey-capture behavior, and physiology associated with the hypothalamic-pituitary-adrenal/interrenal axis, and that these effects vary by sex. Taken together, our results suggest that the expression of the carnivore tadpole has pleiotropic effects on later life, terrestrial juveniles, consistent with populations where carnivore induction is infrequent, and selection has fewer opportunities to decouple early and later life traits. More generally, by measuring fitness-related phenotypes throughout an organism's life, our results contribute to a more comprehensive understanding of how selection maintains developmental polyphenism.

## Engaging communities in genomic research through diverse outreach programs

*Kevin Neumann, Claudia Lutz, Dan Urban*

Disseminating scientific research to broad audiences can be challenging, particularly with complex fields like genomic biology. Graduate programs and academic departments typically prioritize engagement with academic communities, and students and faculty may not know how or where to communicate their research to more general audiences. Here, I discuss outreach efforts I have pursued in collaboration with the Institute for Genomic Biology (IGB) at the University of Illinois. At the IGB, we have a large team working on various outreach events and programs that are curated around the interests and concerns of specific audiences. The "Genomics For…" workshop series aims to help various professionals, including judges/lawyers, teachers, or faith leaders, incorporate genomic biology into their work. At "Game Day Genomics", volunteers brings science-inspired activities to tailgates prior to Illinois football games. The STEAM Train program provides middle school students with mentorship on a science project from both high schoolers and college students. Finally, Genome Day is a massive community-wide event held at the main library where students and faculty at the university share their research through various activities and discussions. Programs like these provide a strong model for how to design effective outreach programs that take into account the unique interests and concerns of different community members.

## Changes in muscle physiology over the course of spinal cord regeneration in the larval sea lamprey

*Caraline New, Sonia Ali, Kylee Meece, Hilary Katz*

The larval sea lamprey, Petromyzon marinus, is a well-established model for successful spinal cord regeneration due to its unique ability to recover after a complete spinal transection. Immediately following a transection, the animal is paralyzed below the injury site, and over the course of 11 to 12 weeks, it exhibits substantial swimming recovery. Spinal injuries in non-regenerative species, such as mammals, produce many acute and chronic medical issues including progressive muscle atrophy. To our knowledge, it is unknown whether the lamprey exhibits muscle atrophy during their initial recovery period, and whether such muscle atrophy could reverse as animals regain their swimming ability. We sought to examine muscle physiology in the larval lamprey after a period of disuse (3 weeks post-injury), and after progressive swimming recovery (11 weeks post-injury). We developed a procedure to analyze lamprey muscle structure with transmission electron microscopy pre- and post-injury. Briefly, muscle tissue was collected from uninjured control, 3 weeks post-injury, and 11 weeks post-injury individuals. The tissue was then fixed, infiltrated in resin, thin-sectioned with an ultramicrotome, and imaged with a Transmission Electron Microscope (JEM-

1400Plus). Preliminary observations of 11 weeks post-injury animals revealed shrunken sarcomeres with abnormal z-discs. In contrast, the muscle above the injury site maintains its integrity. These results suggest that lampreys experience muscle atrophy in response to traumatic nerve injury despite their regenerative capabilities.

## Regeneration in *Berghia stephanieae*: cell proliferation and the necessity of the nervous system

*James Newcomb, Lourdes Ricks, William Scala, Haleigh Bilodeau, Dominic-Naomi Thoroughgood, Emily Wightman, Becca Pouliot, Rebecca Soulia, Abigail Chapin*

Gastropods exhibit regeneration and their accessible neurons provide an opportunity to investigate the regrowth and necessity of the nervous system in this process. The regenerative capacity of the nudibranch Berghia stephanieae was assessed by removing portions of the body and monitoring regrowth. Berghia regenerated cerata, oral tentacles, and rhinophores within three weeks of amputation. However, coronal bisections of the body at various locations did not result in whole-body regeneration of any segments. Regeneration can involve cell proliferation and/or remodeling of tissue, so antibodies to phosphorylated histone-3 (H3P) were used to investigate the extent of cell division during regeneration of rhinophores. The number of H3P-positive cells in regenerating tissue started to increase by day 3 and was significantly higher by day 7. Antibodies to serotonin were also used to monitor regeneration of the peripheral nervous system. Three weeks after lesion, regenerated rhinophores contained serotonergic fibers similar to controls. Last, the necessity of the nervous system in early stages of regeneration was investigated by anesthetizing Berghia before and after lesion of a rhinophore, and then using H3P immunohistochemistry. The density of H3P-positive cells was significantly reduced in regenerating tissues 4 and 48 hr after lesion, compared to unanesthetized controls. This is similar to preliminary studies by others in axolotls and planaria, suggesting that the nervous system may have an ancestral role in early stages of regeneration.

## Effect of toe spacing on dynamic interactions with granular media using responsive DEM simulations

*Nathaniel Newcomer, S. Tonia Hsieh, Sonia Roberts*

The effect of complex foot morphologies on locomotion performance in granular media is not well understood. We identify two areas in which we can improve our understanding: First, models of granular media physics do not account for complex foot morphologies, considering only surface area. Previous work has shown that a single rectangular intruder and two parallel intruders with the same surface area produce different force responses from the ground, with the greatest force responses coming from two parallel intruders spaced 3-5 particle diameters apart – similar to the spacing between the toes of sand specialist lizards. Second, simulations of intrusions into granular media have previously been limited to known trajectories, typically either simple forced intrusions or trajectories measured experimentally from a behaving animal using complex and expensive setups. We developed a responsive discrete element model simulation of a leg modeled as a spring hopping on granular media using LIGGGHTS and Python. The simulated leg can respond to changes in the forces from the ground and the ground can respond directly to the forces exerted by the leg. We report on simulated jumping experiments using a simple compression-extension controller and feet with the same surface area but different numbers of radially symmetric toes.

## Tryptophan hydroxylase gene expression in the brain of a nudibranch mollusc

*Wonser Newman, Kate Otter, Paul Katz*

Serotonin, often referred to as the “feel-good” chemical, plays a crucial role in regulating a wide range of behaviors in many animals. In nudibranchs, it is known to modulate feeding behaviors and other behaviors such as locomotion and learning. Tryptophan hydroxylase (TPH) is the rate-limiting enzyme for the production of serotonin. We investigated the effect of food deprivation on the expression of the gene that codes for TPH in the nudibranch mollusc, Berghia stephanieae. To study this, we used in-situ hybridization chain reaction (HCR) to fluorescently label TPH mRNA in the brain, which was then imaged using a laser-scanning confocal fluorescence microscope. Images from sated animals showed TPH expression in specific neurons in the cerebral and pleural ganglia and clusters of neurons in the pedal ganglia. We then compared the results from sated animals with animals that had been food-deprived for 14-days. Expression of TPH appears to be consistent in individually-identifiable neurons across food-deprivation lengths, but the number of neurons in clusters varied. This variation does not appear to be correlated with hunger state. To further this investigation we identified genes for serotonin receptors. Ongoing work is characterizing the localization of serotonin receptors in the brain.

## Assessing the tastant sensitivity of extraoral taste buds in blind Mexican cavefish

*Danielle Newsome, Bryce Lewis, Joshua B Gross*

Enhanced gustation in cave animals is a constructive evolutionary feature likely aiding detection of sparse nutrition in caves. The Mexican tetra includes both cave- and surface-dwelling morphs with notable differences in anatomy, behavior, and taste perception. Taste sensitivity variation likely evolves between cavefish populations due to unique nutritional profiles of each cave. The behavioral attributes of taste signaling are attraction or repulsion. To assess taste in cavefish, we sought to evaluate behavior in response to putative tastants. We present an approach integrating components of previously-published behavioral studies: a circular tank design, and a classical delivery of putative tastants. To score behavior, we illuminated individuals from below with a flexible LED light sheet and tracked behavior using an automated open-source software, AnimalTA. This software allowed us to examine variables such as swimming speed and time spent within tank zones. Additionally, we manually scored turns away from a putative repulsive tastant. Pilot studies showed consistent behavior among cavefish individuals in response to no-tastant delivery controls. Interestingly, delivery of a putatively repulsive sour tastant (acetic acid) resulted in inconsistent behavioral changes, suggesting cavefish populations harbor differences in taste tuning. Broadly, this approach provides a new window to examining how taste evolution evolves in animals living in low-nutrition environments. Specifically, this work will inform how nutritional availability diversity mediates variation in behavioral responses to diverse natural tastants in caves.

## Effects of heat stress on biological markers and histological alterations in tissues of goldfish

*Ngozichukwu Ngozichukwu, MD Rahman*

Global warming is a major menace to ecological systems, and the adverse effects of heat stress present a substantial challenge to the health and survival of aquatic creatures. This work aimed to investigate the impact of heat stress at medium (28°C) and high (32°C) temperatures on several biological markers including condition factor, absolute growth rate, instantaneous growth rate, and body value gain of the length and weight of goldfish. Histopathological analysis revealed significant morphological changes in the kidney tissues, particularly in fish exposed to high-temperature conditions. The kidney tissues showed evidence of glomerular atrophy, with fish in the high-temperature aquarium exhibiting more pronounced tissue damage. Additionally, analysis of the integrated density of melanin granules indicated a slight reduction in fish exposed to medium and high temperatures, suggesting that heat stress may lead to decreased melanin production. Our findings indicate that high temperatures significantly disrupt the primary osmoregulatory systems and affect melanin dynamics, potentially resulting in compromised physiological functions in goldfish.

## Ecological correlates, genetics, and maintenance of a female-limited polymorphism in slender anoles

*John Nguyen, Karla Alujevic, Leah Bakewell, John David Curlis, Catherine Grey, Elizabeth Hoffman, Yanileth Lopez, Kelly Wuthrich, Christian Cox, Michael Logan, Claire Williams, W. Owen McMillan*

Coloration and patterning can play a critical role in organismal fitness, especially when color patterns are present in discrete morphs (i.e., polymorphism). In many Anolis species, dorsal pattern polymorphisms are sex-limited, with females typically being more polymorphic than males. However, the drivers of female-limited pattern polymorphisms are still unclear, with several studies suggesting that microhabitat use, differential predation rates, or mate avoidance may play roles in this phenomenon. The slender anole (Anolis apletophallus) is distributed across an ecological gradient in central Panama and exhibits a female-limited polymorphism in dorsal patterning making it a tractable system to link ecological variation and natural selection to molecular evolution. In this study, we explored how variation in female color patterning is maintained in populations of the slender anole. Leveraging genetic, morphological, physiological, behavioral, and environmental data collected over seven years, we 1) characterized phenotypic variation in female slender anoles, 2) determined if female color pattern morph frequencies are associated with either broader geographic or finer-scale microhabitat variation, 3) identified the underlying genetic architecture of female color pattern polymorphism, and 4) investigated the evolutionary forces maintaining this polymorphism. This study contributes to our mechanistic understanding of the processes generating and maintaining female-limited pattern polymorphisms in the wild.

## Shadows of radiations past: Scanning pharyngeal jaw diversity in Neotropical Cichlids

*Benjamin Nicholas, Hernan López Fernández*

Understanding how continental radiations have diversified is difficult as they are products of extinction, biogeographic rearrangements, and changing environments over millions of years. Much of our knowledge of adaptive radiations stems from relatively recent insular-like systems, however increasing evidence suggests that adaptive radiations have a major role in hyper diverse continental assemblages like Neotropical cichlids. This primarily riverine group has undergone adaptive diversification into many ecologically, morphologically, and behaviorally complex lineages. Surprisingly, the macroevolutionary patterns of the entire pharyngeal jaw in Neotropical cichlids is relatively understudied. We use μCT scans to describe the morphological diversity of the upper and lower pharyngeal jaw, fit models of evolutionary divergence, and measure morphological disparity through time and among clades. Until now, studies of various axes of diversification in Cichlinae found a congruent signals an early bursts of divergence in multiple trait dimensions, however we find no evidence of an early burst in the pharyngeal jaws. Additionally, we find morphological disparity of early diverging and highly specialized tribes (Cichlini, Retroculini, Chaetobranchini, and Astronotini) an order a magnitude more disparate than the species rich tribes (Geophagini, Heroini, and Cichlasomatini) suggesting that highly specialized pharyngeal morphologies became established early in continental radiation and have remained relatively unchanged. Our results further highlight the necessity to study adaptively radiating lineages in multiple trait dimensions as some axes of diversification may be overlooked.

## Froude number determines mechanical coupling of synchronizing podia in the sea star gait transition

*Brady Nichols, Olaf Ellers, Dale Syphers, Mary Lou Zeeman, Amy Johnson*

Sea stars transition from an uncoordinated crawling gait to a coordinated bouncing gait as they accelerate. It is unknown whether this transition is driven behaviorally, or if it is a natural consequence of the body weight mechanically coupling the podia as they move faster. It is physically impossible for humans to walk faster than a given Froude number (Fr)–the ratio of kinetic to gravitational potential energy–hence the transition to running happens regardless of behavior and is mechanically driven. Consequently, the walk-run transition occurs at a consistent dynamic Froude number of ~1, where the kinetic and gravitational potential energies are close in magnitude. In contrast, the sea star crawl-bounce gait transition is more complicated to characterize because it occurs around Fr = 10^-4, where kinetic energy is much lower than gravitational potential energy, and because it is difficult to identify a unique transition point between the gaits. Here we model sea star podia as a system of pendulums coupled through the motion of a common base and show that Froude number is directly related to podial coupling strength. Whether this relationship between Froude number and the podia coupling constant implies that variation in sea star transitional Froude numbers will be greater than for terrestrial gait transitions is unknown.

## What does it mean to think of the organism as a system?

*Daniel Nicholson*

Despite the spectacular successes of traditional reductionistic approaches in biology, there is a growing recognition across various biological subdisciplines that organisms need to be treated as integrated systems if we are to fully come to terms with their most distinctive features. Nevertheless, it is often unclear how exactly systems thinking might enrich our understanding of organisms (beyond providing such platitudinous statements as 'the whole is greater than the sum of its parts'), and even less so how such thinking could be put to work in actual experimental contexts. In this paper, I draw on the neglected philosophical ideas of the embryologist and theoretical biologist Paul Alfred Weiss (1898-1989) to outline what a systems-oriented conception of the organism might look like, and what it can potentially do for us.

[To be presented as part of the symposium on 'Organismal Systems Biology']

## Independence and constraint: how functional and genetic integration define a polyphenism

*Rose Nicholson, Nicholas Levis, Erik Ragsdale*

Often, phenotypic plasticity requires the coordinated response of multiple component traits, including morphology and behavior. The integration, and hence functionality, of this response may be influenced by whether and how these component traits share a genetic basis. Developmental polyphenism, or discrete developmental plasticity, offers a simple readout for determining whether and to what degree individual components of a plastic response can be decoupled. Using the sharktooth nematode Pristionchus pacificus, which has a resource polyphenism characterized by a microbivorous and a predatory morph, we tested the integration of morphology, behavior, and genetics using both mutant lines and natural variants. From our analysis of mutant lines, we found that morphology predicts both predatory activity and ability, different axes of morphological variation are associated with different aspects of predatory behavior, and rearing environment can decouple predatory morphology from behavior. Using recombinant inbred lines made from parental wild isolates that are divergent in their morph frequencies in the same environment, we determined the genetic architecture of morph bias, fine-scale morphological variation, and predatory behavior. We found that, despite their functional integration, these traits differ in their genetic architectures and thus their potential responses to evolutionary forces. In general, our results link laboratory manipulations with natural evolutionary divergence to describe both the integration and evolutionary independence of the developmental and genetic bases of plasticity.

## An investigation into passive rate of heating and cooling in *Polistes dominula*

*Edgar Nickols*

Bees are some of the most well-known pollinators in the world, they are also the most efficient pollinators in the world. The bulk of research involving heat tolerance and the effects of climate change have gone towards bees, as it should. However, with the field expanding to include areas such as critical thermal max, it is important that we include other pollinators into the overall picture we are starting to uncover. Through first-hand observations, the presence of Vespa orientalis and Megascolia maculata was noticeably lower than in years prior. This observation coupled with the heat wave that was present during our time on Lesvos brought into question how the other pollinators were dealing with the heat. Due to time constraints and some technical difficulties, I focused my efforts on observing the rate of heating on a common and plentiful species Polistes dominula, the European Paper Wasp. The overall results showed that there was no impact on passive thermal loss or gain in relation to body size. My hope with starting to look at other pollinators abilities to live with heat is that the research will expand into other areas. Climate change causing rising temperatures will most likely cause changes in behaviors that will affect others beyond bees. Ultimately, these changing interactions can be another form of disruption to bees that must be taken into account.

## Titin is an active suspension in muscle that harvests energy from environmental interactions

*Kiisa Nishikawa, Jenna Monroy, Siwoo Jeong, Richard Casler, Natalie Holt, Apolo Ibanez Rincon, Katelyn Manross, Madhusudhan Venkadesan*

Recent studies have suggested that the giant titin protein is a tunable viscoelastic element in skeletal muscle whose stiffness and damping depend on strain and activation. To test this hypothesis, we conducted a series of ramp stretch experiments in passive and active muscles along the length-tension curve. The experiments were conducted in muscles from three mouse genotypes (wild-type, mdm, and TtnD112-158; n = 7-9 muscles per genotype) and bullfrog muscles that express different titin isoforms (sartorius and semitendinosus; n = 6-7 muscles each). We found that a viscoelastic model with two Kelvin-Voigt elements in series best fit the step response data. The model yields length- and activation-dependent stiffnesses, damping constants, and time constants. The viscoelastic parameters varied with length and activation by over 100-1000 fold in passive muscles from all genotypes. In contrast, parameters varied over a range of only 2-3 fold in active muscles. The change in parameters with activation suggests that an adjustable clutch-like behavior may reduce muscle equilibrium length on activation. The model resembles the active suspensions of automobiles that harvest energy by using vibrations from the environment to charge a battery. In muscles, the Kelvin-Voigt elements appear to represent PEVK titin, with slow (0.04 – 2.5 s) and fast (1-15 ms) elements storing elastic energy that can be recovered as kinetic energy during interactions with the environment. Supported by NSF DBI-2319710.

## Comparative Performance of Different Survey Methods for Monitoring Tropical Fish Assemblages

*Lotanna Nneji, Segun Oladipo, Kehinde Adelakun*

The decline in fish biodiversity has been widely reported worldwide, drawing greater attention to the need for improved, rapid and reliable tools for assessing and monitoring fish diversity and community assembly patterns. Nevertheless, the commonly used conventional survey methods, such as using fish gears, electroshocking, etc., could cause significant damage to fish communities and have become increasingly unsuitable for frequent and large-scale fish diversity surveys. In this study, we conducted environmental DNA (eDNA) metabarcoding to investigate the distribution, diversity and assemblage of fish communities along the longitudinal (upstream-downstream) gradient of the Jebba dam, a tropical dam in Northcentral Nigeria and compared it with the previous results of our traditional fish surveys. Our results showed that eDNA metabarcoding has a higher detection rate than traditional survey methods. In addition, our result showed that both fish population parameters, including species abundance and eDNA Operational Taxonomic Unit

(OTU) richness, showed significant differences in local fish community composition across longitudinal gradients. Our eDNA metabarcoding results reveal differences in the fish assemblages and compositions between upstream and downstream zones. Overall, our results demonstrated that eDNA metabarcoding can be used as a highly effective tool for revealing fish composition and diversity in tropical ecosystems, which is important for fish resource monitoring in tropical ecosystems.

## Fitness consequences of natural incubation environments: A test of the EMH

*Mike Norris, Sydney Wayne, John Rodgers, Anthony Gilbert, Daniel Warner*

Environmental heterogeneity can be challenging for many organisms. Embryos of oviparous species, which are subject to the stochasticity of the environment and unable to behavioral change environments, may be especially vulnerable. Adaptive developmental plasticity is one-way embryos can cope with environmental heterogeneity. The environmental matching hypothesis (EMH) predicts that organisms will develop phenotypes suited to their environment when the developmental environment matches the post-developmental environment. We collected eggs (n = 2,296) from a wild-caught colony of brown anoles (Anolis sagrei) and subjected them to incubation profiles that mimicked the shaded and open environments in the field. Hatchlings (n = 1,535) were released on one of two islands that corresponded with the incubation conditions in the lab: an open island that has very little structure and or shaded island that was mostly covered with trees. Our reciprocal transplant design ensured that the developmental environment matched or mismatched the post-hatching environment on the island. We recaptured hatchlings over a 5-month period to access growth and survival. Preliminary results show that hatchlings from the open incubation treatment have increased survival on the open island compared to those from the shaded incubation environment regardless of post developmental environment. These results provide evidence that the fitness consequences of the developmental environment may depend on the post-hatching environment.

## Echinoder-bot-a: A sea urchin-inspired camera

*Julia Notar, Hazel Havens*

Several species of sea urchin have been shown to have low-resolution spatial vision, but the optics of how this system functions remain contested. One hypothesis proposes that sea urchin image resolution is mediated by the spines. Sea urchin skin is broadly photosensitive and therefore spines sticking out from the body could be shading off-axis light from hitting a patch of skin, essentially functioning as an incomplete screening mechanism over a photoreceptive surface that is otherwise non-directional. To test whether this spine-mediated mechanism is physically plausible and can provide enough screening for image formation, we built a low-resolution camera based on the morphology of sea urchins. The light detector of the camera is comprised of an unshielded array of photocells that change resistance with fluctuations in illumination. To test the image-forming abilities of the photocell array, we showed it simple high-contrast images at a standardized distance, both with and without varying numbers of spines. Readouts from each photocell were normalized and displayed for comparison to the original image, and different spine configurations were assessed for their contributions to contrast enhancement. Results indicate that as spines are added to the array, image resolution improves.

## Investigating the leptinergic regulation of weakly electric fish communication signals

*Mehrnoush Nourbakhsh-Rey, Michael Markham*

Weakly electric fish (WEF) rely on weak electric fields called electric organ discharges (EODs) produced by electrogenic cells (electrocytes) in their tail to sense their environments. EOD production in weakly electric fish electrocytes incur significant metabolic costs. Efficient energy management for these signals is crucial for fish survival and reproductive fitness, particularly in the face of anthropogenic disruptions to aquatic habitats affecting food availability. During food scarcity, Eigenmannia virescens species respond to dietary energy shortfalls by reducing EOD amplitude (EODa) to conserve energy, but at the cost of degrading sensory and communication performance.

This study used a multifaceted approach that integrated molecular, pharmacological, and computational techniques, to elucidate the cellular and molecular mechanisms associated with leptin-induced regulation of WEF communication signals, then compared the peripheral effects of leptin between two species of WEF with different responses to energy shortfalls: E. virescens and Brachyhypopomus gauderio.

The findings revealed that leptin directly regulates EODa of E. virescens by changing the magnitude of the voltage-gated sodium current and the synaptic current during food deprivation. Furthermore, the leptinergic regulation of EOD characteristics varies between E. virescens and B. gauderio, two species with distinct life histories and reproductive strategies, and may involve distinct pathways.

Overall, this work provided crucial insights into how leptin regulates communication signals and energy-information tradeoffs in WEF, offering valuable implications for neurobehavioral studies.

## Unveiling mutable collagenous tissue modulators in the brittle star Ophiomastix wendtii

*Reyhaneh Nouri, Vladimir Mashanov, Denis Jacob Machado*

Echinoderms are capable of nervous and reversible control of the pliability of connective tissue components (i.e., tendons and ligaments) that are composed of mutable collagenous tissue (MCT). The variable tensility of the MCT allows echinoderms to perform unique functions, including posture maintenance, reducing the use of muscular energy, autotomy to avoid predators, and asexual reproduction through fission. Changes in the tensile strength of MCT structures are controlled by specialized neurosecretory cells called juxtaligamental cells (JLCs). These cells release substances that either soften or stiffen the MCT. So far, only a few of these substances have been purified and characterized, and the genetic underpinnings of MCT biology remain unknown. Therefore, we have conducted this research to identify MCT-related genes in echinoderms as a first step towards a better understanding of the MCT molecular control mechanisms. Our ultimate goal is to unlock new biomaterial applications based on this knowledge. In this project, we use transmission electron microscopy (TEM) to identify tissues with different concentrations of JLCs and conduct RNA-seq to annotate differentially expressed genes potentially associated with MCT modulation in the brittle star Ophiomastix wendtii (Müller & Troschel, 1842) (Ophiuroidea: Ophiacanthida: Ophiocomidae). As a result, we present a list of putative MCT modulator genes, which will be validated and characterized in forthcoming functional analyses.

## Dietary impacts on larval sand dollar performance under marine heatwave conditions

*Ruby Novogrodsky, Kit Yu Karen Chan*

Marine heatwaves (MHWs) pose a growing ecological threat, yet few experimental studies to date have interrogated how they disrupt ecological processes. Here, we investigated if MHWs disrupt trophic transfer using the planktotrophic larvae of the Pacific sand dollar Dendraster excentricus and three species of their algal prey (Rhodomonas lens, Chaetoceros mulleri, and Nannochloropsis sp.) as a study system. With a factorial design, we manipulated algal and larval rearing temperature and tested if larval performance was influenced by the consumer's experience alone or if the prey's experience posed an interactive effect. Indeed, we observed significantly lower larval survivorship when both larvae and algae were subjected to MHW conditions. We explored the underlying mechanisms by quantifying algal responses to the simulated MHW. The MHW did not affect algal per-cell lipid content, but we observed a significant difference in algal growth rate. Cell density of the diatom C. mulleri nearly quadrupled over 4 days, while the cryptomonad R. lens only doubled (a larger discrepancy than in the control). The diatoms likely outcompeted the other algae during the MHW but were then not accessible to the larvae, as these non-motile cells sink at a measured speed of 0.4 m day-1. Thus, during a MHW, larval echinoids likely suffer not only from physiological stress, but also from reduction in food supply due to interspecific competition among primary producers.

## Are song sequencing rules learned by song sparrows?

*Steve Nowicki, Susan Peters, Jill Soha, William Searcy*

The learning of song structure is well studied in songbirds, but little attention has been paid to the learning of syntax at the level of song sequences. We investigated song syntax learning in two groups of lab-reared song sparrows (Melospiza melodia): an isolate group raised with no exposure to external models, and a trained group exposed to recorded song sequences exhibiting syntactic rules that differed from those normally observed in the field. Regardless of early experience, males in both groups followed four syntactic rules previously described for wild song sparrows: 1) they sang their repertoires with eventual variety; 2) they cycled through their repertoires in close to the minimum number of bouts; 3) they consistently sang certain song types more than others, and 4) they did not prefer certain song type transitions. One aspect of syntax that was affected by experience in both groups was the rule that long bouts of a song type are followed by long intervals before that type is repeated. Isolate males showed no bout length/recurrence interval correlations while trained males showed reduced correlations relative to field-recorded males. It remains unclear why most syntactical rules followed by song sparrows are not learned while others may be.

## Mean mares? Habitat features influence female aggression in the feral horse (*Equus caballus*)

*Cassandra Nunez, James Adelman*

It is unclear how habitat features alter animal response to social instability. Only by uncovering such interactions can we fully understand the evolutionary drivers and fitness consequences of sociality across species. We capitalize on a management-induced manipulation of social stability in an island population of free-ranging feral horses (Equus caballus), living across three distinct habitat types. We tested whether female group changing behaviour (a reliable measure of social instability) affected 1) their female-female aggression, 2) their rank within female dominance hierarchies, 3) the stability of female hierarchies (in the groups they joined and/or left), and 4) how habitat characteristics shape these responses. Females changing groups more often received more aggression from other females, but only when habitat features such as visibility and freshwater distribution were considered. We found no association among female group changing behaviour and the aggression initiated, female rank, or the stability of female dominance hierarchies. Our work reveals that animal responses to social instability are nuanced and impacted by the surrounding habitat. A better understanding of these impacts can elucidate the evolutionary drivers of sociality and may prove useful in mitigating unintended effects of our management practices.

## Exploration of brain neurosecretory centers in the annelid Capitella teleta

*Matt O'Connell-Vale, Neva Meyer*

Many animals have specialized neurosecretory neurons that release neurotransmitters as hormones and communicate between nervous and endocrine systems. In some animals with central nervous systems, a collection of neurosecretory cells forms a discrete brain center. The vertebrate hypothalamus is a well-studied example of one of these centers. However, data for brain neurosecretion are lacking for many invertebrate groups, including Spiralia. Existing data from single-cell RNAseq in the annelid Capitella teleta revealed an undescribed population of cells that expressed homologs of genes involved in neurosecretion in other animals. For this project, we began characterizing these putative neurosecretory cells in C. teleta. We examined spatial expression patterns for several genes identified in the neurosecretory cluster from the RNAseq data along with homologs of a gene expressed in the apical organs of other animals, another head neurosecretory center in many marine invertebrate larvae. Expression patterns for all candidate neurosecretory genes revealed a population of cells associated with the brain in C. teleta that is not seen with more general neural gene markers. These cells may represent a brain neurosecretory center in this species. We are currently utilizing CRISPR-Cas9 gene editing technology followed by behavioral assays for larval settlement to determine a possible function for a brain neurosecretory center. Further research is needed to finalize CRISPR-Cas9 results as well as a procedure and data for the behavioral assay.

## Do electrical deterrents attract sharks? Assessing the risks of an emerging animal management tool

*Casey O'Connor, Laura Ryan*

Two of the greatest threats to global shark populations are incidental commercial fishing bycatch and lethal mitigation strategies designed to prevent shark-human conflicts, such as culls and baited drumlines. Electrical deterrents, devices that emit strong pulsed fields designed to overstimulate shark electrosensory organs, offer a potential solution. However, widespread adoption is being hindered by critical issues, including the popular belief that such pulses, when distant from the source and therefore relatively weaker, may mimic prey biopotentials. Although the deterrent efficiency of various pulse waveforms has been evaluated, potential attraction effects have yet to be assessed. This study exposed captive white-tip reef sharks to an array of low-voltage pulses resembling the weakened gradient strength of deterrent-emitted fields. Pulses included those emitted by commercially available devices. We quantified various behavioral metrics that may indicate heightened foraging, curiosity, or aggression. Video analysis showed that a constant DC pulse was the only one to trigger any significant behavioral change, most notably in the form of an increased frequency of rapid shifts in swimming direction. None of the other pulses, however, had any effect. While promising, further experiments are essential to determine the specific characteristics of electrical stimuli (e.g., frequency and peak magnitude) that differentiate between those that alter behavior and those that do not.

## Mice in motion: swimming and climbing kinematics of salt marsh harvest mice compared to house mice

*Sharon O'Connor, Dulce Robles Martinez, Arianna Ramirez, Diego Sustaita*

In the San Francisco Estuary, the salt marsh harvest mouse's home range is limited to marshes during both dry and wet periods. Inhabiting a tidal environment has forced this mouse to rely on climbing and swimming for survival. Here we compare the kinematics of swimming and climbing to determine the extent of their stereotypy vs. behavioral flexibility for navigating terrestrial and aquatic environments, and whether this limits the salt marsh harvest mouse's adaptability for other forms of locomotion. Compared to the house mouse–a coexisting generalist species–we expected to find greater behavioral flexibility in the salt marsh harvest mouse since it is an endemic wetland specialist that has likely experienced selection for a more diversified locomotor repertoire. To test this, we used high-speed video footage to calculate velocity, stride/stroke frequency, stride/stroke length, and stance/stroke power phase durations for the same individuals performing terrestrial and aquatic locomotion. Preliminary results show the salt marsh harvest mouse has a higher swimming velocity with a lower power phase duration, compared to a relatively lower terrestrial velocity with a higher stance phase duration. The aquatic stroke and terrestrial stride variables were not correlated, suggesting that swimming and climbing kinematics are independent. Our goal is to understand the ability of the salt marsh harvest mouse to persist in its changing wetland environment through its locomotor adaptability.

## Opportunities and challenges to incorporate ecoimmunology strategies into conservation action

*Teague O'Mara, Tina Cheng, Luz de Wit, Winifred Frick*

Ecoimmunology presents enormous opportunity to understand how individuals respond to threats in their environment. Immune perspectives on ecological concepts—including the costs and benefits of social environments, the multifaceted effects of habitat degradation, and the risks of pathogen exposure—have been fundamental to understand ecological and environmental responses. However, placing conservation threats in an immunological context is also crucial to understand how individuals and populations respond to pathogens and environmental stressors. As yet, there have been limited approaches that leverage strategies derived from ecoimmunology directly into a theory of change to achieve conservation outcomes. We discuss examples of high-priority research that integrate ecoimmunology and conservation, and how this has been applied to challenges in bat conservation. These include the invasive fungal pathogen White-nose Syndrome (WNS) in North America, where resistance by bat immune systems may exacerbate the effects of WNS and that immune-derived treatments may have some tractability in managing the disease. Additionally, zoonotic spillover compounds conservation risk and vice-versa, and the interaction of those factors highlights the importance of reducing allostatic overload and immunopathology to minimize zoonotic spillover through ecological countermeasures to prevent pandemics. The potential success of integrating ecoimmunology strategies for managing for positive conservation outcomes is a fruitful area of synergy, but requires extensive collaboration to scale from research to evidence-based conservation action.

## Antennal posture in spiny lobsters during orientation

*Elizabeth O'Melia, Hazel Havens, Kenneth Lohmann*

The Caribbean spiny lobster, Panulirus argus, is a migratory crustacean that inhabits shallow coastal waters of the southeastern United States, Bermuda and the Caribbean Sea. In autumn, spiny lobsters in many locations undergo mass migrations in which numerous lobsters move together from shallow locations to deeper, more temperature-stable offshore waters. Little is known about how lobsters guide themselves to their migratory destinations, but a combination of sensory cues, including visual, olfactory, and magnetic stimuli, are likely to be involved. The antennae may be involved in some of these senses, and thus, it is possible that the antennae play a role in lobster orientation. Here, we investigated differences in antennal posture during directed and undirected movement. We used video of a previous orientation assay to capture screenshots during bouts of directed and undirected movement. The angle from the body to the antenna was measured in each screenshot using ImageJ to determine antennal posture. Here, we assess whether antennal posture correlates with orientation behavioral state and explore possible roles of antennal posture during movement.

## Are you my mother? Imprinting across bird species from an eco-evolutionary perspective

*Kelly O'Neil, Marcus Lashley, Mark Turner, Alex Potash, Zachary Steele*

During imprinting, young birds learn to recognize and respond to a sensory pattern, or a set of visual, auditory, and/or olfactory cues, to which they are exposed during a critical point often early in their development. This process may determine their social affiliations, which can have cascading effects on individual behaviors often vital to fitness. In some species, imprinting may play a role in self-perception, kin recognition, species recognition, and/or migration and song-learning; in others, it is a necessary requirement for receiving the parental protection and guidance needed to survive. Imprinting has attracted interest from developmental, cognitive, neurological, sensory, behavioral, and conservation disciplines. In species capable of imprinting on humans, this process provides a unique window into the umwelt of a species that is difficult to attain by monitoring wild populations or by other methods in captive settings. Despite the large, multi-disciplinary body of research on imprinting and its wide variability between species, its ecological function and evolutionary trajectory across avian phylogenies has yet to be systematically evaluated. Here, we review the literature on a wide array of bird species to characterize this spectrum of imprinting behaviors and explore the selective forces and life history traits – such as developmental mode, parental care strategy, and social structure - that may have shaped the role of imprinting over the course of avian evolution.

## Legacy-plus-innovation: Cnidarian visual systems exemplify a ubiquitous macroevolutionary pattern

*Todd Oakley*

Cnidarian visual systems provide a striking example of a legacy-plus-innovation pattern in evolution, where deeply conserved genetic toolkits are repeatedly deployed along with new genes. Medusozoan cnidarians (∼ 'jellyfish') have a remarkable diversity of visual systems that evolved convergently at least nine times. These range from larval eyes – containing photoreceptor, pigment, and motor cilium in a single cell – to the oldest complex camera eyes with lenses. Although there is still very much to learn about cnidarian visual systems, we already know that ancient gene families involved in light detection and conserved across metazoans have been recruited repeatedly. At the same time, the visual systems of cnidarians sometimes use genes not shared with other animals. This pattern of legacy-plus-innovation is common across repeated origins of other complex systems, showing that deeply conserved gene families are often re-deployed when there is a restricted array of genetic solutions and when that gene family is available for recruitment. In contrast, repeated innovations, exemplified by lens proteins, indicate a wide array of genetic solutions. By exploring the genetic and morphological diversity of cnidarian visual systems, we can gain key insights into the macroevolutionary patterns that shape the origins of biological complexity.

## *Naegleria gruberi* amoeba as model organism for teaching biotechnology in two-year institution

*Yoshi Odaka, Keen Wilson*

One of the primary challenges in teaching biotechnology at two-year institutions is the expense associated with maintaining cultured mammalian cells. This involves costs for tissue culture vessels, CO2 incubators, culture media, biosafety cabinets, and other equipment. To mitigate these costs, our program has utilized Naegleria gruberi amoeba as a model organism.

Naegleria species possess the unique capability to transition from a vegetative trophozoite state to a flagellate or metabolically dormant cyst under specific culture conditions. While N. fowleri is a pathogenic species within the Naegleria genus, N. gruberi is a well-studied, biosafety level 1 (BSL-1) organism. It can be cultured in untreated petri dishes at room temperature using relatively inexpensive culture media.

In recent years, students in our program have employed N. gruberi to acquire essential skills, including maintaining cells in an axenic environment, practicing aseptic techniques, performing transfections, conducting immunofluorescence, extracting RNA, and executing quantitative PCR.

We present here a selection of assays conducted and data obtained by our students and instructors.

## Mucus properties and pulse behavior function to optimizes food capture in upside-down jellyfish

*Aki Ohdera, Laura Miller*

The upside-down jellyfish Cassiopea are endemic to shallow water mangrove habitats worldwide, and recently suggested to play an important role for nutrient cycling in these environments, perhaps as an ecosystem engineer. As coastal environments are altered due to climate change, these jellyfish are poised for expansion into new habitats, potentially impacting local ecology and community composition. A key feature of the jellyfish that could allow these animals to be effective in new environments is their mucus. Cassiopea release large amounts of mucus in response to the presence of food (plankton) and agitation (defense response). To understand the role of mucus as a prey capture and defensive strategy, we investigated the physical and chemical properties of mucus using multiple approaches. Using particle imaging velocimetry (PIV), 3D reconstruction, and computational modeling, we investigate the macro-structure of jellyfish mucus, its viscoelastic properties, and how fluid flow generated by jellyfish pulsing can be altered by the release of mucus. Preliminary data demonstrate how the structural plasticity of jellyfish mucus, coupled with pulse generated fluid flow can make Cassiopea efficient feeders.

## Microbial adaptation in response to environmental and maternal influences in *Tribolium castaneum*

*Esther Okamoto, Jennifer Kovacs*

The gut microbiome plays a pivotal role in host fitness, influencing factors such as fecundity, lifespan, and stress responses. In this study, we utilized Tribolium castaneum, a model organism completing its entire lifecycle in a flour environment, to investigate how gut microbiomes are shaped by both maternal and environmental factors across generations. By employing 16S and ITS rRNA sequencing, we explored microbial community changes in beetles reared under varying nutritional and population density stress conditions.

Our findings indicate that T. castaneum displays a high degree of microbial adaptability, with environmental factors such as diet exerting a stronger influence on microbiome composition than maternal inheritance. Specifically, changes in diet from standard to nutrient-rich flours led to significant increases in microbial diversity, particularly among bacterial taxa associated with metabolic functions. These shifts highlight the resilience of the T. castaneum gut microbiome to environmental changes, which may contribute to its success as a global pest.

These results provide insights into the evolutionary strategies of host-microbe interactions, suggesting that environmental pressures can rapidly reshape microbial communities, which in turn may affect host adaptability and ecological fitness. Our study emphasizes the importance of considering both immediate environmental contexts and historical lineage when examining host-microbiome dynamics.

## How does exposure to iron oxide nanoparticles effect on bioaccumulation of house sparrows?

*chisom Okogbue, Shae Johnston, John Wenderski, Liam Hanlon, Natalia Gonzalez-Pech, Kelly Ronald*

Air pollution caused by urbanization has resulted in health detriments and harm to biodiversity. Solid nanoparticles are one component of particulate matter (PM) within air pollution that are small enough to bypass the blood-gas barrier and the blood-brain barrier; this allows them to cause many adverse health effects to humans and other organisms. Avian species in particular are more susceptible to airborne contaminants because they have thinner blood-gas barriers and more substances can bypass this barrier. The aim of this project was to determine whether chronic iron oxide nanoparticles (IONP) exposure results in bioaccumulation of excess iron in the house sparrow (Passer domesticus). House sparrows are an appropriate avian model because they can reside across an urbanization gradient from rural to more populated. Birds were captured from locations around Holland, MI, USA and then exposed to either aerosolized MilliQ water (i.e., control animals), or aerosolized IONP (i.e., experimental animals) for 50 hours over 10 days. Bioaccumulation was accessed in relevant organs (i.e., brain, heart, lungs, liver, kidney, gastrointestinal tract, and blood) via an Inductively Coupled Plasma (ICP) spectrometer. Results from this project will inform whether modeled chronic exposure results in excess bioaccumulation and whether this impairs the birds behaviorally or physiologically. Ultimately a better understanding of air pollution exposure will inform better city management and air pollution standards.

## Architects of the Sand Flats: Uncovering the Burrow-Building and Substrate Selectivity of Alpheus CF

*Amarachukwu Okongwu, Paul Barber, Peggy Fong, Tre-Vaughn Ellis, Ruth Viveros, Sugey Galvan, Alexandra Davis, Alexys Long*

Mutualistic associations are common in coral reef ecosystems and one of the most documented is between shrimp goby guards and their burrow-building shrimp. Previous work on this diverse group examined habitat preference, burrow structure, and entrance shape, but what remains unexplored is whether the composition and structure of their highly-ornamented burrow entrances are functional, and if so, are they constructed with intentional design. We observed that A. cf. berumeni exhibits peak burrow-stabilizing activity in the afternoon, builds two distinct types of burrow entrances that are equally stable for up to 4 days and utilizes specific shapes and weights of ornamentation that differ from those available in the surrounding environment (LME, p,0.0462) Next, we conducted a choice experiment where we offered the 4 choices of shapes of ornaments we quantified surrounding the burrows: flat, cylinder, globular, and branching A. cf. berumeni actively selected for branching and cylinder ornaments and avoided the flat shapes when offered a choice (Chi2, $0.01496 < 10.471$). Our work establishes that Alpheus cf. berumeni is not just an ecosystem engineer that builds a habitat, but an architect that does so with an intentional structural design.

## The role of urbanization on the evolution of an immune gene in house finches, Haemorhous mexicanus

*Emmanuel Okposio, Joel Slade, Kevin McGraw*

Urbanization is associated with novel habitats, food sources, pathogens, and a general decline in species and genetic diversity for wildlife like birds. However, most of the studies investigating how urbanization impacts the genetic diversity of species are conducted using neutral loci, which may often not reflect the diversity associated with fitness-related loci. In this study, we will determine the role of urbanization on an adaptive polymorphic gene, the major histocompatibility complex (MHC) class I in house finches, Haemorhous mexicanus, a sedentary species in western United States. We have collected blood samples from at least 30 house finches in each habitat along an urban-rural gradient (urban, suburban, and rural) in and around Fresno, California. We hypothesize that MHC will vary in individual diversity and in allelic membership between rural, suburban, and urban habitats because of disruption in gene flow and differential habitat-related pressures. We have PCR-amplified the peptide binding region (exon 3) of MHC class I in these birds. MHC will be characterized on the Illumina MiSeq platform. We will compare the number of MHC alleles, the number of private alleles, nucleotide diversity, nucleotide substitutions, number of segregating sites, and amino acid changes) between the three population units. Also, I will determine population divergence by calculating Jost's D and using STRUCTURE. This novel study will shed light on the associations between urbanization and the evolution of passerine MHC.

## DNA metabarcoding reveals the diet of an economically important fish - Chrysichthys nigrodigitatus

*Segun Oladipo, Kehinde Adelakun, Ifeanyi Nneji, Olabisi Atofarati, Lotanna Nneji*

The investigation of the diet of fish is essential for understanding their ecology and local adaptations, as well as long-term conservation. Despite being recognized as one of the highly valued fish for human consumption in Africa, little is known about the feeding ecology of the African Forktail Catfish - Chrysichthys nigrodigitatus. To understand its feeding ecology, we applied DNA metabarcoding to analyze its gut contents to unveil the diet composition. We collected gut samples of C. nigrodigatus from four Nigerian water bodies (Epe, Makoko, Jebba and Kainji). We applied a metabarcoding protocol based on 12S and 18S rRNA genes to identify diet compositions in the gut contents of C. nigrodigatus. Diets were grouped into ecologically significant taxonomic groups based on the lowest taxonomic level sequences that could be identified using sequences available on the global databases. Our results showed that C. nigrodigatus is a generalist that consumes diverse diets. In addition, our study further recorded important changes in the diet compositions and abundance linked to sampling locations, suggesting an adaptive spatial variation in the diet compositions of C. nigrodigatus. Our study shows how DNA metabarcoding can be used to provide novel ecological information associated with feeding strategies of fish from West African water bodies, thus providing essential information for future management and conservation of C. nigrodigatus and their habitats.

## Exploring Regional Diversity in Solenogastres (Mollusca, Aplacophora): Insights from Icelandic Water

*Chandler Olson, M. Carmen Cobo, Kevin Kocot*

Solenogastres, a group of marine mollusks characterized by their vermiform body covered by calcium carbonate sclerites, inhabit oceans worldwide, from shallow subtidal to abyssal depths. Despite their widespread distribution, the full extent of their global diversity remains poorly understood. Currently, 313 species are described, yet estimates suggest that the true diversity could be ten times greater. This study investigates the diversity of Solenogastres by analyzing over 2,000 specimens collected in the waters around Iceland from a broad depth range (169-5484 m). By integrating morphological and molecular data, we identify over 120 morphospecies, most of which are new to science. Of these, many are rare, represented by only one or a few specimens, suggesting even more diversity could exist in the region. We present the family Macellomeniidae, where we more than double the described number of species, as a case study. The submarine ridges surrounding Iceland create a bathymetrically dynamic environment with many unique habitats. We assess diversity patterns in relation to environmental factors (depth, ocean basin, latitude, or sediment type) and hypothesize how they might be reflected in solenogaster diversity trends in this region. Additionally, through sequencing the gut content, we aim to understand their ecological roles and determine dietary trends of higher taxonomic groupings. Our findings provide new insights into the unexplored diversity, the ecological roles, and the evolutionary history of Solenogastres.

## The evolution of specialized skull shapes in the burrowing worm lizards

*Maxwell Olson, Philip Bergmann*

The shape of the skull characterizes many vertebrate clades, often reflecting specializations in certain functions like feeding or sensory systems. The amphisbaenians (worm lizards) are a clade of highly derived burrowing lizards with a diverse array of skull shapes specialized for different modes of head-first burrowing. Amphisbaenians have four burrowing phenotypes, each associated with an external head shape and burrowing behavior. The ancestral type is the most expansive in both number of species and geographic range. It appears to be the most generalized, with a rounded head driven forward to extend and expand the burrow. The other three phenotypes are further specialized relative to the ancestral type, using dorsoventral, lateral, or twisting motions during burrowing and with head shapes specialized for each behavior. Two of these phenotypes have evolved convergently multiple times within amphisbaenians. However, despite similar external head shapes, there is considerable variation in the underlying skull morphologies of convergent forms. We used a high-density 3D landmark-based geometric morphometric approach to robustly quantify skull shape and reconstruct cranial evolution across the Amphisbaenia, including all extant genera. We test the hypothesis that skull shape has evolved according to burrowing behavior in amphisbaenians. We predict that skull shapes will cluster in morphospace by the four burrowing behavior categories, with relatively small areas occupied by the three specialized forms.

## The oral sensory system and dynamic modulation of the tongue during chewing in carnivorans

*Rachel Olson, Moriah Wood, Stephane Montuelle, Susan Williams*

The tongue plays an important role in mammalian feeding: positioning and manipulating the bolus and aiding in swallowing. The oral cavity is rich with sensory innervation to the tongue, teeth, and mucosa that are necessary to adapt movements during feeding. As a muscular hydrostat, tongue movements and its deformation are particularly dynamic during feeding. Here, we explore the effects of bilateral oral sensory blocks (lingual nerve, superior/inferior alveolar nerves) on tongue kinematics during chewing in several small carnivoran species. XROMM was used to collect feeding data, with additional soft tissue markers throughout the body of the tongue to quantify lengths, widths, and protraction. Prior to blocks, timing and amplitude parameters of tongue movements/deformations differed between foods. A variety of interesting responses to the blocks were observed in these kinematic parameters. First, regardless of the food, we generally observed similar patterns in the response within species. For example, in skunks, maximum tongue length during chewing was reduced following blocks to the teeth, but unaffected by lingual nerve blocks in some foods, yet lingual nerve blocks impact tongue protraction-retraction. Our results show that the dynamic modulation of the tongue is the result of complex sensorimotor interactions, which may be particularly important for a muscular hydrostat lacking typical constraints of a skeletal system. Funded by NSF-IOS 1456810.

## OCEANS: A Place-based Educational Approach

*Dara Orbach, Lorenzo Fiori, Katie Doyle, Larisa Ford*

OCEANS (Oceanography, Conservation, Ecology, Arts, Nature, and Stewardship) is a community partnership between a Hispanic Serving university, underserved K-8 school, and non-profit conservation organization. We use a collaborative and innovative place-based approach to learning that invigorates environmental literacy while connecting students, teachers, and the community to natural resources. Our pilot program empowers university students to develop educational curricula focused on ecosystem sustainability, to inspire young minority students to pursue higher education, and to mentor the next generation of coastal ecosystem ambassadors. A core component is cross-generationally led field trips to explore diverse coastal habitats, collect environmental data, and assess temporal and spatial changes. Findings are disseminated broadly through community-wide, hands-on, outreach events organized by students, formal presentations to diverse stakeholders (including town hall meetings), and an Environmental Stewardship and Ocean Literacy Plan. During the inaugural year of OCEANS, 6 university interns, 400 K-8th grade students, 20 teachers, and 8 community leaders directly benefited. We present an actionable model on how to develop and implement place-based environmental stewardship collaborations that engage varied community stakeholders in ecosystem resiliency planning.

## Dolphins save energy by bow-riding on vessels

*Dara Orbach, Lorenzo Fiori, Randall Davis, Bernd Wurzig*

Dolphins ride on the pressure waves produced by moving vessels globally, although the biological benefit is unclear. We used unoccupied aerial vehicle (UAV) video recordings of dusky dolphins (Lagenorhynchus obscurus) free-swimming and riding on the bow of a vessel to quantify swimming energetics. Respiration rate was used as a proxy of energy expended in locomotion. Bow-riding dolphins spend 36% less energy on average than free-swimming dolphins. When traveling at fast speeds exceeding 4 m/s, bow-riding dolphins respired 45% less than free-swimming dolphins, highlighting the locomotion advantage of bow-riding. We demonstrate a non-invasive novel approach to calculate locomotion energetics in free-ranging small cetaceans, with conservation applications such as quantifying the physiological consequences of anthropogenic disturbances.

## Is Signaling Between Mitochondria and Nuclei Disrupted During Extreme Hypertrophic Muscle Growth?

*Dylan Orcutt, Stephen Kinsey*

Anaerobic light fibers and aerobic dark fibers power swimming in the blue crab, Callinectes sapidus. These muscle fibers grow hypertrophically from However, we would not expect this disruption in dark fibers, where mitochondria and nuclei are in close proximity throughout muscle growth. The best described mito-nuclear communication is mitochondrial-generated reactive oxygen species triggering expression of nuclear-encoded mitochondrial genes. We evaluated spatially resolved ROS damage to proteins, lipids and DNA in light and dark muscle fiber cross-sections. As expected, ROS damage in light fibers was present near the peripheral mitochondrial clusters in light fibers and did not reach interior nuclei, whereas this was not the case in dark fibers. These results indicate mitochondria become divorced from interior nuclei in light fibers, making this a unique model for evaluating mito-nuclear communication.

## Investigating morphology and function of the distributed visual system of scallops

*Ceren Ordas, Malissa Jeffrey, Jeanne Serb*

Eye morphology influences function. For instance, narrow pupils and tightly packed photoreceptors enhance resolution, while wider pupils and larger photoreceptors improve sensitivity. Unlike many animals with paired eyes, scallops have tens to hundreds of eyes with overlapping visual fields, where multiple eyes receive the same visual information. However, differences in eye size and pupil orientation among eyes may influence functional capabilities. This study investigates whether the many eyes of an individual vary in traits that would affect optical function. Using histological methods, we analyzed 42 eyes from two individuals, measuring key features such as eye-to-pupil diameter ratio, photoreceptor spacing, rhabdom length, and photoreceptor cell counts. Our findings reveal no significant differences in photoreceptor spacing between different eye sizes. However, significant variations in total photoreceptor cell count, mean rhabdom length, and internal eye-to-pupil diameter ratio among big, small, and super-small eyes indicate possible differences in sensitivity and resolution. These results suggest that while scallop eyes may share overlapping visual fields, they may be used for different visual tasks. This study provides new insights into the morphological adaptations of scallop eyes and helps understand the functional diversity within their visual system.

## Standardized imaging practices in fixed fish specimens for the analysis of color and color patterns

*Rosamari Orduna, Michael Alfaro*

Coral reef fishes represent one of the most colorful assemblages of vertebrates on the planet, yet progress towards understanding the gamut of their color and color pattern has been slow relative to other colorful groups such as birds and insects. One reason for this is that the fixation process results in a rapid loss of color in fishes, seemingly excluding the vast majority of specimens in museum collections from color studies. However, the precise effect of fixation on color has received little attention. Here we present preliminary results on the change in reflectance of fishes as they move through the fixation process. Using an imaging spectrophotometer and microscopy, we examine changes in the reflectance spectra and skin microstructure. We acquired freshly sacrificed fishes and imaged the specimens on the spectrophotometer prior to fixation, followed by a time-series of imaging at one-week intervals post-fixation to extract reflectance measurements. In addition, we imaged cross-sections of fixed fish skin to compare the arrangement of pigment cells across individuals and species. Furthermore, we measured the reflectance of fixed specimens from the Natural History Museum of Los Angeles (NHMLA). Our results shed light on the ways that reflectance measures differ between living and preserved fishes and are a potential first step towards unlocking the collection of data on color and color patterns from the vast array of specimens in collections.

## Neoavian nepobabies: How parental investment in early development supercharges bird evolution

*Andrew Orkney, Priscila Rothier, Brandon Hedrick*

Different bird species exhibit dramatic differences in early development after hatching, from highly precocial chicks that hatch fully-feathered and almost immediately capable of flight, to altricial lineages whose young emerge naked, blind and require intensive parental investment until fledging. It is widely hypothesised that a more altricial developmental strategy affords an evolutionary opportunity to alter formative patterns of growth in early life, potentially providing a pathway to generate anatomical novelty. However, systematic studies investigating this question in vertebrate groups such as mammals have yielded ambiguous results. Here, we leverage published datasets of adult skeletal proportions and detailed ecological descriptions across hundreds of precocial and altricial bird species to investigate whether correlated patterns of limb proportion evolution are influenced by developmental mode, determine if altricial development is significantly associated with the exploration of a wider range of ecologies and specifically test whether the exploration of novel ecological activities in altricial lineages is associated with pathways of limb proportion evolution that are less accessible to precocial birds. We show that wing and leg proportions evolve independently in altricial but not precocial lineages, that altricial lineages access a wider repertoire of specialist ecological activities, and that divergent evolution of overall wing and leg lengths is exploited in altricial bird lineages and gives rise to species that practice specialist flight-styles.

## Effects of pesticides on caste development in bumblebees

*Sarah Orr, Kayla Murray, Emma Leigh Bossard, Jixiang Xu, Michael Goodisman*

Successful crop production depends on agrochemicals to control pests. However, agrochemicals can have negative consequences on beneficial insects, such as bees. We investigated the effects of an emerging pesticide, sulfoxaflor, on the common eastern bumblebee, Bombus impatiens. We performed a series of chronic toxicity tests in replicated microcolonies to determine how sulfoxaflor affected the physiology and behavior of B. impatiens. Our results showed that chronic exposure to sulfoxaflor significantly reduced the number of honey pots, egg batches, and amount of sugar syrup consumed in microcolonies. Notably, the observed changes in the reproductive abilities of bees were caused by impeding ovary development and reducing egg laying. Surprisingly, we found that chronic sulfoxaflor exposure did not affect bee crawling velocity or time spent moving. We also conducted long-term experiments in queenright colonies to investigate how sulfoxaflor affected the timing of reproductive caste development and sex ratios. After eight weeks, we found that treated colonies had fewer reproductives, but a greater number of gyne pupae. This suggests sulfoxaflor significantly delays the production of reproductives, which could have important implications for colony success. Overall, this investigation provides novel information on how an important pesticide impacts caste development of an important native pollinator at field realistic concentrations.

## Phantom Crane Flies spread their long legs to glide in the sky without a single wing beat

*Victor Ortega Jimenez, Sarahi Arriaga-Ramirez*

Phantom crane flies (Bittacomorpha clavipes) are one of the most mysterious fliers in the insect world. Adults are characterized by a black and white camouflage that makes them hard to spot and follow, and their hollow elongated legs seem to be used to enhance aerial dispersal without the active use of their wings. However, it is puzzling how these dipterans are able to use their legs and body to generate aerodynamic forces and still keep a tight aerial control. Insects' 3D aerial kinematics were compared during ascent flights in still air and in the presence of an upward flow using a vertical wind tunnel. We found that individuals use their flapping wings to ascend vertically in still air, while keeping their legs spread. Remarkably, in the presence of an upward flow ($\sim$1m/s) they maintain their haltiers oscillating but stop flapping their wings. Then, they adopt "dandelion-seed posture" with their legs fully extended. These postural adjustments are effective to hover or lift them up, depending on the cone angle formed by the legs. Thus phantom crane flies use leg-mediated aerodynamics to reduce flight cost, which can be beneficial for mating given that adults usually do not feed. Our results can be applied to micro aerial vehicles that can switch to appendices and wing flapping depending on favorable wind conditions.

## Innate control: Jumping Water Striders use leg-mediated aerodynamics for perfect landing

*Victor Ortega Jimenez, Elio Challita, Robert Wood, Robert Dudley*

Hemipterans in the genus Trepobates (Gerridae) are a lineage of millimeter-sized water striders that live in huge colonies distributed on lakes and rivers of the Western Hemisphere. In addition to their minute size, these semi-aquatic insects are known for their exceptional ability to jump from the water's surface as an effective means to escape fast predators. However, such catapulting abilities have never been properly described, and it is unclear if they are able to effect subsequent aerial control and upright landings without using wings. We show that adults of T. subnitidus are able to jump $\sim$10 times their body length, to self-right in mid-air in milliseconds, and to consistently land ventrally via leg-mediated aerial control. Experiments with individuals falling in the jet of a vertical wind tunnel indicate that they can regulate pitch, yaw, and roll via asymmetric leg positioning. Even newly hatched instars can use leg-mediated aerial control to successfully land. We flew a robotic version of these water striders in a wind tunnel to characterize how asymmetric leg deployment influences body orientation and flow dynamics of the insect as a whole. Such outstanding aerial control in water striders facilitates rapid repeated jumping, and likely serves to evade predators along with cannibalistic interactions. Such aerial control can also be implemented in interfacial jumping robots with leg-mediated aerodynamics to aid in successful landing.

## The influence of hunger on predatory behavior and sensory processing of a specialist predator

*Kate Otter, Paul Katz*

Finding food is crucial for animals and is influenced by their hunger level. Hunger can change how animals perceive food cues, especially for predators facing both food and potential injury. The nudibranch, Berghia stephanieae, preys on the anemone Exaiptasia diaphana. We hypothesized that Berghia's response to prey cues shifts from aversive to appetitive when food-deprived. We expected that sated Berghia would avoid their prey due to potential injury, but would find them attractive when hungry. To test this, we observed Berghia with 0 to 5 days of food deprivation in an arena with a single anemone. In another experiment, we placed gelatin probes with or without prey toxins on different parts of Berghia's face to study their reactions. We found that the slugs were attracted to distance cues (e.g. olfactory) regardless of hunger. Most animals make contact with their prey during the trial regardless of food-deprivation, but the responses to contact cues are state-dependent and dependent on location of contact. When hunting, distance cues appear to be attractive regardless of hunger state while contact cues drive state-dependent behavioral choice. The behavioral response and thus perceived valence of contact cues are primarily driven by where on the body the Berghia is touched. Thus, hunger shapes the body positioning during the approach phase of hunting and thus where they get touched and whether they approach or avoid.

## Biology but make it gay: A case study teaching a first-year seminar on queer and feminist biology

*Kate Otter, Denise Pope*

One of the frontiers of animal behavior is challenging gendered norms and presupposed binaries that are embedded in our studies of animal behavior. This is especially essential given how gender-inclusive curriculum is one method of retaining and supporting diverse scientists in the field. I designed and taught a first-year seminar "Biology but make it Gay" in Fall 2022 and 2023, which challenged first-year college undergraduates to think critically about biology and especially animal behavior, from feminist and queer perspectives. Using an ethnographic approach, I document how the course shifted students' thinking about sex, gender and same-sex sexual behavior with course assignments, concept maps and student reflections. As first-year students, this course came at a critical point in their college education, and I have been able to survey students 1 and 2-years post completion of the course. I also surveyed students to get their suggestions for researchers in the field seeking a more expansive understanding of animal behavior. This course provides a case-study of how gender inclusive teaching of animal behavior can affect a student's desire to study biology and how they understand the nature of science.

## Earthworm diversity under cover objects in wooded natural areas is mostly introduced species

*Patrick Owen, Keen Wilson*

We created a collection of earthworms found under cover objects in wooded natural areas of southwestern Ohio, USA, between 2017 and 2024. Reproductively mature individuals were identified using external morphology. Additionally, we used mitochondrial cytochrome oxidase subunit 1 (COI) to identify a random sample of earthworms in our collection that included mature as well as immature specimens. In contrast to historical records which documented a high diversity of native earthworm species, the majority of individuals that we collected from natural areas (over 90%) were of non-native species, especially lumbricids and megascolecids. Two non-native species, Lumbricus castaneus and Amynthas tokioensis, represent new species records for the region. Similar to work in other areas of eastern North America, we found A. tokioensis, A. agrestis, and Metaphire hilgendorfi present together as part of a morphologically cryptic species complex. Finally, we report a non-native moniligastrid earthworm (genus Drawida) of uncertain ecological impact which was previously unknown in continental North America. Earthworms native to North America (Diplocardia and Sparganophilus) represented the smallest portion of earthworms in our collection with no native lumbricid earthworm species detected. Given the potential negative ecological impacts of non-native earthworms on such things as changes in soil nutrient composition, increased soil erosion, and competitive effects on other species, it is important to continue to document which native earthworm species persist in natural areas as well as which new species become introduced.

## The secret life of sand dollars: an immersive and interactive exhibition

*Douglas Pace, Siavash Ahrar, Behnaz Farahi*

Learning through interactive exhibitions has the potential to promote lifelong learning and engage broader audiences across disciplines. Using an immersive 360° projection screen theater located in CSU Long Beach's Innovation Space, we created an exhibit that focused on the complex life history of the Pacific sand dollar, Dendraster excentricus, with an emphasis on the phenomenon of larval phenotypic plasticity. The exhibit included two microscope stations showing adult and larval sand dollars. These live images were projected onto the 360° screen. A third station housed 3D-printed physical models of low- and high-fed larvae. These 3D models could be manipulated and placed on a screen to project a hydrodynamic recording of their swimming behavior (i.e., flow traces of fluorescently labeled beads). After the exhibit, visitors voluntarily participated in an anonymous survey to reflect on their experiences and provide feedback. The survey included 7 Likert scale statements (strongly disagree to strongly agree) and two open-ended questions. One hundred fifty three responses were collected (50% students, 32% CSULB staff or community members, 17% broader community members). Most participants found the exhibition engaging and reported learning about marine organisms, with some wanting more discussion about climate change. These data are being used to inform a revision of this immersive experience so as to more effectively educate the importance of the marine habitat to a broad diversity of people.

## Effects of ocean acidification on larval bay scallops *Argopecten irradians* across generations

*Dianna Padilla, Samuel Gurr, Shannon Meseck, Genevieve Bernatchez, Lisa Guy, Mark Dixon, Dylan Redman, George Sennefelder, Lisa Milke, Gary Wikfors, Katherine McFarland*

Along coastlines changes in water chemistry, known as ocean acidification (OA) are impacting bivalve larvae, but we do not know whether species can adapt to these changing conditions. Most studies are of short duration, limiting our ability to determine long term effects of OA on bivalve populations. Therefore, we conducted experiments with northern bay scallops reared under OA conditions for two generations to assess the impacts of OA. We grew a first generation (F1) of larvae of under three OA conditions: low, moderate, and high OA, and quantified survivorship, growth and time to metamorphosis. Larvae under high OA did not survive past metamorphosis. Scallops in the other two treatments were reared under those same larval treatments until they produced a second generation (F2), reared under those same conditions. For the F1, we saw a significant effect of OA on survivorship and growth, but not on time to metamorphosis. For the F2 there was no effect of OA on survivorship or development, but there was an effect on growth. Survivorship overall was lower than for the F1. F2 larvae were fed a slightly different diet than the F1, and metamorphosed later, but at a larger size. These data suggest that there may be tradeoffs between survivorship and growth, and the potential for metamorphosis at a larger size across generations under OA conditions.

## A putative ctenophore neurogenesis GRN from scRNAseq timecourse

*Natalia Padillo-Anthemides, Brent Foster, Fredrik Hugosson, Urvashi Goswami, Yuriy Bobkov, Rhonda Bacher, Yanping Zhang, Mark Q. Martindale, Joseph Ryan*

As the sister lineage to all other animals, ctenophores provide essential insights into the evolution of gene regulatory networks, developmental processes, as well as the origin and evolution of cell types. To date, we know very little about developmental regulatory networks in ctenophores. To remedy this, we have sequenced RNA from over 23,000 cells across eleven timepoints between 4 and 24 hours during the embryogenesis in the ctenophore, Mnemiopsis. Using this robust dataset, we used URD to reconstruct the transcriptional trajectories and cell state transitions of the early Mnemiopsis embryo. Within a neuronal trajectory, we have identified expression of most of the core components of the canonical Notch signaling pathway, neurogenesis-related transcription factors such as LHX, MEIS, ARX, and SOX, as well as key neuronal effector genes like voltage-gated calcium, sodium, and potassium channels. Our data suggest that several key developmental regulatory genes and gene networks pattern the neurons of ctenophores. These results provide compelling evidence that these conserved networks were present in the last common ancestor of animals and that the link between these factors and neural effector components is ancient and well-conserved.

## Drosophila need green and UV wavelengths for sun orientation but lack a time-compensated sun compass

*Haneal Pae, Jingzhu Liao, Nicole Yuen, Ysabel Giraldo*

Celestial cues allow animals like Drosophila to orient in a stable direction for hours. Indeed, field studies show that Drosophila can disperse over 10km under two hours. However, we still do not understand how multiple aspects of celestial cues and pauses in flight impact flies' headings. To assess individual heading, we tested flies in a magnotether arena using a green LED as a sun stimulus. We found that flies robustly perform menotaxis – adopting an arbitrary orientation relative to a stimulus - and fly straight for at least 20 minutes. Flies maintain their preferred heading directions after experiencing a period of darkness or stopping flight, even up to 2 hours, but reset their heading when the LED changes position. Next, we assessed the flies' responses to a UV LED alone or a paired UV-green stimulus - two LEDs situated 180° apart to simulate the solar and antisolar hemispheres. We found that flies respond to UV similarly to green, performing menotaxis however, when presented with paired stimuli, flies track a 90° stimulus movement, indicating sun orientation. Lastly, we found no evidence of a time-compensated sun compass when we moved the paired stimuli at 15° per hour for 6 hours. This study provides the framework for future exploration of how multiple aspects of celestial cues are integrated by the nervous system and processed to influence flight behavior.

## Developmental exposure to PAHs causes transcriptional and metabolic shifts in an avian model

*Yulianis Pagan, Christopher Goodchild*

Large crude oil spills can cause extensive ecological damage to aquatic and near-shore animal environments. For instance, wild birds exposed to crude oil exhibit several pathologies. While several studies have examined the effects of crude oil on adult birds, the developmental effects from crude oil exposure remain unclear. Polycyclic aromatic hydrocarbons (PAHs) are naturally occurring toxic chemicals found in crude oil and are known to transfer from the external eggshell surface to egg contents. We conducted an egg-injection study with White Leghorn chicken (Gallus gallus) eggs and identified two PAHs, chrysene (Chr) and phenanthrene (Phe), that increased embryonic heart mass and decreased embryonic heart rate. Further, we investigated whether co-exposure to Chr and Phe resulted in additive or synergistic effects. We measured embryonic gross organ mass, heart rate, metabolic rate, and cardiac and hepatic mRNA expression of detoxification enzymes on embryonic day (ED)18. We observed a decrease in ED 18 heart rate across all treatments. We also saw an increase in ED 18 liver mass in eggs exposed to Chr and Phe simultaneously, and shifts in metabolic rate and mRNA expression of cardiac detoxification enzymes. However, embryonic growth or morphology did not vary among treatments. Collectively, these data suggest in ovo exposure to PAHs may lead to congenital heart defects, which may have long-term implications for hatching success and hatchling survival.

## Manta ray filters serve as a model for bio-inspired industrial applications

*EW Misty Paig-Tran, James Strother, Shirel Kahane-Rapport, Leandra Hamann, Karly Cohen, Julia Teeple*

Bio-inspired designs for human-based uses have revolutionized the modern world. Examples of these transformative inventions include, but are not limited to: Velcro developed based on the burs of burdock plants, long term vaccine storage inspired by anhydrophobic organisms, and more efficient wind turbines designed to mimic the fins of humpback whales. One particular area of interest for applying bio-inspired design is focused on improved industrial water filtration systems. Here we look to large-scale filter feeders as inspiration for creating high-efficiency, non-clogging filters. We present the lessons learned from >15 years studying the mega-filter feeders (e.g. mantas and devil rays, whale sharks, basking sharks, megamouth sharks, oarfish, and baleen whales). We iteratively explore how morphological changes to manta filters affects the filtration performance and create optimized filters for industrial filtering. Our work spans the gamut from in situ exploration (using live video) to three dimensional morphological investigations (using museum specimens and CT scanning, Scanning Electron Microscopy) to performance testing using computational and physical modeling. Our findings demonstrably show that large-scale filtering in nature is vastly different and more nuanced than the sieve filtering we once attributed to be ubiquitous for the filtering vertebrates.

## Influence of season and temperature on cell-based immune function of the Mojave Desert tortoise

*Mariah Painter, Lexi Anderson, Jenna Morales, Holly Nelson, Franziska Sandmeier*

Temperature and season have a profound influence on the immune systems, including those of reptiles. Seasonal changes in the ratio of circulating leukocytes as well as seasonal and temperature-based changes in the bactericidal ability of plasma have been demonstrated in several species. However, seasonal and temperature dependence of the immune system are often studied independently of one another, and so we do not have a clear picture of how the reptile immune system is affected by both temperature and season. Additionally, many seasonal studies pair leukocyte counts with bacterial killing assays using plasma, hindering our understanding of how changes in leukocyte subpopulations change cell-based immune functions. To address these questions, we utilized a simple bacterial killing assay using blood cells from the Mojave Desert tortoise (Gopherus agassizii) across 7 ecologically relevant temperatures during spring, summer, and fall of 2023. Our results showed a significant effect of temperature and season on bactericidal ability, suggesting a thermal and seasonal dependence of cell-based immunity. This study helps to bridge the gap between thermal and seasonal changes in reptile immune function.

## Developmental endocrinology before gonads: Do extraembryonic membranes initiate sex differences?

*Ryan Paitz, Mark Haussmann, Ken Field*

The traditional paradigm for understanding sex differences is that individuals inherit chromosomes that dictate whether ovaries or testes form during embryonic development. Those differentiated gonads then produce sex specific hormones that direct sexual differentiation. But, it is now increasingly recognized that some sex differences can arise in a cell-autonomous manner that does not involve gonadal hormones. This concept is best exemplified by studies that demonstrate sex differences at early developmental stages before gonads differentiate. In this study, we used developing chicken embryos to test for sex differences in the response to maternally derived steroids early in development. We used RNA-Seq to examine the whole-transcriptome response of the extraembryonic membranes to corticosterone, pregnanedione, and both steroids combined. There was a differential gene expression response of the extraembryonic membranes to corticosterone, but this response did not appear to vary by sex. However, independent of any steroid effects, there were widespread sex differences in the transcriptomes of the extraembryonic membranes. While many of the differentially expressed genes were located on sex chromosomes, others were located on autosomes. We will discuss these sex differences that are occurring prior to gonadal differentiation and the implications this may have for how each sex could respond to maternal steroids.

## Using a convolutional neural network for pollen grain identification in the Michiana region

*Samantha Pajak, Erian Stewart, Peculiar Emmanuel-King, Morgan Carr-Markell*

Pollination is essential to ecosystems and crop systems. However, pollinator populations have decreased in recent years partly due to human-caused environmental change. Pollinators require nutrients from the pollen they collect, and different plant species provide these nutrients for different pollinators. Determining which plants pollinators collect from and which they collected from in the past can help inform pollinator conservation efforts. The most commonly used methods for identifying pollen grains are: 1) manual observation under a microscope and comparison with reference slides by a trained professional and 2) DNA barcoding and comparison with a region-specific database of plant DNA sequences. While these methods are relatively accurate, limitations include cost, time, and training. To make pollen identification more cost-effective, we employed a machine learning approach using a convolutional neural network (CNN). We collected pollen from plant species in our region (southern Michigan and northern Indiana), used a Keyence BZ-X810 slide scanner to photograph microscope slides of this pollen, and trained a CNN using cropped images of individual pollen grains. We tested the network's accuracy using a held-out training set of pollen images and also by comparing the network's classifications of honey bee-collected pollen to identifications from DNA barcoding. We discuss the benefits and limitations of this machine learning approach relative to other methods and how it could be applied to identify pollen in other regions.

## Studying the resonance frequency of hawkmoth antennae

*Isaac Palmer, Adam Puchalski, Kostya Kornev*

We investigate whether hawkmoths (family Sphingidae) could use specific morphological properties of their antennae to probe the wind direction, not at the level of a single sensillum but at the scale of the entire organism. At this scale, the antenna works as a mechanical beam, and hence, its inherent bending properties become critical. We developed a specialized device that provides precise control over air pressure, frequency, and amplitude to investigate the dynamic response of hawkmoth antennae under varying wind conditions. A hawkmoth Manduca sexta was confined in a paper towel, but its antenna was sticking out and exposed to an oscillatory flow of air through a tube. By utilizing a high-speed camera, we captured the oscillatory motion of live hawkmoth antennae, enabling us to accurately track and quantify their amplitude. Our findings revealed a resonance frequency in the antennae that coincides with the wingbeat frequency of hawkmoths, suggesting a possible functional relationship between these two parameters. This relationship is prevalent in both males and females. The male hawkmoths have much more movement at the tip of their antennae when compared to the females. These findings showed that the resonance properties of the antennal beam are fine-tuned to the wing beat frequency. The biological implication of this coupling requires further comparative study to see if this feature is present in the other hawkmoth species.

## Transformations in the main and accessory olfactory systems in secondarily aquatic carnivorans

*Stephanie Palmer, Thomas Kirkwood, William Foster, Margot Michaud, James Rule, Julia Schwab, Siobhán Cooke*

Secondarily aquatic transitions are characterized by dramatic anatomical modifications. Navigation in an aquatic environment necessitates a drastic reorganization of the musculoskeletal system and the cranial and endocranial anatomy that supports it. Our goal is to understand the unique characteristics of the olfactory system in secondarily aquatic vertebrates.

Here, we investigate the anatomical transformations of the main and accessory olfactory systems in secondarily aquatic mammals including Pinnipedia (seals, fur seals, sea lions, and walruses) and Lutrinae (otters). We integrate published histological data, DiceCT and CT-based observations, and measurements of skulls and endocranial volumes within a phylogenetically justified sample of carnivoran taxa. Importantly, our sample includes fossils (e.g., Eoarctos vorax, Potamotherium valletoni) critical for more accurately informing character transitions during the pinniped land-to-water transition, and amongst carnivorans more broadly.

Our findings reveal that the volume of the main olfactory bulb relative to the rest of the endocranial volume is reduced in secondarily aquatic carnivorans. We identify a potential osteological correlate for the vomeronasal organ in Carnivora, the vomeronasal groove. Although this feature appears to be reduced in aquatic clades, there seems to be intra-specific variation and only minor differences among different ecological groups. Finally, we identify the presence of a vomeronasal organ in the lutrine, Lontra canadensis, using DiceCT data and discuss its implications for the evolution of the vomerolfactory system in secondarily aquatic mammals.

## A New Tool for Surveillance: PCR Assay for Raillietiella orientalis Infection in Live Snakes

*Jenna Palmisano, Anna Savage*

Raillietiella orientalis is a hematophagous crustacean that inhabits the lungs of reptiles and has spilled over from invasive pythons into Florida herpetofaunal populations. Raillietiella orientalis is rapidly spreading throughout Florida and is threatening native snakes. Infections in snakes are associated with lesions of the lungs, pneumonia, sepsis, anorexia, mortality events, and population declines. Rapid geographic expansion of R. orientalis is likely unavoidable, as it moves readily with abundant, widespread, and synanthropic host species. To provide a rapid and inexpensive surveillance tool for the detection of R. orientalis, we designed a novel PCR assay specific to R. orientalis that uses primers based on fixed DNA differences in the COI gene sequence between R. orientalis and other pentastomes. We validated this assay with 368 snake samples, including R. orientalis eggs, larvae, and adults, as well as adults and eggs of two native Florida pentastomes, Porocephalus crotali and Kiricephalus coarctatus, and adults of the congener Raillietiella indica. All negative controls (n=37) and samples of Kiricephalus (n=18), Porocephalus (n=20), and R. indica (n=11) did not amplify. In contrast, ~70% of fecal samples with egg presence and ~30% of positive control cloacal swabs amplified. This accessible detection tool will advance the monitoring of R. orientalis spread by supporting effective surveillance and informing response strategies to mitigate its impact on native snake populations.

## A rose by any other name: establishing the evolutionary origin for a "unique" reproductive organ

*Varun Paluri, Melissa Plakke*

The bursa copulatrix is an organ found within the reproductive tract of female butterflies and moths. The bursa presents as an outcropping of the reproductive tract and possesses teeth-like structures. It acts to accept and digest the complex male ejaculate and is intricately linked to the battle over female remating rate, fecundity, and paternity. Multiple insect species possess a similar organ, though parallels had not been previously established. Despite some of the female-specific organs possessing the same name and others their own unique classifier, it was unknown whether these organs stemmed from a single evolutionary origin or whether they represented convergent traits. We examined the scientific literature to determine whether there was evidence for the existence of a bursa-like organ within the female reproductive tract for each family of insects. These classifications were then used in an ancestral state reconstruction analysis to determine a possible evolutionary history for the bursa across insects. These results can be used to predict the functions and characteristics in the understudied systems and to make large-scale conclusions about the patterns of female-mediated reproductive outcomes.

## Morphological variation in mink mandibles (*Neogale vison*) not structured by continent-wide factors

*Alexandra Pamfilie, Natasha Vitek*

Trait variation within species is critical to population persistence under stressors such as disease, climate change, and habitat loss. A knowledge of the extent of this variation is important to predicting the responses of different species. In addition, the geographic structure of trait variation among populations can be used to infer the drivers of this variation. Here, we demonstrate the geographic structure of variation in mandibular and dental morphology in the American mink (Neogale vison), a North American mammal. The mink's native range stretches across multiple ecoregions, from Alaska to Florida, presenting a multitude of opportunities for local adaptation and variation in traits. Mandibular morphology was quantified using automated placement of high-density pseudolandmarks. Climate, available prey, and habitat vary widely across the mink's range and might reasonably select for mandibular traits. However, these factors do not strongly correlate to morphological variation over space at broad or continental spatial scales. High levels of morphological variation are exhibited within putative populations when compared to average shape differences across broad spatial scales. This may reflect the importance of competition and niche partitioning within populations, or it may reflect high levels of trait plasticity. The strength of the correlation between the morphological variation and the genetic architecture of these putative populations will inform if the shape variation within populations is driven by genetic dissimilarity or plasticity.

## Robotic fish swimming with the school: unlocking insights into collective behavior dynamics

*Yu Pan, George Lauder*

Fish collective behavior is a complex and interconnected process essential for foraging, evading predators, engaging in social interactions, and navigating through flow environments. While observations in the wild and in the lab have provided insights into fish collective behavior dynamics, controlled fish schooling experiments that involve behavioral modulation, particularly within altered flow environments, are limited. The impact of individual fish behavior and the associated altered flow on schooling dynamics remains largely unknown. To address this, we have developed a 3D-printed flexible fish robot, actuated by a servo motor, that mimics fish-like locomotion and interacts with a school of giant danio (Devario aequipinnatus) in a circulating water channel with controlled flow speeds. The fish robot is modeled after a giant danio, matching its size. Using two orthogonally arranged high-speed cameras in ventral and lateral views, combined with machine learning-based tracking methods, we capture the positions and undulating kinematics of individual live fish within the school for detailed analysis of schooling dynamics. Additionally, with digital particle image velocimetry (DPIV), we measure the flow field around both the fish robot and the live fish school, characterizing the hydrodynamic interactions between them. Our results reveal how the robotic fish, with varied swimming kinematics, influences the collective behavior dynamics of fish schools and how live fish dynamically respond to the altered flow environment introduced by the robotic fish.

## Phylogenomic reconstruction of the North American desert flowering genus *Fouquieria*

*Emeline Pano, Nico Cellinese*

Fouquieria is a flowering plant group native to North American deserts and dry tropical forests of Mexico. Diversifying about 7 Ma., transitions in growth habit, pollinators, and floral changes have occurred. Members exhibit woodiness or succulence, and the corolla ranges from white to bright red. Pollinators have been documented for some taxa and for others corolla color is suggestive of the pollinator, where white flowers are insects, whilst bright red are mainly hummingbird, and pink a combination. Fouquieria is monophyletic based on limited nuclear and plastid markers providing our current view of its evolution and biogeographic history. However, discordance at deep and shallow nodes pose challenges. Whole genome duplication events occurred at least twice, posing questions for the origin of polyploids: why are Fouquieria polyploids found only in the Sonoran Desert, and did WGD facilitated the distributions of polyploids? Here, I propose a deep genome skimming approach to generate a dataset of low-copy nuclear and plastome loci to reconstruct the history of Fouquieria to address trait shifts (e.g., succulence vs woodiness), the origin of polyploids and elucidate their population structure. Herbarium collections create the potential to sample across the distribution of Fouquieria and highlighting the importance of collections in phylogenetics. These peculiar plants present a system to study the evolution of polyploids and niche shifts in/between arid ecosystems of different climatic and geological histories.

## Characterizing food hoarding, stress, and anxiety in a mammalian hibernator

*Sebin Park, Ni Feng, Rose Margolies, Haocheng Wang, Genevieve Durtis*

Hibernators exhibit remarkable flexibility in behavior and neuroendocrine function across seasons and physiological states. Therefore, hibernators present a unique opportunity to investigate the mechanisms underlying dramatic and reversible changes in behavior and physiology across dimensions of biological variation. A typical hibernation season is characterized by alternating between two extreme physiological states: torpor, characterized by extended periods of low metabolism and body temperature, and inter-bout arousals (IBA), characterized by brief returns to an active-like state for 24 to 48 hours. Here, we investigate the neuroendocrine mechanisms underlying food hoarding in relation to stress and anxiety in a North American seasonal hibernator, the thirteen-lined ground squirrels (Ictidomys tridecemlineatus, 13LGS). Although 13LGS store and use body fat as the main source of energy during hibernation, individuals have been found to hoard food in the wild and captivity. We analyzed food hoard size and composition biweekly across seasons and physiological states. In the same cohort of animals, behavioral assays for anxiety were performed in the active state during the summer, fall, winter, and spring, as well as in the IBA state during hibernation. Finally, stress hormone levels were measured from fecal samples. Understanding how stress and anxiety contribute to survival behaviors such as food hoarding will provide novel insights into how conserved vertebrate physiological pathways can drive adaptive and maladaptive behaviors in diverse species, including compulsive hoarding in humans.

## The effects of feeding regime on energetics in common wall lizards (Podarcis muralis)

*Brittney Parks, Ashley Mollett, Eric Gangloff, Allison Litmer*

Understanding the interplay between feeding, energetics, and temperature in ectotherms is essential to understand population dynamics, especially in novel or changing environments. The impact of feeding regimes—including meal timing and size—on digestion has been underexplored, despite its important implications for reproduction and fitness. Previous research suggests that digestion is thermally-dependent, with warm temperatures promoting quick digestion, and that consuming smaller meals results in slower digestion. However, empirical evidence is limited. Our study quantified digestive passage time, energy budgets, and fecal and urate production in common wall lizards (Podarcis muralis) from introduced populations. We implemented four treatment groups based on meal size (large or small) and timing (morning only or morning and evening), with all animals experiencing a naturalistic temperature cycle (warm days at 34°C and cool nights at 25°C). Lizards consuming small meals took significantly longer to completely pass food items, regardless of meal timing. Energy budgets and fecal and urate production did not differ among lizards consuming food at different times of day or different meal sizes. Our findings suggest that wall lizard digestion is robust to temperature and food availability, which may contribute to their success in establishing introduced populations. This study highlights the importance of carefully considering feeding regimes and natural temperature cycles in laboratory studies, with implications for invasion biology and predicting responses to climate change.

## Ghosts in glass: ghost crabs as judges of glass sand for coastal restoration

*Emily Parrish, Jonathan Perez, Jeremiah Henning*

Coastal erosion impacts ecosystems worldwide. Restoration typically involves replenishment of sand that is dredged from deepwater despite evidence of high ecological damage and economic costs. As an alternative, sand made from recycled glass bottles may provide more sustainable substrate while reducing glass entering landfills. Our goal is to determine whether glass sand is a viable option for coastal restoration via its impact on a critical indicator organism in coastal dune ecosystems, the Atlantic Ghost Crab, Ocypode quadrata. Ghost crabs were live-trapped from Dauphin Island, Alabama and reared in sand environments containing full beach sand, half beach sand and half glass sand, and full glass sand for 8 weeks. In order to compare the stress responses of each treatment, the crab's initial and final stress hormone levels (Crustacean Hyperglycemic Hormone), carapace widths, weights, and claw dimensions were collected. There were no significant differences in mortality ($F=2,30=0.7585$, $p=0.4771$), carapace widths ($F2,14=0.4131$, $p=0.67$), weights ($F2,14=2.8286$, $p=0.09362$), or claw dimensions (dominant $F2,14=3.5073$, $p=0.05824$ and non-dominant $F2,14=0.2404$, $p=0.7895$). Overall, our growth and survival data indicate that recycled glass substrates may be a viable option for beach restoration projects, as evidenced by the lack of differences between ghost crab growth and survival between natural and glass substrates. Followup studies will focus explicitly on physiological and behavior changes in ghost crabs between our substrates.

## The presence of microbes on adult chondrichthyan skin

*Elizabeth Parsons, Katelyn Mika*

There is little known about the development and survival of marine organisms' external microbiomes. Within the chondrichthyan clade, it has been suggested that a minimal number of microbes are present on adult skin, however, the reason for this is still undetermined. The chondrichthyan epidermis is composed of dermal denticles and a mucous layer, each of which has been proposed to contribute to the limited existence of microbes in this environment. To examine this further, I utilized electron microscopy to determine where the microbes are seated on and around the denticles of Chain Catsharks (Scyliorhinus retifer). The results of the electron microscopy guided the experiment in two different, ongoing directions. Electron microscopy would be repeated on a 3D printed model of dermal denticles at different curvatures to see how the shape affects microbiome acquisitions over time. This would determine if the turbulence of ocean water through the denticles is contributing to the absence or presence of microbes on the epidermis. Subsequently, I am designing a protocol to isolate the chondrichthyan mucous layer to test its antimicrobial properties. This will provide more insight into how these microbes were acquired and adapted. Further research will investigate if these external features (dermal denticles and the mucous layer) are independent or interact in regard to the chondrichthyan microbiome.

## Linking neurocranial shape evolution and feeding performance in Lake Malawi cichlids

*Sarah Pascarella, Craig Albertson, Andrew Conith*

Cichlid fishes have undergone multiple adaptive radiations in the rift lakes of East Africa paring rapid taxonomic and morphological diversification. To assess the pattern of morphological evolution during adaptive radiation, we examined the neurocranium of four wild-caught cichlid genera from Lake Malawi: Labeotropheus, Tropheops,Maylandia, and Petrotilapia. Using 3D geometric morphometrics, we placed 39 homologous landmarks across the neurocranium and subjected these data to principal component (PC) analysis. We find cichlid neurocrania have diversified along a depth gradient, with shallow habitat species exhibiting shorter, wider neurocrania, and deep habitat species showing longer, narrower neurocrania. PC2 highlighted differences in the morphology of the vomer, a bone at the anterior tip of the rostrum that likely dissipates stress from feeding. In Tropheops, vomer angle is correlated with habitat depth—acute in shallow habitats and obtuse in deep habitats. To assess how vomer morphological differences impact performance, we will conduct behavioral trials using lab-reared specimens of the same genera, focusing on suction and scraping feeding modes. Suction feeding will be quantified using high-speed cameras to measure maximum gape, jaw protrusion, and prey velocity during feeding. Scraping behavior will be assessed by approach angle to an 'algal mat' and capturing dental impressions. Our findings highlight neurocranial shape variation among Lake Malawi cichlids and emphasize how traits like the vomer evolve rapidly as cichlids adapt to different habitat depths and feeding strategies.

## Characterizing auditory escape responses in *Aedes aegypti* mosquitoes

*Apple Patel, Michael Rauscher, Gabriella Wolff*

With mosquito-borne illnesses spreading into new territory due to climate change, it is increasingly important to understand mosquitoes' behavior in order to combat disease transmission. Mosquitoes rely on their auditory system for fitness as it plays a role in courtship and mating. Recently, studies have shown that the auditory system may also be used to mediate predator escape in mosquitoes. Lapshin and Vorontsov (2018) found Aedes diantaeus mosquitoes were repelled by sound in the 140-200 Hz range. These sounds may represent signals of aerial predators such as dragonflies and birds. Here we used a tethered flight behavioral paradigm to characterize auditory escape responses in male and female Aedes aegypti mosquitoes by tracking the kinematics of their responses to a range of sound stimuli. High speed videography showed sound stimuli in the 140-200 Hz range elicited increases in wing amplitude and wingbeat frequency changes. Directional steering changes in the head and wings were frequently observed, but did not clearly reflect the azimuth of the originating sound. Males responded to the stimulus with a slower time to peak wing amplitude response compared to females, indicating a sexual dimorphism not observed in visually mediated escape behaviors. Our results are consistent with the hypothesis that mosquitoes respond to low frequency sound stimuli with escape maneuvers, which may provide information towards future efforts in developing novel methods of mosquito control.

## The effects of eutrophication on the dwarf seahorse (*Hippocampus zosterae*)

*Darshi Patel, Dalila Sanchez, Emily Rose*

Algal-induced turbidity can alter several important aspects of reproduction and sexual selection. The dwarf seahorse (Hippocampus zosterae) exhibits conventional sex-roles and are an indicator species for threatened seagrass ecosystems. This study investigated the impact of algal turbidity and varying sex ratios on mate choice parameters and reproductive success of seahorses from Tampa Bay. The experimental design consisted of an equal 1:1 sex ratio and two sex-biased treatments: female-biased (2F:1M), and male-biased (1F:2M) with varying sized mate options in clear and turbid water (n=8, 128 seahorses). Clear treatments favored size-assortative mating (75%), while turbid treatments resulted in random mating regarding body size. However, reproductive success was similar across clear and turbid treatments (22.88 ± 4.35 offspring and 25.70 ± 3.55 offspring, respectively). Courtship behaviors were analyzed using BORIS for morning, noon, and night for 20 minutes each until copulation. Results reveal that behavioral investment is a strong indicator of mate choice preferences in sex-biased treatments regardless of turbidity. Rate of courtship behaviors show positive trend with brood size in clear water, with no relationship in turbidity. These minimal impacts of turbidity suggest that dwarf seahorses may have adapted to the varying seasonal eutrophic conditions in Tampa Bay and provides validity of prior findings from laboratory behavioral studies. Given potential environmental threats, this study highlights the impacts of eutrophication on seahorses to better implement effective conservation efforts.

## Conserving elasmobranch biodiversity: the urgent plight of shark-like rays in Sri Lanka

*Buddhi Maheshika Pathirana, Sahan Thilakaratna*

Guitarfishes are commonly described as shark-like rays due to their morphological features that closely resemble those of sharks. In Sri Lanka, only a small portion of small guitarfishes are locally consumed, the rest are often discarded at landing sites or used as bait for valuable fish species, which is not reflected in fisheries data. Hence, 20 randomly selected survey days were conducted at three sites (Negombo, Peliyagoda, and Dehiwala) between March 2023 and July 2024 to assess the catch composition and the type of fishing gear commonly encountered by these species. The catch was dominated by Rhinobatos annandalei (n=472), followed by Acroteriobatus variegatus (n=113), and Rhinobatos lionotus (n=31) respectively. Additionally, 02 specimens that may be new to Sri Lanka were recorded, and they morphologically differ from A. variegatus and R. lionotus. One A. variegatus specimen was a gravid female with 08 embryos and an interesting fact is that during embryonic development, gender differentiation occurred independently on both uteri. Ten pregnant specimens were recorded from all three confirmed species. These species were harvested using bottom-longline (n=122) and bottom-gillnet (n=08) in the coastal waters, with the gear used for the remaining being unknown. All confirmed species recorded above are listed as Critically Endangered in the IUCN Red List, highlighting the urgent need for conservation. Hence, this study continues to evaluate these species' status to develop management measures.

## Abundance of elasmobranchs observed on two separate days at two selected sites in Sri Lanka

*Buddhi Maheshika Pathirana, Sahan Thilakaratna*

In Sri Lanka, fisheries data on elasmobranchs' catch composition and diversity are limited. This study reveals the one-day catch composition observed separately at Negombo Fishery Harbour (NFH) and Peliyagoda Central Fish Market (PFM). Three hundred and twenty-three specimens were recorded from NFH on July 25, 2024, including 05 shark species (n=271) and 08 ray species (n=52). The shark catch was dominated by Prionace glauca (68.3%) followed by Carcharhinus falciformis (17.3%), and Galeocerdo cuvier (13.3%). The ray catch was dominated by Rhinobatos annandalei (46.2%) followed by Pteroplatytrygon violacea (27%), and Rhinobatos lionotus (19.2%). In PFM, 02 shark species (n=26), and 09 ray species (n=430) were recorded on July 28, 2024. The shark catch comprised 77% of Iago species and 23% of C. falciformis. The ray catch was dominated by Neotrygon indica (45.8%) followed by R. annandalei (34.4%), and Acroteriobatus variegatus (6%). Many fishers consider the quantity of harvest over the quality of meat, leading to the use of many landed species for low-quality dry fish production. From the recorded species, R. annandalei, R. lionotus, and A. variegatus are listed as critically endangered, and Isurus paucus, Isurus oxyrinchus, Mobula mobular, Mobula tarapacana, and Mobula birostris are listed as endangered in IUCN Red List. Hence, this study continues to evaluate species catch composition and the gear used in elasmobranch landings over time to develop a proper management framework.

## Preliminary insights into Galeocerdo cuvier and Brevitrygon species from Sri Lanka (ICONIC Oceans)

*Buddhi Maheshika Pathirana, Sahan Thilakaratna, Jasmin Graham*

This study is a part of the ICONIC Oceans project focusing on data-deficient fisheries of Galeocerdo cuvier and Brevitrygon sp. in Sri Lanka. At the preliminary stage, 24 muscle samples and 17 teeth samples from G. cuvier, and 44 tissue samples from Brevitrygon were collected for stable isotope analysis (SIA). For the DNA analysis, 47 and 50 tissue samples were collected from G. cuvier and Brevitrygon spp. respectively. The Brevitrygon specimens (27 females and 23 males) were harvested by coastal fishers using bottom gillnets. The disc width of females ranged from 150 to 250 mm while males ranged from 160 to 225 mm. Five specimens were gravid females. The weight of females ranged from 0.130 to 0.660 Kg and males from 0.167 to 0.425 kg. Offshore longlines were used to harvest G. cuvier. The total length of females (n=23) and males (n=24) ranged from 1900-3770 mm and 1860-3850 mm, respectively. The specimens were gutted soon after the landings, making it more difficult to get weight data. The samples collected for SIA will be used to track energy flow within ecosystems, and DNA samples will be used to confirm the species, especially the Brevitrygon sp. which is not identified to the species level. This study will continue with the support of the ICONIC project to improve fisheries management measures in Sri Lanka.

## The dietary ecology of sharks landed in Sri Lanka based on stable isotope analysis

*Buddhi Maheshika Pathirana, Sahan Thilakaratna, Karson Burton-Reeder, Divia Feinstein, Raven Harrison, Rose Leeger, Ashley Liao, Norah Mendoza, Ashley Mocorro Powell, Lelah Munyer, Jasmin Graham, Sora Kim*

Sri Lankan fisheries have substantial elasmobranch catches, but local ecology is not specified. We examine Galeocerdo cuvier Tiger shark and Brevitrygon sp. stingray, two elasmobranch species with variable life history and feeding ecology. Tiger sharks have a global distribution and are well-studied in some regions, but there is a lack of diet information for the Indian Ocean. In contrast, Brevitrygon are often misidentified to species-level but thought to largely feed on benthic flatworms. Here, we compare and contrast the feeding ecology of these two species with stable isotope analysis, which tracks the nutrient flow through food webs. Elasmobranchs were sampled after boats were on shore; muscle and teeth were sampled and dried before transport for stable isotope preparation. Muscle tissues were treated for lipid and urea extraction and dental collagen was isolated via demineralization. After treatments, all samples were frozen overnight, freeze-dried, and weighed for analysis at the Stable Isotope Ecosystem Laboratory of UC Merced (SIELO). The $\delta$13C and $\delta$15N values were normalized and corrected for linearity as well as drift with reference materials. These data were generated as part of the MISS ICONIC program that seeks Integrated, Coordinated, Open, Networked Inclusive Collaborations to characterize data deficient fisheries. Insights to the diet and trophic ecology will help determine conservation and management practices for these sharks that are classified on IUCN Red List of Threatened Species.

## Gene expression as a function of light: daily cycles and artificial light in green anole lizards

*Florissa Patterson, Grace Anderson, Violeta Trejo-Reveles, Alex Johnston, Simone Meddle, Michele Johnson*

Most organisms detect and respond to light through opsin proteins, present in both ocular and extraocular tissues. Diurnal patterns of photoperiod are predictable in the natural world, but the widespread use of artificial light at night, especially in urban environments, has altered the patterns of light exposure for many organisms. To determine how artificial nocturnal light influences the diurnal expression of opsins and other genes, we used RNAseq in green anole lizards (Anolis carolinensis; both sexes) to measure gene expression across diverse tissue types. In the laboratory, we sampled brain, eye, skin, gonad, and liver tissues of anoles at midday in full spectrum light, midnight in full darkness, and midnight with exposure to artificial light, and performed transcriptomics. Our initial analyses indicate that opsin expression patterns differ among tissue types, but not as a function of time or day or light exposure. We have found that overall gene expression varies in the brain between midday and midnight, and there is highly variable expression in anoles that have been exposed to artificial light at night. Together our findings highlight the importance of understanding the effects of light pollution on wild, free living, anoles as well as the complexities of light detection and its response across anole tissues.

## Effects of captivity on red ketocarotenoid production in Northern Cardinals

*Sara Patton, Rebecca Koch, Matthew Toomey, Yufeng Zhang, Geoffrey Hill*

Carotenoid-based coloration is a well-documented example of a signal used in mate choice, but the information conveyed by ornamental coloration remains contentious. We hypothesized that variation in the expression of carotenoid coloration is a result of environmental challenges affecting the production of the ornamental pigments from dietary precursors. We tested this hypothesis in a study of the Northern Cardinal (Cardinalis cardinalis), a songbird with extensive red coloration derived from metabolized red ketocarotenoid pigments. We induced an environmental challenge in wild male cardinals by holding them in captivity, and we measured bill coloration and the concentrations of red metabolized pigments in the plasma and growing feather follicles of both captive-held and free-living cardinals. We provided captive birds with abundant zeaxanthin and lutein, the dietary yellow pigments that cardinals enzymatically convert into red astaxanthin and alpha-doradexanthin. At the end of the environmental challenge, we observed no significant difference in bill color between captive and free-living cardinals, but captive males circulated significantly lower levels of alpha-doradexanthin. We observed no significant difference between captive and free-living birds in total yellow pigments within the follicles, indicating that captive birds ingested sufficient precursor pigments. These observations support the hypothesis that variation in red coloration can arise from environmental effects depressing the production of red pigments.

## Assessing the impacts of sensory pollutants on songbird diet and fecal microbial diversity

*Tessa Patton, Sara Lipshutz*

Human activities have transformed a majority of the Earth's land surface, resulting in unprecedented environmental challenges for species that inhabit these areas. Anthropogenic changes may impact the diets and gut microbiota of wild animals, and these can in turn impact growth, survival, and reproductive success. We propose to measure the effects of light and noise pollution on avian diet and fecal microbial diversity in a wildlife management area without other urban features. We will examine a wild community of insects and 6 songbird species that vary in life history traits. To identify family-specific impacts of light and noise pollution on insect richness and abundance, we will deploy insect traps across our sensory pollutant gradients. We will capture juvenile birds and collect fecal samples. We will extract DNA and conduct metabarcoding and microbiome sequencing, allowing for the identification of insect and microbial taxa. We predict that 1) overall insect richness and abundance will be positively correlated with light and negatively correlated with noise pollution, 2) insects in higher abundance will be found in greater quantities in the diet, and 3) dietary changes and environmental stressors will be reflected in the gut microbiome. Thus, we aim to determine species- and stage-specific responses to altered sensory landscapes to better understand the impacts of light and noise pollution across trophic levels in a rapidly changing world.

## Mus, mitos, & mammary glands: effects of heat stress during lactation on mitochondrial respiration

*Kailey Paul, Natalie Harris, Charlie Scharnatta, KayLene Yamada, Wendy Hood*

Lactation is one of the most energetically demanding events in a female mammal's life. Female mammals can increase their sustained metabolic rate up to 7-fold, suggesting that mitochondrial performance is central to successful reproduction. However, the tissue-specific mechanisms supporting mammals' energetic capacity increase are currently understudied. This study focuses on how oxidative phosphorylation and the electron transport chain support increased energetic demand by measuring mitochondrial respiration in lab mice (Mus musculus) under standard conditions and a heat challenge. Furthermore, this study is among the first to utilize mammary tissue in mitochondrial respiration measurements. We hypothesized that exposure to high temperatures would inhibit mitochondrial performance, decreasing maximal respiration. Seven days post-gestation, experimental mice were moved to heat treatment (30C) or remained at standard temperature (22C). Processing occurred on the 12th day post-gestation. Mitochondrial respiration was measured in the maternal liver and mammary tissue due to their integral role in supporting lactation. Contrary to our hypothesis, preliminary data reveals no difference between the two groups in maximal (mammary: $P=0.95$; liver: $P=0.41$) or baseline respiration (mammary: $P=0.84$; liver: $P=0.19$). Maternal and offspring body mass was significantly lower in 30C individuals (Maternal $P = 2.22 \times 10\text{-}5$; Pup $P= 1.69 \times 10\text{-}7$), indicating variation in nutrient allocation. Data on relative complex abundance and relative activity of the electron transport system complexes will be presented.

## Next Generation Developmental Evolution: A mechanistic model for tissue origination

*Mihaela Pavlicev, James DiFrisco, Alan Love, Gunter Wagner*

Although evolutionary transitions of individuality have been extensively theorized, little attention has been paid to the origin of levels of organization within organisms. How and why do specialized cells become organized into specialized tissues or organs? What spurs a transition in organizational level in cases where the function is already present in constituent cell types?

We propose a model for this type of evolutionary transition in terms of two key features of cellular self-maintenance: metabolic constraints on functional performance and the capacity for metabolic complementation between parenchymal and supporting cells. These features suggest a scenario whereby pre-existing specialized cell types are integrated into tissues when changes to the internal or external environment favor offloading metabolic burdens from a primary specialized cell type onto supporting cells. We illustrate this process of "supra-functionalization" using the pancreas and nervous system as examples. The model reveals distinctive concerns for explaining this type of evolutionary transition—instead of the suppression of "cheating" by components, the issue is how a tissue comes under modular genetic control to secure an identity as a body part—and also points to a novel type of evolutionary complexity-increasing ratchet.

## Assessing genome reference assemblies for use in sex chromosome telomere sequencing

*Brynleigh Payne, Tonia Schwartz*

Telomeres, protective sequences of DNA at the ends of chromosomes, are known aging biomarkers. Understanding how sex chromosome telomeres respond with age, relative to each other and autosomes, is especially limited. We are optimizing methods to sequence chromosome-specific telomeres in brown anole lizards, Anolis sagrei. Nanopore sequencing allows single, long reads through the telomeres providing chromosome-level information on telomere length/sequence not acquired through other quantification methods. This method requires high quality genome reference assemblies. Aims: (1) Assess the relative qualities of the two A. sagrei genome assemblies and their suitability as a reference. (2) Test if telomeres on sex chromosomes degrade more rapidly in the heterogametic sex (XY) versus the homogametic sex (XX) in parallel with sex-specific aging. To address the first aim, we contrast reference genome assemblies for summary statistics, BUSCO, and telomere-to-telomere assembly completeness. The Vertebrate Genome Project brown anole genome assembled telomeres/subtelomeres ranging ∼850bp to ∼22,000bp in length, sex chromosomes specifically ranging ∼7,500bp to ∼10,800bp. Multiple Nanopore MinION sequencing trials addressing the second aim are underway, comparing the Selective Sequencing Mode using genomic DNA and CRISPR telomere-enriched libraries. This new genome assembly allows the investigation of questions previously hindered by assembly completeness, including studies of chromosome-specific telomeres. This research will provide insight on the relationship between sex and telomere length at the chromosomal level, and how this changes with senescence.

## Has the European green crab (*Carcinus maenas*) benefited from parasite escape in North America?

*Catlin Payne, Carolyn Tepolt, Yaamini Venkataraman*

The European green crab (Carcinus maenas) is a non-indigenous species invasive in North America. NIS may benefit from parasite escape, which occurs when they lose co-evolved parasites during the introduction process. Free from parasite-associated physiological stress, NIS may be more resilient to other stressors. I surveyed parasite prevalence in North American C. maenas populations, then compared responses to heat stress in crab populations with and without parasite infections. Populations from Harpswell, ME (prevalence: 91.66%, metacercarial cysts); New Castle, NH (prevalence: 64% metacercarial cysts, 32% acanthocephalans); and Willapa Bay, WA (no parasites) were subjected to a heat stress of 30°C for 22 hours. Righting response, a measure of physiological health, was assessed before and after heat stress. Time-to-right in ME ($p = 0.0002$) and WA ($p < 0.0001$) populations significantly increased after exposure to heat stress, but not in the NH population ($p = 0.4$), likely due to small sample size and high inter-individual variability. Parasite load had no significant effect on individual righting response in any population. Since C. maenas are exposed to 19 parasite species in their native range, these results suggest that they tolerate the two species of parasites in North American well. Robust host defenses may be allowing C. maenas to benefit from parasite escape in North America despite their over 200 year occupancy on the Atlantic coast.

## Turning the frickin' frogs gay: the intersection of herpetology and queer internet culture

*Kannon Pearson*

A herpetologist asked to list essential features of a frog might describe the metamorphic life cycle, the skeletal morphology, or perhaps the skin's glandular composition. If an internet-savvy teenager were asked the same question, they might have a very different answer: frogs are gay. The association of anurans with queerness is a recent but prevalent phenomenon in digital spaces. This talk explores the possible origins of this association, from a beloved children's book series to homophobic conspiracy theories. I describe the unexpected cultural consequences of amphibian endocrinological research, and what this could mean for herpetologists – queer and otherwise – who engage in public outreach, teaching and mentorship.

## An investigation of developmental toxicity patterns in Rough-skinned and California Newts

*Kannon Pearson, Natalie Meyer, Michael Westphal, Gary Bucciarelli, Rebecca Tarvin*

Pacific newts (Taricha spp.) are poisonous salamanders common to the west coast of North America. Taricha are chemically defended against predation by tetrodotoxin (TTX), a paralytic neurotoxin which may be synthesized by bacteria living on the skin of the newts and which is most concentrated in cutaneous granular glands. The existing literature shows a predictable pattern in toxicity across rough-skinned newt (Taricha granulosa) development, wherein TTX is present in eggs, declines after hatching and during larval development, reaches its lowest point in newly metamorphosed newts, and then dramatically increases in the first three years of adulthood. Granular glands develop during metamorphosis, and amphibian skin microbiomes typically change dramatically at this time as well, suggesting a relationship between morphological and microbial developmental changes and tetrodotoxin acquisition. We seek to investigate the role and timing of microbial symbiosis and granular gland development in Taricha toxicity. We collected skin biopsies from larval, metamorphic, and adult T. granulosa and T. torosa (California newts) found together in a breeding pond in Santa Cruz County, California in September 2023. Our results narrow the developmental window in which TTX accumulation is known to start in T. torosa. We will subsequently investigate changes in microbiome composition, host and microbiome gene expression, and skin morphology and TTX distribution across sampled age stages.

## Thermal imaging indicates epinephrine is vital during stress-induced escape flights

*Bradley Pedro, L. Michael Romero*

The acute stress response is adaptive and key for surviving unpredictable environmental threats. Within seconds of experiencing a stressor, sympathetic-adrenal-medullary activation alters physiological processes, such as vasomotor activity, leading to body surface temperature changes. For wild animals, this ability to escape a threat is linked to fitness by increasing survival rates. However, few studies attempt to link an individual's physiological stress response to behaviors that increase survival. Here, we address this gap by eliciting escape flights in wild-caught house sparrows (Passer domesticus), a behavior associated with an acute stress response and essential for survival. During escapes, body surface temperature was measured as a proxy for sympathetic activation using infrared thermal imaging cameras, allowing for non-invasive continuous monitoring. Birds were housed in a large aviary and playback cues were used to induce escapes, wherein birds fly from one end of the cage to the other. Body surface temperature was measured before and after an induced flight. Body surface temperature decreased immediately following an escape flight and the timing of recovery varied between individuals. This study provides valuable insights into the dynamics of sympathetic activation during an essential behavior. Moreover, this work is a step towards linking the acute stress response with behaviors that increase fitness in wild animals.

## Cell proliferation in the nervous system during development and early ontogeny in the chain catshark

*Emily Peele, Jennifer Wyffels, Kara Yopak*

Chondrichthyan fishes (along with some bony fishes, amphibians, and reptiles) experience indeterminate growth, whereby the body and brain grow continuously throughout life. Previous studies on chondrichthyan nervous system development have described neurogenic niches, developmental timing events, and migratory pathways during both embryogenesis and adulthood. However, quantification of cell proliferation throughout the brain during embryonic and ontogenetic nervous system development in these species are comparatively undescribed. Cell proliferation was assessed in the chain catshark (Scyliorhinus retifer) at four embryonic stages (30-33; Ballard and Mellinger 1993) and three juvenile stages (1 week, 1 month, and 3 months post-hatch; n=5 per stage). Quantification of proliferating cells was assessed through the incorporation of the thymidine analogue 5-Ethynyl-2′-deoxyuridine (EdU), a marker for DNA synthesis. Brains were cryosectioned sagittally at 10$\mu$m and assessed immunohistochemically. NeuN and DCX antibodies were used to identify mature and migrating neurons, respectively, and proliferating cell nuclear antigen (PCNA), a nuclear marker reflective of cells entering the cell cycle, was used to identify proliferative neurogenic niches. Slides were imaged using a Zeiss Celldiscoverer7 and key proliferative zones in the forebrain, midbrain, and hindbrain were identified and compared across life stages using fluorescence intensity. This study characterizes cell proliferation across the entire rostrocaudal brain axis in a cartilaginous fish and provides a foundation to better understand plasticity in the nervous system during embryogenesis and early ontogeny.

## Testing for differences in sperm across an urbanization gradient

*Britta Pellegrin, Benjamin Pethe, Shannan Yates, Wayne Wang, Alex Gunderson*

Rising global temperatures present an ever-growing threat to the organisms on our planet. Many studies have examined the effects of heat on adult and sub-adult individuals, but the impact of climate change on gametes like sperm requires further study. Reproductive success is heavily dependent on gamete performance, and drastic changes in temperature may decrease their functionality. Cities provide a way to investigate adaptation to rapid climate change because they are warmer than nearby rural areas due to the Urban Heat Island effect. We tested for differences in sperm heat tolerance between male green anole lizards (Anolis carolinensis) from rural and urban areas in Baton Rouge, Louisiana. We predicted that urban animals would have a greater sperm tolerance than rural animals.

## Mechanics of bipedal hopping on uneven terrain

*Mary Pena, David Lin, Craig McGowan*

For animals that locomote on uneven terrain, the ability to negotiate abrupt surface changes that can impede forward progression and cause instability is critical for survival. The musculoskeletal system mediates such perturbations, but the mechanisms by which the elements of the musculoskeletal system work together to enable dynamic stability under such conditions are still not thoroughly understood. Here, we examine the mechanics in how kangaroo rats Dipodomys Deserti negotiate abrupt changes in surface slope. We collected high-speed video and ground reaction force (GRF) data of kangaroo rats (n=6) hopping bipedally on our variable terrain rotatory treadmill at 1.77m/s under two conditions: 1) level ground hopping, 2) perturbed hopping invoked by an instrumented 12 degree up-sloped wedge. We measured whole body and joint level mechanics observed in bipedal hopping using an inverse dynamics analysis to understand changes with the perturbation. We hypothesized GRFs would be modified to minimize whole body pitch and forward velocity changes. Although preliminary results are consistent with this hypothesis, we observe that the animals maintain forward progression by preemptively encountering the sloped plate with a greater forward velocity to compensate for increase braking impulses caused by altered GRFs, in which this absorption is mediated mostly at the proximal joints. These results are consistent with prior perturbation studies that shows division of labor across the hindlimb functions to maintain forward progression and stability.

## Testing spatial vision in apple snails, an emerging model for eye regeneration studies

*Quaid Pendleberry, Brandon Jolley, Madison Janakis, Daniel Chappell, Daniel Speiser*

Apple snails (Pomacea) are freshwater gastropods that can fully regenerate their camera-type eyes. They are an emerging model for studies of eye regeneration because they can be bred and raised in captivity and are amenable to genetic manipulation. A challenge common to all studies of eye regeneration is that eyes that appear to have fully regenerated may not be fully functional. Newly regenerated eyes, for example, may need to re-establish synaptic connections with the central nervous system before an animal regains vision. Demonstrating the functional significance of eye regeneration thus requires reliable tests of visual performance, which we are working to establish for Pomacea using behavioral assessments. We tested the responses of Pomacea to static isoluminant visual stimuli (of varying sizes) in their lateral field of view. Each stimulus consisted of a black stripe flanked by thinner white stripes against a gray background with an integrated reflectance value halfway between the black and white stripes. Under relatively bright light, apple snails showed a significant displacement with a unimodal distribution towards an isoluminant visual stimulus with an angular size of 40°, but displayed a uniform distribution when presented with a visual stimulus with an angular size of 80°. These trials indicate that apple snails have coarse visual spatial resolution and they provide methods for testing if and when spatial vision returns in Pomacea during eye regeneration.

## Lateralization of coiling behavior in Sistrurus rattlesnakes

*Zander Perelman, Jenna Palmisano, Terence Farrell, Michael Dreslik*

Brain and behavioral lateralizations are well studied in “higher” vertebrates but are overlooked in other taxa. Increasing evidence of lateralized behaviors in “lower” vertebrates, including fishes, reptiles, and amphibians, suggests brain lateralization may have evolved earlier than previously thought. Further studies in lower vertebrates are needed to better understand the evolution of lateralization among vertebrates, and here, we explored coiling behavior (clockwise vs anticlockwise) in free-ranging Eastern Massasaugas (Sistrurus catenatus, n = 68), free-ranging Pygmy Rattlesnakes (Sistrurus miliarius, n = 340), and captive Eastern Massasaugas (n = 319). There was no evidence for a coiling direction preference at the population level for any of the three groups and no preference when coiling observations of all free-ranging Sistrurus (i.e., Eastern Massasaugas and Pygmy Rattlesnakes) were combined (% clockwise = 0.51). However, repeated observations of captive Eastern Massasaugas reveal significant coiling asymmetries at the individual level. Although our results are similar to those found in previous snake laterality research, our study is the first to collect data from free-ranging and captive individuals. Our findings of a lateralized behavior displayed by a reptile provide additional insight into the evolution of behavioral lateralization among vertebrates. Future research should focus on understanding the causal mechanisms, such as potential associations between behavioral and brain lateralizations, and possible adaptive significance of individual-level coiling direction preferences in snakes.

## May the bite force be with you: a force-based classification of biting mechanisms in fish

*Tal Perevolotsky, Roi Holzman*

Biting fish display an astonishing trophic diversity, feeding on practically any prey that can be found in the water and is inaccessible by suction feeding. This trophic diversity is reflected in the morphologies of the jaws and bodies of biting fish, their behaviors, and ecological functions. Despite the potential richness in feeding mechanisms entailed by this diversity, there is much ambiguity in the biomechanical classification of biters.

Here, we define biting as force-dominated feeding form in which the fish's teeth and jaws directly contact the prey and exert force to procure it. This force can be exerted by the cranial muscles, but also through the movement of the head, fins, and body. The kinematics and morphology of each of these parts, and their integration, produce different force dynamics which lead to different prey capture performance.

We argue that the force exerted on the prey during feeding, its magnitude, direction, and timing are the key functional characteristics that determine biting success on different prey types. Accordingly, we suggest a force-based framework to reconceptualize and better understand the diversity of biting mechanisms. We use published and original results as well as first principles to generate a force-based classification of biting mechanisms. This framework could provide a grounded, quantifiable, and functionally relevant approach to understanding this complex feeding form.

## Diving into the Functional Morphology of the Northern Gannet, Morus bassanus, Cervical Vertebrae

*Alissa Perez, Meg Vandenberg, Bart Boom, Adam Summers, Ed Habtour*

High-velocity water diving is a rare hunting technique throughout the class Aves. The Northern Gannet is known for its unique plunge-diving method, surviving impacts up to 70 mph. This feeding strategy is mechanically counterintuitive for their survival due to the morphology of their long, slender, segmented necks. We describe the functional morphology of the Northern Gannet's cervical spine structure using contrast-enhanced and standard computed tomography scanning. We compared the morphology of 14 cervical vertebrae using 3D geometric morphometrics and took a range of motion measurements for each cervical joint to compare the flexibility along the neck. It was found that C1-C4 have an abnormally high aspect ratio and muscle volume aiding in counteracting sagittal plane bending behind the head. C5-C11 exhibits an increased range of motion and low aspect ratio, while the anterior C12-C14 vertebrae has a small range of motion and increased muscle volume, helping to counteract large moments near the base of the neck. These observations indicate that the vertebrae morphology helps counteract the bending moment around the head and body caused by diving. In contrast, the middle part of the neck functions more like a spring, offering a large range of motion with lower muscle volume. This morphological adaptation reduces the forces experienced during water entry, as demonstrated by our previous research.

## Individual recognition and group dynamics in a miniaturized gecko (Sphaerodactylus grandisquamis)

*Christian Perez, Brandon Hofmann, Manuel Leal*

Social recognition (SR), discrimination of conspecifics based on familiarity or class, underlies the evolution of social behaviors. Individual recognition (IR) represents a finer level of discrimination, in that an organism recognizes individual conspecifics via identity cues, increasing complexity in social structure. Group-living mammals and birds exhibit IR, whereas in reptiles, most empirical work has focused on SR in the context of territoriality. We use a miniaturized Puerto Rican gecko (Sphaerodactylus grandisquamis) to test each type of recognition behavior. In nature, Sphaerodactylus has the highest population densities among terrestrial vertebrates. We replicated their social environment by establishing 81 individuals in 18 social groups of 3-5 individuals. In 72 experimental trials, we introduced an unfamiliar individual or reintroduced a familiar individual to existing social groups, recording all pairwise interactions for two hours. We examined whether sex, familiarity, and group composition (i.e., sex ratio) are predictors of social interactions. Our preliminary findings suggest geckos show a higher frequency of interactions with unfamiliar individuals, regardless of sex, with more exploratory (tongue-flicking) and agonistic (tail-waving, darting, biting) behaviors. Across trials, individuals maintained consistent interaction types and frequencies with other individuals, suggestive of IR. Trials with a greater number of males showed an increase in agonistic female behaviors. Ultimately, our study characterizes social dynamics in Sphaerodactylus, and we highlight its potential as a system to study social behavior in reptiles.

## Effect of altered nest microclimate on hatchability of Eastern bluebird eggs across latitudes

*Jonathan Perez, Allison Cornell, Katalina Cunningham, Jennifer Houtz, Joanna Hubbard, Sila Inanoglu, Virginie Rolland, Lynn Siefferman, Sarah Knutie*

Climatic change is one of the most pressing threats faced by species worldwide. The frequency of extreme weather events including extreme temperatures is expected to increase under global climate change. This is likely to stretch the thermal limits of many species. These challenges are particularly acute in egg laying species, where environmental changes not only affect adult animals, but can also exert profound effects on developing young in ovo. Unable to thermoregulate for themselves, the developing young rely on parental care via incubation, in most cases, to maintain an appropriate environment for development. Extreme temperatures, either too hot or cold, will result in the death of the developing embryo and reproductive failure for the parent. However, the effects of climate change are unlikely to be homogenous in space and time. Here we utilize experimental manipulation of nest temperatures to investigate how nest temperature impacts fertility and hatchability of Bluebird eggs. Temperature manipulations including heating, cooling, or control treatment were performed at multiple sites across a latitudinal gradient stretching from Minnesota to coastal Alabama for approximately seven days during the second half of incubation. In assessing hatchability and incubation failure rates across treatments and sites we examined interacting effects of temperature, site and day of year.

## Do Darwin's finch mothers mediate the effects of urbanization on nest parasite pressure?

*Lorraine Perez, Jailene Contreras, Katia Goldberg, Gabriela Mena, Alexandria Soldo, Adriana Ugarte, Jaime Chaves, Sarah Knutie*

In the Galápagos Islands, the avian vampire fly (Philornis downsi) causes up to 100% nestling mortalities in Darwin's finches. Past studies have found that flies have less of an effect on urban nestlings compared to non-urban nestlings. One explanation is that the fly's ability to find nests varies across urban and non-urban areas since fewer urban nests contain parasites. Using nest video footage, we found that adult flies enter nests after the finch mothers leave it, suggesting that the departure of mothers provide a cue for flies to find active nests. For our study, we first evaluated whether sensitivity to nest disturbance by small ground finch mothers (Geospiza fuliginosa) differed between an urban and non-urban area. Urban females were less sensitive to nest disturbance than non-urban females (GLM, ($\chi 2 = 13.06$, df $= 1$, $P = 0.0003$). We then compared parasite prevalence and intensity in urban and non-urban nests and whether disturbance sensitivity by finch mothers mediated the effect of urbanization on parasite pressure. Parasite prevalence, but not intensity ($\chi 2 = 1.46$, df$=1$, $P = 0.23$), differed between urban and non-urban nests ($\chi 2 = 14.44$, df $= 1$, $P = 0.0001$), with fewer urban nests containing parasites. Contrary to our prediction, females who were highly sensitive to disturbance were less likely to have parasitized nests ($\chi 2 = 6.90$, df $= 1$, $P = 0.009$).

## Ontogenetic dietary shifts in deep-sea yeti crabs *Kiwa puravida* revealed by stable isotope analysis

*Rosamia Perez, April Stabbins, Emily Cowell, Kat Dawson, Erik Cordes*

Cold seeps are chemosynthetic habitats found in the deep ocean, where producers like bacteria generate energy from inorganic carbon sources. Kiwa puravida, an Anomuran yeti crab endemic to Mound 12, a cold seep on the Pacific Costa Rican margin, cultivates and feeds on these chemosynthetic bacteria. These bacteria employ different carbon fixation pathways, with the most common being Gammaproteobacteria, which use the Calvin-Benson-Bassham (CBB) cycle, and Epsilonproteobacteria, which use the reverse-tricarboxylic acid (rTCA) cycle. Previous research has shown many chemosymbiotic crustaceans experience a shift in the relative abundance of these bacterial groups throughout their development, which potentially leads to dietary changes. We hypothesized that as K. puravida matures from juveniles to adults, it undergoes dietary shifts driven by changes in the dominant bacterial communities. To explore this, we collected individuals across all life stages, from young juveniles to fully grown adults, and performed stable isotope analyses. Initial results revealed that juveniles exhibited lower $\delta$13C values, consistent with a diet dominated by Gammaproteobacteria, which use the CBB cycle. In contrast, adults showed more enriched $\delta$13C values, indicating a greater reliance on Epsilonproteobacteria, which use the rTCA cycle. These findings support the theory that K. puravida undergoes an ontogenetic shift in diet as it matures, reflecting changes in the bacterial communities associated with different life stages.

## Indicators of bull shark population health in a natural spring fed shark nursery

*Stephanie Perez, Alyssa Andres*

Kings Bay and its associated Crystal River represent the second largest spring-fed ecosystem in Florida, offering idyllic nursery habitat for young, temperature-sensitive bull sharks. Natural freshwater springs provide thermal and saline stable waters year-round distinguishing this potential nursery and ecosystem from known bull shark nurseries across the US Gulf of Mexico and Atlantic coasts. The strength of a nursery ecosystem is pivotal for survival in sharks' most vulnerable life stages but may vary significantly between nursery locales. To determine the strength of the Crystal River nursery, we aimed to identify the health of the bull shark population within. Biometric and blood parameters (lengths, girth, mass, external parasite presence, dermal denticle integrity, evidence of previous capture, blood hematocrit and platelet volumes) were collected from newborn-juvenile bull sharks captured within the Crystal River Bull Shark Project monthly shark survey. Parameters were modeled across sex, life stage, and seasons and compared over the project's initial 18-month period. Results will be used to create visual indices of health when paired with analyses of total muscle lipid content, blood indicators of stress (stress hormones, pH, electrolyte and metabolite levels), and immune system response (white blood cell counts) planned for spring 2025. This work will allow us to better understand the efficacy of this bull shark nursery and can be used as a model for evaluating a healthy shark population.

## Heterogeneity in gene expression during infection is augmented by host prior pathogen exposure

*Anna Perez-Umphrey, Jeremy Miller, Edan Tulman, Jesse Garrett-Larsen, James Adelman, Steven Geary, Dana Hawley*

It is increasingly recognized that in many wildlife disease systems, prior pathogen exposure results in incomplete or waning immunity, leading to reinfections of some hosts. However, the effects of this heterogeneous protection on the within-host environment and the selective pressures on the pathogen remain poorly understood. In this study, we tested how variation in songbird prior exposure to a pathogen (none, low, or high dose) alters gene expression variation during reinfection. We experimentally varied house finch (Haemorhous mexicanus) exposure to their endemic bacterial pathogen, Mycoplasma gallisepticum (MG), which causes conjunctivitis, and allowed them to recover. Then we collected transcriptomic datasets during in vivo secondary challenges with the same MG strain: two host lymphoid tissues (conjunctiva - the primary infection site - and spleen). Our results show that, relative to pathogen-naïve individuals, prior pathogen exposure increases host gene expression heterogeneity in the conjunctiva, with low priming doses resulting in greatest variation in host gene expression. Likewise, prior exposure treatment modulates differential gene expression at several hundred genes in the conjunctiva. Interestingly, host prior exposure treatment did not influence expression variation in the spleen and differential gene expression was minimal. Our findings suggest that variable acquired protection among previously exposed hosts, particularly those given low prior exposure doses, may create heterogeneous within-host conditions that ultimately influence pathogen evolution.

## An inexpensive off-the-shelf plankton roller for rearing individual marine invertebrate larvae

*Bruno Pernet*

In laboratory experiments in larval ecology larvae are usually reared in only a few large stirred containers per treatment. The small number of replicates means that statistical power is often low. An alternative is rearing larvae individually in many small containers, but attempts to do this are rare, perhaps because it is not obvious how to stir such containers. Plankton rollers are a possible solution to the stirring problem. I evaluated the performance of an inexpensive, easily available plankton roller – a hot dog roller – for this purpose by culturing larvae of the sand dollar Dendraster excentricus in three treatments: in typical 500 mL stirred culture beakers, and in 20 mL vials with and without rolling. Larvae in rolled vials grew at the same rate and reached metamorphic competence at the same time as those in beakers, but had higher (but acceptable) mortality rates; larvae in vials without rolling grew more slowly and reached competence later than those in the other treatments. To demonstrate the utility of this approach, I then reared individual larvae of D. excentricus across a range of food rations to describe family reaction norms for phenotypic plasticity in ciliated band length. This method allows intensive replication of treatments and easy tracking of individual larvae, complementing more traditional experimental methods in larval ecology.

## Vertebral Variation in Juvenile Goby Fish, ‘O’opu Nōpili, in Relation to Escape Performance

*Emily Pertuit, Kelly Diamond, Marissa Maheu, Alex Johnson, Richard Blob, Heiko Schoenfuss*

Vertebral morphology can have important impacts on how animals move, especially for animals that rely on axial bending as their primary mode of locomotion. Differences in vertebral number and relative size can affect escape performance by influencing their ability to bend laterally to produce thrust. We studied juvenile goby fish, o'opu nōpili (Sicyopterus stimpsoni), as a model system to test relationships between vertebral morphology and escape performance. We predicted that fish with longer, taller vertebrae and more distance between vertebrae would have more vertebral surface area for muscle attachment and, hence, would accelerate faster than fish with shorter vertebrae. Alternatively, fish with shorter and/or a greater number of vertebrae could increase the amount of bending possible, which could positively impact acceleration. To investigate this, we compared escape performance data, including minimum chord distance and acceleration, to 3D vertebral measurements, such as vertebral length, vertebral height, and intervertebral space along the vertebral column. We find that similar to adult o'opu nōpili, metrics of juvenile vertebral morphology vary along the vertebral column. Intervertebral distance was greatest at the caudal end of the vertebral column, while the opposite pattern was found for vertebral height. Vertebral length was shortest in the mid-section of the vertebral column. This study highlights how variation in vertebral size can influence the bendiness of fish and affect acceleration and the potential to escape predators.

## Cteno-bot: a free-swimming, ctenophore-inspired robot with magnetoactive metachronal propulsors

*David Peterman, Margaret Byron*

Many aquatic organisms swim via metachronal coordination of multiple appendages. This swimming strategy involves sequentially beating propulsors with a phase lag between neighbors. This behavior is observed in organisms ranging from ciliated microorganisms to ctenophores, crustaceans, polychaetes, and others, with propulsors spanning microns to centimeters. Metachronal coordination can offer many benefits across this large range of scales, including the efficient generation of fluid flow and increased performance in acceleration, braking, and turning.

Using magnetoactive silicone elastomers, we developed artificial propulsors inspired by the cilia-based propulsors of ctenophores. On a stationary robotic platform, we demonstrate that subtle differences in beating kinematics can produce large differences in generated fluid flow (influencing swimming performance and feeding). These results highlight the importance of appendage-level kinematics, and several coordination parameters between appendages. We incorporated these magnetoactive propulsors into a free-swimming robot, actuated by a spiral magnetic drive shaft, capable of controlling any number of propulsors within range of its magnetic field. This design offers solutions to several engineering challenges, involving: 1) coordinating hundreds of propulsors at prescribed beat frequencies and phase lags, 2) simplifying actuation mechanisms (requiring only a single motor), and 3) maintaining proper hydrostatics with a weighted, watertight body and external propulsors. It also presents an opportunity to further investigate the physical mechanisms underpinning metachronal swimming while informing the design of free-swimming, bioinspired robots.

## The role of vision and flow sensing in the schooling behavior of fish in flow

*Ashley Peterson, Matt McHenry*

The impressive coordination between schooling fishes is largely dependent on vision and flow sensing. Vision is necessary for schooling in many species and flow sensing has recently been shown to serve as a vital channel of communication for maintaining a cohesive school. However, it remains unclear which characteristics of the wake generated by neighboring fish provide useful information to an individual within the school. Through a combination of synchronous kinematics and flow visualization measurements, we tested the effects of school size, ambient light levels, and flow sensing on the communication between schooling fish. We found that the level of communication, quantified by mutual information, was significantly reduced at low levels of illumination and by chemical ablation of the lateral-line system. By mapping patterns of flow to temporal and spatial variations in communication, we were able to pinpointed the flow cues vital for aiding school cohesion.

## Behavior, hybridization, and range expansion

*Karin Pfennig, Catherine Chen, Patrick Kelly, Sedona Ryan, Bryson Loflin*

Hybridization (mating between species) can enable range expansion by a species into a novel habitat occupied by a resident species. However, random hybridization and genetic incompatibilities between species can impede adaptive evolution to new habitats, precluding range expansion. Yet, behavior promoting predictable hybridization and recurrent selection on hybrids can overcome these issues and allow hybridization to facilitate the adaptive evolution in new habitats required for a species to expand its range. Empirical data in spadefoot toads are consistent with this possibility and suggest that hybridization might be an important way that species rapidly adapt to novel habitats. Such results are important for understanding how species respond to global change.

## Experimental investigation of terrestrial odor perception in loggerhead sea turtles

*Katrina Pfennig, Lillian Prince, Jadyn Sethna, Dana Lim, Kayla Goforth, Catherine Lohmann, Kenneth Lohmann*

Loggerhead sea turtles (Caretta caretta) perform extraordinary long-distance migrations, with remarkable site fidelity to nesting and foraging grounds. It is hypothesized that turtles use bimodal navigation to reach these sites, using magnetic cues to traverse long distance and olfactory cues for specificity. We hypothesized that turtles might use terrestrial olfactory cues for navigation to nesting grounds. Specifically, we determined if turtles detect and respond to alpha-pinene, a plant-based volatile organic compund found in many plants along the coast where sea turtles nest. We tested 16 loggerhead sea turtles in an olfactory arena at UNC Chapel Hill, recording both the number of breaths and the time spent with nares out of the water in response to each treatment: food, seawater, and alpha-pinene. There were significant differences in time with nares out between seawater and food, and between seawater and alpha-pinene. This suggests that turtles detect and respond to alpha-pinene, a first step in suggesting how they might localize their nesting location.

## Variation in physiological responses and its impact on molecular damage markers in the zebra finch

*Kevin Pham, Natalie Gassman, Haruka Wada*

Understanding the causes and consequences of individual variation in physiological responses is one of the fundamental goals of the Damage-Fitness model. Thus, this study aimed to identify the degree to which individual variation in the 1.) adrenocortical and 2.) glucose stress response after exposure and recovery from constant light is related to molecular damage markers in the blood and tissues of zebra finches (Taeniopygia castanotis). To examine this relationship, we designated individuals in the upper and lower thirds of the distribution in stress and glucose responses as “high” or “low” responders. We then compared differences in broad-spectrum DNA damage in the blood, and protein carbonyl and lipid peroxidation in the tissues. We asked whether there were differences in damage markers between high and low responders of both physiological parameters in general, and with respect to treatment groups. In general, we found no differences in damage markers across tissues between high and low responders in the adrenocortical response, and this pattern persisted within treatment groups. In contrast, individuals who mounted higher glucose stress responses suffered greater protein carbonyl damage in the pectoralis muscle, however this pattern did not persist when looking within treatment groups. Our results provide slight evidence that individual differences in mounting physiological responses may come with transient changes in molecular damage, however, does not lead to long-term costs.

## The genomics of urbanization in house mice

*Megan Phifer-Rixey, Renè Clark, Adrienne Kasprowicz, Samantha Giancarli, Stephen Kupchella, Logan Lacy, Nina Mallalieu, Maddie Balman, Jason Munshi-South*

Urbanization introduces a suite of major abiotic and biotic changes, e.g., temperature, pollution, the built environment, and diet. These changes can, in turn, impact the evolutionary trajectory of wildlife. For example, they may alter patterns of gene flow and genetic diversity or exert selection pressure. House mice (Mus musculus domesticus) are a useful system for studying the evolutionary impacts of urbanization. House mice live in close association with humans, are near ubiquitous in both cities and rural areas, and are a genetic model system. Moreover, there are growing population genomic resources for house mice both in the Americas and Europe, their native range, providing key resources. Our ongoing project uses an integrative approach to investigate how mice in urban and rural habitats differ from phenotypes to genomes. We sampled >100 mice in three cities (New York City, NY, Philadelphia, PA, and Richmond, VA) and nearby rural areas. Using a paired replicate approach facilitates identification of novel and shared differences among cities. By bringing together diverse phenotypic data, microbiomes, transcriptomes, whole genomes, and the resources of a genetic model system, we hope to gain new insight into the impacts of urbanization.

## Diversification and speciation in an endemic radiation of Galápagos Land Snails (Naesiotus)

*John Phillips, Dylan DeBaun, Christine Parent*

Adaptive radiations occur in the presence of ecological opportunity, but underlying mechanisms that promote diversification are often poorly understood. To test for influential components of an adaptive landscape, we analyze the impact of extrinsic factors on diversification of an endemic radiation of land snails in the Galápagos Archipelago. We tested for the role of ecological (microhabitat and vegetation zone) and geological (island age, size, isolation) factors in diversification. All analyses accounted for phylogenetic signal and state-dependent speciation extinction (SSE) models were implemented to measure shifts in diversification rates across niche and physical space. We calculated branch specific diversification rates for analysis as they changed over the ontogenetic lifespan of the volcanic islands. Our findings suggest that rates of speciation and diversification are 1) higher in humid than arid vegetation zones, 2) higher in terrestrial than arboreal species, and 3) higher on geologically young than old volcanic islands in the Galápagos Archipelago.

## Do Longer Lizard Jaws Have More Teeth? A Comparison Among Green Anoles with Indeterminate Growth

*Sofia Phucas, Michele Johnson*

Vertebrate teeth facilitate prey capture and consumption, and in some taxa, are critical in social or defensive interactions. Tooth structure, including size and shape, is closely associated with tooth function, but we still know little about how dental composition varies with age and/or size in many vertebrate taxa. Green anole lizards (Anolis carolinensis) have heterodont detention that is used in food consumption and combat. This species experiences indeterminate growth, such that body size is a proxy for age, but we do not yet know how dentition varies from hatching through adulthood. We examined a series of hatchling, juvenile, and adult specimens, measuring variation in tooth size, number of teeth, and intertooth intervals in the lower jaw. Based on findings from other vertebrate taxa, we predict that larger jaws exhibit larger but not more numerous teeth. We also quantified tooth damage, predicting that larger (i.e., older) lizards will exhibit more wear. These results will assess the extent of intraspecific variation in tooth morphology in a wild population, and contribute to our understanding on vertebrate dental ontogeny.

## Identification of an aquaporin (CrAQP2) in *C. riparius* larvae and its response to road de-icers

*Britney Picinic, Maniola Sufaj, Jean-Paul Paluzzi, Andrew Donini*

The freshwater midge, Chironomus riparius, is found throughout the Northern hemisphere and serves as a bioindicator of water quality. Their osmoregulatory organs, including the gastric caeca, midgut, hindgut, Malpighian tubules, and anal papillae allow them to excrete water while absorbing ions from their freshwater habitats. During winter months, snow and ice hazards are mitigated by the application of de-icers predominantly as NaCl. These de-icers enter nearby water as run off contributing to the salinization of freshwater. Recently, "eco-friendly" alternatives to NaCl including brine beet juice de-icer (BBJD) have been implemented, to reduce the use of NaCl. Little is known about their effects on freshwater organisms. This study aimed to identify aquaporin (AQPs) genes in the osmoregulatory organs of midge larvae and study effects of NaCl and BBJD on AQP abundance and function. AQPs are water channel proteins that permit water through the cell membrane and are critical for osmoregulation. We identified an AQP gene, CrAQP2, in larval C. riparius, which is analogous to the Aedes aegypti AQP2 and Drosophila melanogaster PRIP. We found expression of AQP2 in all osmoregulatory organs in the midge, with highest expression seen in the Malpighian tubules. Furthermore, we observed significant changes in AQP2 transcript abundance in the organs of BBJD and NaCl-treated midges. Current work with knockdown of CrAQP2 will allow us to study its functional importance in these midges.

## Coevolution and the phylogenetic comparative method

*Jason Pienaar*

Coevolution can be defined as reciprocal heritable change in interacting species caused by natural selection imposed on each other and is often hypothesized to be a major driver of biological diversification. Phylogenetic comparative methods (PCM's) are a primary tool for assessing adaptive hypotheses, but we lack a rigorous, multivariate framework for analyzing coevolutionary interactions among species. Here we describe a conceptual PCM framework based on the multivariate Ornstein-Uhlenbeck process that can explicitly disentangle specific coevolutionary effects from other evolutionary influences on the trait values of sets of related, interacting species. We discuss how when taken together with patterns of co-cladogenesis, the hypothesis that coevolution drives diversification might be evaluated.

## Rice root navigation in heterogeneous substrates

*Christopher Pierce, Yusuf Tekes, Daniel Goldman*

Roots must navigate complex soil environments to self-anchor and find nutrients. Unlike fossorial animals, they perform this task through growth rather than movement. Previously, Taylor et al [PNAS 2021] showed that in addition to gravitropism (the tendency to grow in the direction of gravity) soil traversal may also be enabled by circumnutation, where the growing root tip articulates a helical path. Gravitropism and circumnutation have largely been studied in homogeneous, transparent substrates (gels), or in experiments that assay successful self-anchoring above ground. Thus, insights into the functional role of these behaviors in soil are limited, due to soil's opacity and rheological complexity. We overcame these limitations by imaging rice roots (Oryza sativa, $N \sim 10$) in quasi-two-dimensional, resin-printed lattices of mm-scale posts in various geometries. This model substrate elicited several features of root growth in complex environments: solid obstructions, self-anchoring, and geometries that prohibit alignment with gravity. We quantified root kinematics in the obstacle fields, identifying several reproducible behaviors. For example, roots pushed themselves out of the array during collisions until three discrete anchor points (root against post) were established. When the lattice contained no gravity-aligned paths, roots periodically reoriented their growth direction to maintain an overall downward trajectory. This system allows the realization of behaviors previously observed above ground, with simultaneous access to the root growth dynamics that facilitate them in the substrate below.

## Characterization of mites and their effects on the development and microbial systems of dung beetles

*Eve Pieri, Armin Moczek, Joshua Jones*

Dung beetles are a diverse group of beetles that are important in many agricultural, ecological, and evolutionary systems. Adults filter feed herbivorous mammalian feces and move from one dung patch to another, using them as habitats and reproductive materials. In many dung beetle habitats, it is well established that there are a variety of different mite species living amongst and interacting with the population of dung beetles. The relationship between mites and beetles is unclear, however it is hypothesized there may be a symbiotic relationship between them. The complex parameters of this relationship are yet to be elucidated. One known relationship characteristic is phoresy. Phoresy is when an individual uses a host as a method of transportation from one location, often a food source, to another. Phoretic mites (mites exhibiting phoresy) are commonly seen in dung beetle colonies, however it is unclear if all mites fit into this category. Here, we aim to (i) identify the species of mites present via genomic DNA sequencing, (ii) characterize the developmental relationship between dung beetles and mites, and (iii) determine if mites act as vectors of microbes. Further research will continue to clarify the recondite relationship between mites and dung beetles.

## Effects of exercise on starvation-selected Drosophila melanogaster

*Katrina Pinili, Elena DeLaTorre, Allen Gibbs*

We studied the effects of exercise on replicated populations of Drosophila melanogaster that have been selected for starvation resistance for over 180 generations. Starvation-selected (SS) flies display cardiomyopathy, poor locomotor ability, and reduced flight ability compared to fed control (FC) flies. Because D. melanogaster is considered a model of both obesity and exercise, we investigated the effect of exercise on survival, locomotor ability, and endurance of SS and FC flies. Flies followed a 3-week exercise regimen using the Fly Roller, a custom-built device that rotates cohorts of flies in vials, inducing movement through their negative geotactic and positive phototactic responses. Upon exercise completion, locomotor ability was assessed by conducting a rapid iterative negative geotaxis (RING) assay. To quantify survival and endurance of flies we counted the number of survivors daily throughout the regimen, and assessed fly exercise activity from video recordings, respectively. Results suggest that exercise can increase survivability in FC and SS females but not in males. Exercise may not affect locomotor ability for flies, which decreased for all populations throughout the regimen. SS males exercised longer on the Fly Roller than females. This work highlights the impact of exercise on important life traits of obese Drosophila.

## Any Cut, Anywhere – Programmable Synthetic Restriction Enzymes

*Brian Pipes, Kayla Kelly, Michele Nishiguchi*

Symbiosis between the luminescent marine bacterium, Vibrio fischeri, and its squid host, Euprymna scolopes has become a powerful model for studying the molecular mechanisms of bacterial specificity during symbiosis. Environmentally acquired bacteria can be genetically modified before being introduced into newly hatched aposymbiotic squid hatchlings, however, design and construction of commonly used plasmid vectors is time-consuming and intensive, hindering the advancement of symbiosis research. Therefore, as a modern alternative to standard plasmid cloning, we report on the development and application of a novel plasmid construction methodology that utilizes programable synthetic restriction enzymes, based on the Pyrococcus furiosus Argonaute (PfAgo) enzyme. PfAgo can introduce double strand cuts at any location on a plasmid by binding to target plasmid DNA sequences with the aid of complementary16bp ssDNA guide sequences. To demonstrate proof-of-principle of PfAgo cloning, we constructed plasmids designed with artificial restriction sites in place of natural restriction sites and used PfAgo digestion to generate both blunt and sticky-end products. Ligase Cycling Assembly was used to combine our PfAgo generated products, along with synthetic dsDNA constructs, into multiple novel V. fischeri strains for use in natural transformation studies. The ability of our PfAgo cloning methodology to construct plasmids without the limitations of traditional restriction enzyme cloning will greatly expand the potential of synthetic biology and advance our understanding of the molecular underpinnings of bacterial symbioses.

## SwarmZoo: Development of Collective Behavior Datasets

*Ava Pistacchio, Audrey Kellogg, Amani Webber-Schultz, Joseph Legris*

The SwarmZoo Project, funded by the Office of Naval Research's Collective Autonomous System Technology (CAST) program, harnesses collective animal behaviors to enhance models of group dynamics, inspired by phenomena such as schools of fish and swarms of bats. This research contributes to the development of a neural network framework designed to analyze and interpret behavioral data from diverse species. Using footage collected in the field from three angles, we extracted and processed viable segments from two camera angles, using a k-means algorithm to select segments with the most movement. This resulted in the detailed tracking and labeling of approximately 90 individuals. Challenges such as brief visibility and occlusion were addressed to ensure accurate data. These labeled datasets were integrated into DeepLabCut, a 3D markerless pose estimation tool to develop a neural net that learns the movement of each individual in a swarm as well as the movement of the swarm as a whole. The positions output from the neural net allow for the modeling of hydrodynamic interactions and predator-prey dynamics. Insights from swarm behavior, including object avoidance and foraging patterns, further inform these models. Future research will explore the application of these models to a mechanical system simulating interactions with environmental factors such as predators, allies, and objectives.

## Time-calibrated functional phylogenomic analyses of the metazoan pangenome

*David Plachetzki, Jennifer Spillane, M Pankey, Joseph Ryan, Matthew MacManes*

Phylogenomic analyses of genomic datasets have revolutionized our understanding of metazoan relationships, but the functional composition of such datasets is also informative of phylogeny and may contain important recursive insights on the diversification of animals. To explore this potential, we examined the evolutionary histories of animal gene families using 115 high quality genome scale datasets representing the major lineages. Leveraging a robust phylogeny placing ctenophores as the sister to the remaining metazoan clades, and information on ∼600,000 discrete orthogroups obtained in separate analyses, we reconstructed the evolutionary histories of animal gene families using Dollo parsimony. Our approach provides insights on the metazoan pan genome, and the timing of functional genomic diversification of animals. The functional genomic landscape of animals is vast and only a fraction is contained within the human genome, or any extant species. Lineage specific genes are common and account for roughly half of the unique orthogroups. While most nodes in animal phylogeny are characterized by a net loss of gene families, a few lineages, including sponges and cnidarians show elevated degrees of loss, thus eliminating several major functional classes and highlighting the role of gene loss as an engine of adaptive evolutionary change. Conversely, only a few ancestral nodes in animal phylogeny represent significant bursts of genomic innovation, emphasizing the infrequency of sustained genomic expansion as a catalyst for evolutionary shifts.

## Which factors affect thermoregulatory decisions in urban common wall lizards (Podarcis muralis)?

*Gabrielle Plunkett, Tyler Williard, Logan Fraire, Sierra Spears, Emma Foster, Devon Haley, Alyssa Head, Maya Moore, Brittney Parks, Jasmyn Zimmerman, Shala Hankison, Allison Litmer, Eric Gangloff*

The ability to effectively thermoregulate is important for most ectotherms, since body temperature determines the rate of nearly all physiological processes. However, for most organisms we lack understanding of which environmental factors affect thermoregulatory behaviors and their behavioral patterns over an entire day. Introduced populations of the common wall lizard (Podarcis muralis) in Cincinnati, Ohio, USA are thriving after an introduction 70 years ago. Notably, they display increased thermophily compared with native European populations. To non-invasively quantify daily thermoregulatory behaviors, thermoregulatory effectiveness, and variation across populations, we used infrared thermography (a thermal imaging camera) to conduct repeated standardized surveys every 30 minutes across their normal activity period (08:00 to 20:00) in multiple locations. We also measured wind speed, air temperature, humidity, solar radiation, and UV radiation while 3-D printed operative temperature models measured potential available temperatures throughout the activity period. Wall lizards are highly effective thermoregulators, though activity time is limited by available environmental temperatures even on extremely hot days. Further, high levels of UV exposure limit activity, even when temperatures are favorable. Such data on daily activity and thermoregulatory decision-making, especially in an urban habitat, provides great insight into how wall lizards can thrive in cities and have the potential to expand their current range.

## Integrating collective and centralized control in sea star locomotion

*Theo Po*

Locomotion is guided by a combination of mechanics and neural control. Neuromechanics provides a framework for integrating neural signals, body mechanics, and sensory feedback to allow organisms to adjust their movements under varying environmental conditions. While traditional models of neuromechanics emphasize central nervous control, a diversity of animals use a distributed nervous system to control appendages that collectively work together during locomotion. My research on sea stars identified how they use both collective and centralized control to coordinate hundreds of appendages within a single organism. This unique combination of collective and centralized control is what I call Collective Neuromechanics. A striking feature in sea stars is that hundreds of appendages called tube feet move in unison during locomotion. Through animal experiments, mathematical modeling, and robotics, I found that hundreds of tube feet can collectively increase their coordination in timing based on mechanics alone. Additional animal experiments demonstrated that sea stars are capable of phototaxis. The results suggest that sea stars can centrally integrate light information from their eye spots to control for directional coordination of their tube feet. My research with sea stars demonstrates how diverse biological systems integrate both collective and centralized control to achieve effective locomotion.

## Antibiotic activity detection by the disk diffusion method in plasma from healthy domestic dogs

*Eliza Podlas, Zach Lightfoot, Jack Bennink, Priscilla Van Wynsberghe, Ana Jimenez*

Much research in ecoimmunology has focused on exploring predictions that larger animals that tend to be longer-lived would have a higher investment in safety because they are longer-lived. The domestic dog is an interesting model to consider for this type of question, as smaller dogs tend to live comparatively longer than larger dogs. Here, we used frozen blood collected from dogs, from a 2-lbs Chihuahua to a 217-lbs mastiff, to screen for antibacterial activity across body sizes and ages of dogs by standard disc diffusion method against three bacteria: Escherichia coli (CSH36), Bacillus subtilis (6051), and Micrococcus luteus. We found that zones of inhibition for B. subtilis were marginally significantly different across sex/spay/neuter status, however, corrected zones of inhibition for B. subtilis showed a significant difference across sex/spay/neuter status. Both cases demonstrate a significantly greater zone of inhibition for intact females compared with spayed females, intact males and neutered males. There was a significantly positive correlation between zone of inhibition and age for E. coli and a marginally significant correlation between corrected zone of inhibition and age for B. subtilis. There were no significant correlations with body mass and any of the measured variables. Our data suggest that older dogs can improve their antibacterial activity as they age, and that body size does not demonstrate an effect against antibacterial activity.

## Latitudinal patterns of life-history variation in the egg-encapsulating Eastern mud snail

*Robert Podolsky, Kora Hansen*

A key area of life history theory examines how resources are allocated in the tradeoff between egg size and number. This tradeoff can be shaped by selection, plasticity, or passive effects of conditions on oogenesis. Through its association with environmental variation, latitude can create strong patterning in variation of life history traits. While such patterns are established for free-spawning marine species, we have relatively few tests in species that encapsulate eggs during early development. Eggs in clutches, for example, can experience oxygen depletion, concentration of CO2 and other wastes, and associated changes in pH, which may all be exacerbated by higher temperatures. Thus, the consequences of encapsulation could alter patterns of variation in egg size and number with latitude. We are examining variation among populations of the Eastern mud snail, Ilyanassa obsoleta, along a latitudinal gradient on the Atlantic coast of North America. Adult size, capsule size, and clutch size increase significantly with latitude, though this change is not monotonic. Additional analyses of egg size and energy content are being used to test predictions of the effects of latitude on the tradeoff not only between egg size and number but also between clutch size and number.

## Changes in ambient [Ca2+] levels impact egg production and development of *Lymnaea stagnalis*

*Carolyn Pope, Martin Grosell*

The common pond snail, Lymnaea stagnalis, produces embryos that hatch within 10 days of being laid and emerge from the egg mass with a fully developed shell. Previous studies have shown that the development of L. stagnalis is impaired by a reduction in ambient calcium. In this study we aim to characterize the impacts of ambient calcium on the production of egg masses by adult snails, the calcium content within egg masses, and impacts on adult snails' shell calcium content. Additionally, we aim to identify if L. stagnalis egg masses acquire calcium from the water during their development. Adult individuals were randomly assigned a treatment of low, medium, or high [Ca2+] water, produced egg masses were collected daily, and feed intake was quantified. Egg masses, snail shells, and snail soft tissue were measured for calcium content. Egg masses were collected from culture tanks and [Ca2+] uptake measurements were conducted daily until egg masses hatched. There was a significantly higher number of egg masses produced by snails in higher [Ca2+] compared to lower [Ca2+]. Thus, egg production by adult L. stagnalis is impacted by ambient water calcium levels. Ongoing analyses are examining to what extent adult snails provision egg masses with calcium, a trait potentially limited by low ambient [Ca2+].

## Investigating Regulatory Networks Governing Motor Neuron Development in a Non-Vertebrate Chordate

*Sydney Popsuj, Alberto Stolfi*

Neural regulatory networks in the vertebrate spinal cord and their downstream central pattern generators (CPG) are responsible for complex and essential behaviors ranging from breathing to locomotion. However, given their ponderous responsibility in survival of the organism, it has been difficult to characterize how these essential components develop. To better understand the development of spinal cord neuron subtypes, our work instead focuses on Ciona robusta, a non-vertebrate chordate and closest extant sibling taxa to vertebrates.The Ciona Larval Motor Ganglion (MG) has been proposed to be homologous (or minimally very analogous) to the vertebrate rhombospinal region and is thought to be the CPG for Ciona swimming behavior. This work investigates the maintenance and maturation of the two motor neurons primarily responsible for carrying out locomotion within the MG. We have recently reported that Motor Neuron 2 uses a conserved Neural Agrin/LRP interaction for the formation of a vertebrate-like neuromuscular junction, however little is known about the regulation of Motor Neuron 1, which is thought to control left-right swimming behavior. I am investigating the form and function of genes uniquely expressed in Motor Neuron 1 to better understand the development and regulation of coordinated swimming behavior. Taken together, this work will expand our understanding of the regulatory mechanisms guiding development of a CPG such as those vital to vertebrate evolution.

## Mechanisms for muscle maintenance in hibernation

*Alexandra Porczak, Brianna Mark, Derek Jann, Ni Feng*

Mammalian hibernators exhibit a remarkable ability to preserve skeletal muscle mass and function during prolonged periods of inactivity, a phenomenon that contrasts the muscle atrophy typically observed in non-hibernating species under similar conditions of disuse. Model hibernators, such as the thirteen-lined ground squirrel (Ictidomys tridecemlineatus), must maintain a delicate balance between muscle protein synthesis and degradation despite extended durations of hypometabolism and immobility during hibernation. Hibernation is characterized by alternating physiological states: weeks long torpor bouts are briefly interrupted by 24–48h inter-bout arousals, during which there is a return to an active like state. In this study, we investigate the underlying mechanisms of hibernator muscle homeostasis by measuring key morphological features such as myofiber diameter and myonuclei number. Additionally, Neuromuscular junction morphology is compared across active and hibernation states to determine if there are changes in muscle innervation patterns. Finally, we employ the rotarod to measure behavioral changes in motor performance across hibernation. Understanding mechanisms of muscle maintenance despite prolonged immobility can advance therapeutics for neuromuscular atrophy due to disease, bed rest, and even changes under low gravity during space travel.

## 3D anatomy of the hyolingual apparatus of the white-bellied pangolin (*Phataginus tricuspis*)

*Lillian Porter, Christopher Zobek, Conner Verhulst, Eric Hostnik, Copper Aitken-Palmer, Casey Holliday*

The tongues of pangolins are quite derived compared to other mammalian ant-eating specialists, extending nearly a body length to capture food. Anteaters, aardvarks and pangolins all pack portions of their hyolingual apparatus into their thoracoabdominal cavity via oropharyngeal, cervical and xiphisternal structures. Here we explore the musculoskeletal anatomy of the pangolin tongue using DiceCT, 3D modeling and some dissection of a cadaveric specimen to better understand its function. The tongue extends into an extracoelomic pouch in the abdominal cavity. Retractor muscles attach to paired, elongate xiphisternal bones which form a coil. The tongue is separated by an ensheathing glossal tube by a mucosal layer allowing smooth movements. The glossal tube is an evaginated pouch from the oropharyngeal cavity built by layers of circular and longitudinal muscles. The pharyngocervical anatomy of the system is quite complicated due to the infolding of the glossal tube as it extends caudally from the oral cavity. As the thoracoabdominal portion of the tongue emerges into the oral cavity, it is bounded by not only the walls of the glossal tube, but two, dense, fibrous cushions that extend medially from the oropharyngeal wall, largely blocking access to the esophagus. We interpret these cushions as squeegees, which scrape food items off the tongue as it is retracting. Besides their intriguing functional significance, these structures obstruct safe intubation of pangolins in clinical settings.

## Vertebral mechanics and joint morphology in two divergent dogfish species

*Marianne Porter, John Long, Candido Diaz, Harald Kryvi*

Depending on swimming speed and body position, curvature varies along the body of individuals, and among species. Curvature is mediated by body and vertebral column stiffness. We examined the dynamic mechanical properties and vertebral morphology, including joint histology, along the vertebral column in two phylogenetically distant shark species, Squalus acanthias and Mustelus canis. For dynamic mechanical testing, we translated single axis movement of vertebral column segments into bending over a range of frequencies and curvatures experienced during swimming. We found that the complex modulus (a measure of the composite material properties), the storage modulus (a measure of elasticity), and the loss modulus (a measure of energy dissipation) all varied by bending curvature and body segment, but not between species. Specifically, moduli were all greatest closer to the caudal peduncle, suggesting that the caudal region storesand releases more elastic energy during swimming. Despite similar mechanical properties between species, vertebral morphology varied, most notably in the intervertebral joints. In Squalus the intracentral canal is large, with adjacent intervertebral capsules separated by a thin membrane; in contrast, the Mustelus intracentral canal is narrowed by a fibrous plug. These differences may generate varied hydrostatic stiffness in the joints during swimming. We hypothesize that increased stiffness near the caudal peduncle, in two phylogenetically distant species, suggests that there may be a general solution for thrust production in sharks.

## An AI infrastructure for organismal biology

*Arthur Porto*

Biodiversity, a critical component of our ecological resilience, faces threats from rapid environmental change and habitat degradation, with many species still undiscovered and numerous others endangered. Traditional methods for studying biodiversity are slow and labor-intensive, unable to keep pace with these threats or capture the detailed information needed for effective conservation. In this talk, I will propose a novel solution: a multimodal AI infrastructure to facilitate the querying and processing of biodiversity data. Central to this endeavor is the utilization of extensive, high-quality datasets from pioneering initiatives such as iDigBio and GBIF. These datasets, comprising over 139 million records of text associated with over 55 million images, are meticulously curated, and provide a rich source of authoritative, accurate, and comprehensive data.

Our objective is to transform biodiversity research by leveraging synergistic analyses of textual and image data to enhance species identification, enrich data annotations, and enable robust semantic searches, thereby uncovering novel ecological and biological insights.

## Circadian rhythm of flower traits facilitate nocturnal pollination in apple Malus domestica

*Sushant Potdar, Madison Jennings, My Ly, Dmitry Kutcherov, Neelendra Joshi, Erica Westerman*

Plant-pollinator interactions are complex multi-trophic relationships. Plants have evolved traits for pollination based on native pollinator communities across space and time. Yet, we rely on diurnal non-native bees for pollinating commercial crops, potentially reducing productivity in the face of declining bee populations. Moreover, we know very little about nocturnal pollinator communities, and plant traits that may mediate pollination at night, though recent data suggest nocturnal pollinators are important for apples and blueberries. Using an integrative approach, we first investigated the circadian rhythmicity of plant traits that mediate insect visits, such as floral volatiles and nectar volumes in apple (Malus domestica) flowers. Next, we quantified gene expression in three flower tissues (petal, ovary, and stamen) of non-pollinated flowers collected during the day (11:00) and night (23:00) to assess whether changes in gene expression correspond to changes in volatiles or nectar. We found that flower volatile profiles were different between day and night samples, with higher counts for compounds which attract moths like benzaldehyde and $\alpha$-farnasene at night, while the nectar volumes remained constant. We identified distinct transcriptome signatures associated with time of day in petals and ovaries, but relatively little circadian transcriptomic change in stamen tissue. We discuss these results in the context of the complex suite of diurnal and nocturnal pollinators that visit apples, and implications for future research elucidating pollinator services in the anthropocene.

## Stingray spine diversity reflects trade-offs in breakability, puncture, and removal performance

*Emily Poulin, Matthew Kolmann, Melanie Stiassny, Christopher Martinez*

During predator-prey interactions, the effectiveness of defensive structures directly impacts organismal fitness. Serrated venomous spines, a synapomorphy of stingrays (Myliobatiformes), cause severe mechanical and physiological damage to predators. The effectiveness of a spine to puncture an attacker, and either be withdrawn and reused or fractured and embedded, is central to the stingray's survival. We examined spine diversity across 30 stingray species based on a collection of seven functionally relevant morphological traits measured from micro-CT scans. After a PCA on these traits, we created a series of five 3D-printed models to test puncture and removal performance of linear combinations of spine serration traits sampled across the primary axis of variation (PC 1). Models were embedded or withdrawn from silicon with a density comparable to vertebrate skeletal muscle. Finally, we created four additional model series, varying each spine serration trait in isolation to understand their individual contributions to puncture and removal performance. We show that stingray spine evolution is characterized by a trade-off between gracile forms that puncture deeply and require low removal force versus robust spines that generate shallow puncture depths and high removal forces. Our work illustrates how morphological diversity of stingray spines carries important functional and performance implications that are relevant to their interactions with would-be predators.

## Gene expression responses to drought conditions in two imperiled darter species

*Chance Powell, Erica Westerman, Hans Hofmann, Yiting Ter, Daniel Magoulick, Kearstin Findley*

Anthropogenic changes to the habitats of diverse taxa constitutes one of the leading threats to biodiversity, with ecological impacts on a global scale. Conservation and management practices would benefit from being able to predict effects and mechanisms of anthropogenic disturbance on species. Anthropogenic water demands, drought, climate change, and land use have impacted freshwater ecosystems globally. The Yellowcheek Darter (Nothonotus moorei), an endangered fish endemic to the Little Red River in Arkansas, and a similar species, the Yoke darter (Nothonotus juliae) have shown population declines likely due to a combination of these factors. To investigate the molecular mechanisms behind Yellowcheek and Yoke Darter response to typical seasonal drought conditions we performed mesocosm experiments subjecting both species to drought and non-drought (control) conditions. Fish were recovered alive at the end of the experiment and individuals were processed immediately upon removal from the mesocosms. We grossly dissected gonads, liver, gill and brain (telencephalon, hypothalamus, and rest of brain) followed by transcriptome analysis by organ. We identified distinct transcriptomic signatures between the two species. Additionally, we also discovered species differences in the response to drought that might reflect the difference in resilience that has led to the decline of the Yellowcheek Darter.

## Coral rapid acclimatization is facilitated by microbial and algal communities under climate change

*Maya Powell, Karl Castillo*

Coral reefs are crucial to global biodiversity and local economies, yet highly vulnerable to climate change, making them a research priority. Semi-enclosed inland bays in Curaçao are uniquely extreme and variable, and semi-analogous to future ocean conditions. Studying corals in these multi-stressor environments will help us uncover mechanisms for coral resilience. This study aims to understand coral-associated microbial and algal interactions and their role in acclimatization and stress tolerance. Siderastrea siderea and branching Porites sp. samples were transplanted between a bay and reef in Curaçao over 1 year. We find that Porites sp. shuffled their symbionts to thermotolerant and halotolerant species when transplanted to the bay and to less stress tolerant symbionts when transplanted to the reef. However, Porites sp. microbial communities stayed stable in diversity and composition across transplant sites and time. In contrast, S. siderea all shuffled to increase their thermotolerant symbionts regardless of where they were transplanted. Additionally, transplanted S. siderea microbiome communities shifted drastically, while native S. siderea maintained stable microbiomes. Lastly, we find two different cryptic lineages of each coral species, which show unique correlations with microbial communities for both coral species. These results display how corals can utilize different strategies for acclimatization to stressful conditions, and their genetic diversity, microbial and symbiont communities are all key to future coral survival under climate change.

## Sex on a Spectrum: plasticity in hormones, genitalia, and social behavior in a marine fish

*Devaleena Pradhan*

Sex on a Spectrum: plasticity in hormones, genitalia, and social behavior in a marine fish

Devaleena S. Pradhan

Sex change is an adaptation that allows organisms to increase their reproductive success by transforming to another sex in response to changing environmental conditions. Here, I will provide an overview of both rapid and long-term phenotypic responses during life history transitions in a remarkable natural system – a highly social fish species, the bluebanded goby, Lythrypnus dalli, that is capable of lifelong serial (back and forth) sexual plasticity. These fish live in social groups consisting of a single parenting male and multiple subordinate females. Status resolution following a disruption of hierarchy involves a repertoire of behavioral and functional sex change. I will present ongoing well established and novel approaches used in the lab to investigate the emergence of endocrine, morphological, and spatiotemporal gene expression changes during both protogynous (female first) and protandrous (male first) sex change across the entire body axis. This involves expression of sex-specific displays of behavior and structural reorganization of internal and external reproductive organs for release of functional gametes. While some phenotypes are expressed synchronously whereas many traits manifest at different rates, organisms that change sex exist in a spectrum of phenotypes that are in a state of flux and over time, become fixed into the new discrete sex.

## Spatial patterns and behavioral rules of pollen deposition

*Prathibha Prasanna Chandran, Peter Marting, Stephanie Rogers, Michael Smith*

Over 120 MYA, bees transitioned from insect prey to pollen as their primary protein source. While solitary bees typically place their pollen alongside an egg in a simplified nest, social bees must stockpile pollen within a complex nest. In the honey bee, Apis mellifera, how colonies store their pollen within a 3-dimensional nest remains an open question. Previous work suggested that foragers initiate new pollen cells randomly. Here, we combine descriptive work and mathematical modeling to investigate how pollen patterns emerge. We first describe pollen patterns in 3-dimensional colonies (n=6), showing that pollen storage is highly biased (41.1 ± 16.7% of a colony's pollen is stored in a single comb). We then examine how pollen patterns emerge within empty combs (without brood) and find that pollen is not deposited randomly but highly biased (44.9 ± 14.9% of a colony's pollen is stored in a single comb; n=17 colonies). Finally, we use cellular automata to build three models that differentiate between potential behavioral rules (random, brood-bias, spatial-bias, pollen-attraction) and experimentally show that colonies employ a combination of pollen-attraction and spatial bias when depositing pollen. Combined, this work provides a framework for investigating how behavioral dynamics lead to spatial patterns at the colony level.

## Using fishes to illustrate why we need to talk more about replicability in evolutionary morphology

*Samantha Price*

There are a multitude of 'small' decisions we make every time we do science and not everyone will make the same choices. These decisions are taken throughout the scientific process, from planning to publication, and include choices such as which taxa to work on and what data transformations to use. In psychology this is known as "researcher degrees of freedom". As this phenomenon is rarely considered in evolutionary morphology, I illustrate the impact that decisions taken during the data analysis phase can have on the inferences made from phylogenetic comparative analyses. Combining studies using our publicly available FishShapes v1 dataset of linear morphometric measurements of body length, depth, and width on 6000+ teleost species I demonstrate how common analytical choices including whether to build a morphospace with the correlation or covariance matrix, and what to do with outliers, influence our understanding body-form evolution across teleost fishes. These findings illustrate how small decisions taken during data analysis can influence replicability and reproducibility in studies of evolutionary morphology and thus, why these issues should be discussed more frequently by evolutionary morphologists.

## Prolactin and parental care in a sparrow with a behavioral polymorphism

*Mackenzie Prichard, Isabel Fraccaroli, Frédéric Angelier, Donna Maney*

The hypothalamic-pituitary-prolactin (HPP) axis plays a crucial role in parental behavior across vertebrates. In birds, this pathway is mediated by a neuropeptide called VIP; VIP synthesized in the infundibular nucleus of the hypothalamus (IN) acts as a releasing factor for prolactin from the pituitary. VIP is one of the many genes captured by a chromosomal inversion that affects parental behavior in white-throated sparrows (Zonotrichia ablicollis). It has been shown that individuals of white-stripe (WS) morph, which possesses the inversion, engage in less parental behavior and have less VIP expression in the IN than individuals of tan-stripe (TS) morph. Therefore, we hypothesized that the morph differences in parental behavior may correspond to a general upregulation of the HPP axis. In the present study, we quantified prolactin mRNA expression in the pituitary, prolactin hormone in plasma, and parental provisioning in free-living white-throated sparrows. We predicted that these measures would be higher in the TS birds than the WS birds. Our results showed that plasma prolactin was higher in TS males than WS males, which mirrored a morph difference in parental provisioning. There was not, however, a corresponding morph difference in prolactin mRNA expression in the pituitary. This research provides a uniquely comprehensive view of the HPP axis in free-living birds and may shed light on some long-held hypotheses about the molecular basis of parental care.

## Phenotypic correlations in response to urbanization: a test case for constraints to adaptation

*Eric Prileson*

Rapid adaptation is a vital mechanism for organisms to respond to anthropogenic change, yet adaptive evolution alone might not be sufficient to keep pace. This evolutionary lag could be due to constraints driven by correlations between traits; however, trait correlations might not be antagonistic but instead facilitate adaptation. Cities make an excellent habitats to test if trait correlations hinder or promote rapid adaptation as cities are globally replicated with a suite of heterogeneous novel stressors. Although there are now multiple lines of evidence of individual trait responses to urban stressors across taxa, whether in general multiple traits are correlated in response to urbanization – and how they affect adaptation to the urban habitat – is unknown. Here, we review the urban evolution literature in a meta-analysis to test the degree to which responses to the unique selective pressures of urban habitats are correlated using phenotypic variance-covariance matrices. We concurrently test the direction and magnitude of urban trait correlations and if these differ compared to non-urban populations. If trait correlations of responses in urban habitats are negative, this could be evidence that response to the urban habitat comes with tradeoffs whereas positive trait relationships or a lack of trait correlation, could be evidence for alternative processes. More broadly this study investigates if trait correlations could be a major contributor to the evolutionary lag in response to environmental change.

## Personality and spatial learning in poison frogs

*Claire Pringle, Sabrina Burmeister*

Notable for its complex social and spatial interactions, the green-and-black poison frog (Dendrobates auratus) is an ideal organism for studying the relationship between personality and cognition. In our captive-bred population of D. auratus, we found that some individuals were more successful at learning to use visual cues to exit a two-arm maze than others. However, using standardized assays, we found that the personality traits of boldness and exploration did not predict learning in the two-arm maze. To further explore variation in personality and learning, we conducted the same assays in a wild population of subjects. Wild-caught frogs were bolder and more exploratory compared to captive-bred frogs, but initial results suggest that they were neither quicker to learn nor more successful at learning. However, unlike in the captive-bred population, frogs that learned tended to be bolder than non-learners ($p=0.08$). When the two populations were considered together, there was a trend for latency to first move in the two-arm maze to predict later learning ($p=0.07$), suggesting that initial willingness to explore the maze may predict later learning. Our results suggest that the relationship between personality and learning is weak or context-dependent.

## The Neurodegeneration Computational Fellows Program: A model for computational training at HBCUs

*Dominique Pritchett, Kebreten Manaye, Vilas Menon*

With the advent of large-scale epidemiological, social, genetic, and molecular studies of neurodegenerative diseases, there has been a revolution in our understanding of the genetic, genomic, and socioeconomic determinants underlying these diseases of aging. However, the majority of large cohort studies in the United States have been predominantly composed of individuals of European descent. Recent initiatives at federal and private funding agencies are working to increase the diversity of aging and neurodegenerative disease cohorts. However, there remain two major gaps: a need for computational scientists to spearhead the analysis of these increasingly large data sets, and a lack of representative populations of such computational biologists critically needed for better understanding and interpretation of results from increasingly diverse cohorts. To address these gaps, we have developed the Neurodegeneration Computational Fellows (NDCF) Program to establish a cohort of bioinformaticians, biostatisticians, and computational biologists recruited from Historically Black Colleges and Universities (HBCUs) and Minority Serving Institutions (MSIs) to broaden the community of researchers within the field of neurodegeneration.

## Deformation of the upper vocal tract of birds by passive motion: implications for sound production

*Pauline Provini*

The vocal repertoire of birds is incredibly diverse. They vocalize using a specific organ, the syrinx, producing a primary vibration at the origin of a primary sound. This sound propagates through the upper vocal system, composed of the trachea, the larynx, and the oral cavity. The large volume of this system, compared to mammals of similar size, suggests that it plays a role in the modulation of the sound initially emitted. To investigate this, we filmed 21 species of dead birds and manipulated them under biplanar X-ray. Markers were implanted in tissues (e.g., on the trachea, glottis, beak) to calculate the passive deformations and volume changes of the vocal tract during a range of movements of the neck/head system. Our results show that neck extension and beak closing are associated with an elongation of the trachea of up to 20% of its initial length. We tested the effect of such elongation on sound modulation using computational simulations. Our work shows that the complexity of bird vocalizations is not only related to the syrinx, but also to the entire upper vocal system. This work provides new elements to better understand complex communication, one of the amazing characteristics we share with birds.

## The effect of developmental moisture on morphology and survival in the brown anole (*Anolis sagrei*)

*Jenna Pruett, Axl Defrese, Maggie LaBorie, Ezra Tapponnier*

Plasticity can shape phenotypes across a diverse range of organisms, but also across life stages. Plastic responses during developmental life stages are especially likely to have a significant impact on the trajectory of an organism's life. Egg laying species that lack parental care are well-suited for studies on developmental plasticity because the effect of specific environmental factors can be isolated from parental influence. Two environmental factors of interest, especially in light of changing climates, are temperature and moisture. Most studies on the effect of moisture or temperature on development have a limited number of treatments (hot and cold; wet and dry). These studies are an important starting point, but lack the resolution necessary for quantifying plastic effects in an environment that varies continuously. The brown anole (Anolis sagrei) has been a useful system for studying plastic responses to developmental environments; however, when compared with temperature, less is known about the effects of moisture on development in reptiles more broadly. Anoles, like many other reptiles, lay porous, parchment shelled eggs, making them susceptible to fluctuations in substrate moisture. To quantify the role of moisture in shaping phenotypic variation and survival, we incubated brown anole eggs under seven substrate moisture treatments and measured post-hatching growth and survival. We generated high-resolution reaction norms that show significant effects of moisture on hatching success, hatchling size, and post-hatching survival.

## Transgenerational plasticity as a mechanism of heat wave adaptation in porcelain crabs

*Liliana Pruett, Jonathon Stillman*

The porcelain crab, Petrolisthes cinctipes, is an intertidal crab native to northern California that gets thermally stressed during low tide. Some mothers produce broods of embryos sensitive to thermal stress, while others produce thermally tolerant broods, though the source of thermal tolerance remains unclear. I hypothesized that transgenerational plasticity (TGP) is an important mechanism of thermal tolerance. TGP may occur when mothers experience increased thermal stress during oogenesis and make thermally tolerant embryos. To investigate this, I exposed 48 crab pairs, held immersed at 14°C, to one of four different arial heat stress treatments of 32°C 0, 0.5, 1, and 3 times per week for one hour over 7 months. Broods of embryos were collected within a week of oviposition and divided into two groups of 12 embryos each; a treatment group that was subjected to heat stress for one hour (32°C) and a control group held at 14°C. Embryos were placed in a 96-well plate and imaged weekly to measure yolk-consumption and growth rates, and time to mortality or hatching. In all four treatments, control embryos hatched ~50% of the time. Hatching increased in treatment embryos from a little over 0% in the control group to over 25% in the high treatment. These results suggest TGP is an effective mechanism of adaptation to environmental heat stress. Analysis of growth and yolk-consumption is ongoing.

## Structural control of antennal flexing by hawkmoths

*Adam Puchalski, Kostya Kornev*

To probe their environment, flying insects flex, twist, and maneuver their antennae by coupling mechanical deformations with sensory output. We explored how the material and structural properties influence the reaction of antennae bending loads such as wind gusts. Four hawkmoth species—Manduca sexta, Ceratomia catalpae, Manduca quinquemaculata, and Xylophanes tersa were investigated. Despite similar pectinate (comb-like) morphology across species, we found significant differences in their resistance to bending. Ceratomia catalpae, a non-hovering species, exhibited rigidity nearly two orders of magnitude lower than its hovering counterparts. These differences are linked to the structural contribution of pectinations to rigidity. The most intriguing is the dependence of the bending rigidity of the antennae on the direction of bending: the bending toward the ventral side of the antennae appeared significantly hindered.

We show that the hawkmoth antennae can be flexed on demand by the hemolymph pressure, and the flexural anisotropy enables selective bending toward the dorsal side. Experiments were supported by a model that helps design a bioinspired fiber. The designed fiber was wet spun in the lab setting, and its mechanical and wetting properties were characterized to show that the fibers produced had desirable properties. These fibers could be used in micro robotics as hydraulic actuators.

## Investigating how chromatophore organization underlies variable pattern generation in color change

*Rejana Pullarkat, Mae George, Lorian Schweikert*

Dynamic color change, or the ability to rapidly change skin coloration, is achieved in many animals via pigment cells known as chromatophores. Despite our understanding of how individual chromatophores change color and how they are vertically arranged in skin, there is limited information on their horizontal organization, especially as it relates to dynamic color change. We investigated horizontal chromatophore organization in the Caribbean hogfish (Lachnolaimus maximus; N = 10) and summer flounder (Paralichthys dentatus; N = 10), which are two color-changing species with putatively fixed and variable pattern-generating capacities, respectively. In aim 1, we performed nearest neighbor analyses to calculate the degree of regularity in chromatophore arrangement. Whole-mounted skin tissue was visualized by light microscopy and mean regularity indices were statistically compared to test the hypothesis that hogfish have a higher degree of chromatophore regularity than summer flounder. In aim 2, we examined chromatophore abundances over the body to determine whether chromatophores are uniformly or non-uniformly distributed. Mean chromatophore abundances were statistically compared to test the hypothesis that hogfish have non-uniform chromatophore abundance while summer flounder have uniform abundance. These findings will help indicate if variable patterns are derived from the spatial organization of chromatophores (i.e., color-change hardware) or from patterns of activation alone (i.e., color-change software). This work may also provide insight into the evolutionary tradeoffs associated with different strategies of dynamic color change.

## Walking the tightrope: Is vertical gap crossing in snakes influenced by perch diameter?

*Joshua Pulliam, Jeffery Anderson, Kamau Braxton-Hall, Yohan Sequeira, Joshua Taylor, Jake Socha*

Overcoming locomotion challenges depends on both environment and body morphology. While limbed animals may reach upward to a branch by extending limbs or jumping, limbless animals primarily cross by extending their bodies, anchoring themselves to the origin branch. The diameter of the origin influences the grip animals can apply, affecting their ability to reach and balance. However, how diameter influences vertical gap crossing in snakes has yet to be studied. We recorded 91 trials of two genera of snake, Chrysopelea and Dendrelephis, utilizing one of three cylindrical origins (dia: 2.4, 3.3, 11.4 cm) and allowing them to cross to a target perch above. To determine maximum performance, the target was raised using a linear rail at 11 cm/s until the snake reached its maximum height. A motion-capture system (Vicon) was used to track 10 evenly-spaced points on the snake's dorsal midline at 100 Hz, which were used to calculate the snake's instantaneous displacement, velocity, and torque. As diameter increased, the snakes did not significantly vary their speed, nor did they experience significant changes in maximum torque. However, as diameter increased, snakes reached lower heights, ranging from an average of 45.0% SVL on the smallest origin to 35.2% on the largest. These results suggest that snakes on larger perches require greater body contact to create sufficient counter-torques to support themselves.

## CT imaging reveals eye shape transition in the Banded Flower Mantis: From cone to sphere

*Ruchao Qian, Jamie Theobald, Yash Sondhi*

Most insects that undergo incomplete metamorphosis possess consistent eye morphology throughout their lifecycle. However, Theopropus elegans, commonly known as the banded flower mantis, presents a unique and profound transition: hatchlings emerge with cone-shaped eyes that gradually morph into a spherical form by adulthood. This previously undocumented phenomenon raises intriguing questions about its impact on visual capabilities and evolutionary significance. Specifically, how do visual characteristics like spatial resolution, field of view, and ommatidial count change through their life stages? In this study, we performed high-resolution scans of the head and eyes across different instars of T. elegans, allowing for a comparative analysis of the eye architecture to uncover the functional advantages and trade-offs associated with this transition in eye shape.

## Comparative analysis of shell growth in five species of marine gastropods

*Luigi Queirolo Williams, Alexa Ruberte, Elizabeth Shea, Janice Krumm*

Characteristics of gastropod shells have been widely studied to increase our understanding of shell structure and their role in providing defense from predation. A greater understanding of how shells change as snails grow and develop is a key step in our understanding of predator-prey dynamics over the life of the snail. In this comparative study we examine how shell shape changes with growth in five morphologically distinct species of gastropods. We measured shells from the Delaware Museum of Nature and Science collection to describe how shell shape changes with growth along a continuum of small to very large adult snail sizes. We measured shell length, shell width, aperture length, aperture width and shell weight in the snails Conus virgo, Fasciolaria hunteria, Neoterebra dislocata, Sinistrofulgur perversum, and Triplofusus giganteus. For all five species, shell length and shell width were significantly correlated ($p < 0.0001$). However, preliminary analyses suggest the slopes of these correlations differ between species. Our results highlight general trends in shell growth across species and contribute to our broader understanding of the evolutionary pressures on shell morphology.

## The influence of motivated thinking on Black representation in science

*Catherine Quinlan*

Black Representations in science, science curricular development, and scientific outcomes are driven by our motivated thinking and reasoning. This in turn influences how we reason about issues related to equity, diversity, inclusion, and social justice. In this talk I will address what Black representation means to me and share my observations about the influence of motivated thinking on the outcomes and processes in the work I've done.

## On-wing sensing contributes to control of movement in bats

*Brooke Quinn, Jade Bajic, Santiago Romo, Ariel Wu, Alberto Bortoni, Kenny Breuer, Sharon Swartz*

Bats use sensory systems such as echolocation and vision to track prey, avoid obstacles, and inform their trajectories. In addition, though less studied, bats also have extensive networks of sensory hairs across their wings. Preliminary evidence has shown that these sensory hairs are involved in flow sensing and relay sensory information during flight. However, little is known about the functional role of sensory hairs in flight control or potential intraspecific variation in hair distribution. Through a morphological study of specimens of Seba's short-tailed bat (Carollia perspicillata), we find relatively low intraspecific variability in sensory hair distribution and consistent regional density patterns. Additionally, higher coefficients of variation correspond to regions of higher densities, suggesting some amount of functional redundancy via robustness to variation in hair placement. We also compared flight kinematics from the same species in wind tunnel experiments before and after removal of sensory hairs from the ventral wing. We found significant increases in wingbeat frequency, angle of attack, wing flexion, and chordwise camber after depilation, and a significant decrease in wing area. These changes should result in changes in the modes of aerodynamic force production over the wingbeat cycle. Further, we find more variability in the kinematic traits after depilation. Changes in these traits relating to force production suggest that it is a primary factor regulated by sensory information provided by the hair network.

## Assessing the effect of rainfall on the response to the GnRH challenge in a Neotropical songbird

*Rene Quispe, Camila Villavicencio, Manfred Gahr*

In temperate regions, increasing day length in spring is the primary environmental cue that birds use to initiate gonadal maturation. Later in the year, prolonged photoperiods typically induce a state of photorefractoriness, leading to testicular regression and the cessation of the breeding phase. At the hypothalamic level, this process is governed by gonadotropin-releasing hormone (GnRH), which regulates the release of gonadotropins and testosterone production in males. However, in equatorial regions where photoperiodic changes are less pronounced, the mechanisms governing the timing of avian reproduction are not as well understood. In silver-beaked tanagers (Ramphocelus carbo), a neotropical songbird from equatorial populations, reproduction occurs exclusively during the dry season of the Amazon region, while it is inhibited during the rainy season. This study aimed to experimentally assess the effect of rainfall on testicular activity in silver-beaked tanagers. To achieve this, we housed males in two semi-natural aviaries with simulated contrasting rainfall conditions. After one month, we evaluated the testes' capacity to produce testosterone following exogenous GnRH treatment. Our results indicated that males kept under dry conditions exhibited a more significant change in testosterone production compared to those under wet conditions. These findings suggest that seasonal rainfall acts as an environmental cue regulating gonadal activity in songbirds at equatorial latitudes.

## Shape and Locomotion Dynamics in Batoids

*John Michael Racy, Bart Boom, Thijs Masmeijer, Adam Summers, Ed Habtour*

In batoids that swim via pectoral oscillation/undulation, the shape of the pectoral fin varies along a spectrum from near-circular to swept-diamond. The attachment to the body trunk (pterygial complex) also varies with shape. Correlations have been drawn between fin shape and locomotion style; however, the fundamental mechanics of the shapes of fins and pterygia across batoid diversity are not well understood. Radiographs of eight species that span batoid shape diversity were collected that show the fin and pterygium. Bezier functions were mapped to create 2D generalizations of their geometries. Dynamical testing of flat plate models of the geometries revealed mode shapes and frequencies. Comparison of these results demonstrates how the fins and pterygia contribute to the vibrational characteristics intrinsic to batoid locomotion. Understanding their innate structural dynamics not only provides deep insight into the functional morphology of batoids, but will also enable the engineering of dynamically optimized undulatory propulsion systems.

## Buried secrets: uncovering the impact of formaldehyde on cemetery soil microbes

*Madison Rader, Sarah Foltz, Steven McBride*

Cemeteries are one of the few urban spaces that can provide wildlife with minimal human disturbance. However, a potential hazard in cemeteries is the pollutants that may be leeching into the soil underground. Millions of gallons of embalming fluids are put into American cemeteries each year. This study investigates the effects of formaldehyde, a common embalming chemical, on soil microbial communities. The primary objectives are 1) to assess whether formaldehyde influences soil respiration, an indicator of microbial activity and 2) determine whether cemetery soil microbial communities differ in their response to formaldehyde from control soil communities. Soil samples to assess base soil community response were collected from a non-cemetery site and subjected to an incubation experiment where varying concentrations of formaldehyde were applied. We then assessed the response of soil collected inside a cemetery to repeated formaldehyde applications. Respiration rates were monitored throughout the incubation. Analysis of cemetery soils is ongoing, but preliminary results suggest that formaldehyde increases soil respiration in control soils, indicating potential disruptions in microbial processes. These results will inform further studies on the ecological impact of embalming chemicals on local urban ecosystems.

## Analyzing soft coral tissues using network analysis

*Asja Radja*

Biology generates robust, flexible, organic networks that provide structure and transfer information in ways that human-made networks cannot. Gorgonians, flat soft corals commonly known as sea fans, have tree-like and mesh-like tissue networks that act as distribution networks for food particles between individuals within a colony. These tissue networks must efficiently route resources while simultaneously balancing the cost of building new biological materials and maintaining this infrastructure in the face of environmental changes. These requirements constrain the spatial and topological organization of these tissues. We systematically compiled an image database of gorgonian morphologies including extant species sampled from every gorgonian order and several morphological variants of several species. We then measured both the spatially-embedded geometric and topological metrics to quantify their morphologies and found that there are clear distinctions between how the two morphotypes balance building cost, efficiency, and robustness. Specifically, we found that tree-like networks are much less costly, however, mesh-like networks gain much more efficiency and robustness for proportionally little extra cost. As a whole, this work demonstrates that directing our focus to not-well-studied network systems like those of gorgonian morphology can bring forth novel information on network optimization and identify how relatively simple growth processes lead to optimized morphologies for survival.

## Complexities of phenological shifts for plant-pollinator interactions and ways forward

*Nicole Rafferty, Elena Kaminskaia, Alessandro Fisogni, Natasha de Manincor*

Climate change may cause mismatches in the phenologies of flowering plants and insect pollinators, potentially reducing the fitness of both partners and leading to mutualism breakdown. However, several complexities of phenological shifts hinder our ability to predict their consequences for plant-pollinator interactions. First, metrics of phenological mismatch in pollination, such as magnitude of temporal overlap, may not accurately characterize changes in interaction strength or costs and benefits. Second, phenological shifts reflect variation at multiple levels, including within individuals (plasticity), within populations, and among populations, creating mosaics of response. Third, our focus has been on shifts in individual life history events, such as flowering onset, rather than entire life cycles, despite the physiological integration of phenophases that may be under different selection pressures. We suggest that we can advance our understanding of phenological mismatches and their consequences for plants and pollinators by taking an integrated life cycle approach that can be scaled up, potentially yielding dynamic fitness landscapes and improved understanding of community-level consequences.

## Changes in Joint Coordination Following Chronic, Progressive Joint Injury: Insights from a Rat Model

*Seyed Mohammad Ali Rahmati, Marin Plemmons, Liang-Ching Tsai, Jarred Kaiser, Young-Hui Chang*

Gait deviations arise after lower-extremity joint injury and during associated post-traumatic progressive diseases. However, the factors that determine which kinematic parameters the system can adjust and which are preferentially preserved remain unclear. Traumatic knee injuries accelerate the onset of knee osteoarthritis symptoms, leading to functional limitations earlier in life than typical physiology displays. Using a medial meniscus transection model in rats to induce knee post-traumatic osteoarthritis (PTOA), this study investigates how joint coordination is altered within the locomotor system following injury and during PTOA progression. Similar to what is observed following acute neuromuscular injuries, we hypothesize that PTOA-related gait deviations will prioritize preservation of overall limb dynamics, potentially at the expense of hindlimb joint coordination. Biplanar x-ray videography was employed to collect gait data pre-surgery, and as PTOA progressed over 8 weeks post-surgery. Joint coordination was analyzed using non-negative matrix factorization to determine the number of kinematic synergies involved. Preliminary findings suggest that while certain aspects of limb dynamics are preserved, significant alterations in joint coordination patterns occur post-surgery. Despite the same number of synergies, a smaller proportion of the total system dynamics was captured post-surgery, indicating potential disruption or alteration in underlying coordination patterns with PTOA. These findings offer new insights into the mechanisms underlying gait deviations following peripheral joint injury, particularly in the context of chronic, progressive degeneration compared to acute neuromuscular disruption.

## Cell to organ modeling of circumnutation behaviors in rice roots

*Aradhya Rajanala, Mingyuan Zhu, Christopher Pierce, Madison Hales, Deniz Kerimoglu, Daniel Goldman*

Navigating subterranean terrain is a complex task that plant roots confront without the use of a central nervous system. One strategy that plants use to improve penetration into soil and navigation around obstacles is circumnutation, the helical motion of the root tip. How this growth strategy is coordinated through cellular processes and how it reacts to different environments is largely unknown. We grew O. sativa rice roots (∼ 200 um diameter) in transparent gels of different stiffnesses. Across environments, we observed a negative correlation between amplitude (the angle at which the root tip bends) and frequency (how often the tip sweeps a full circle). To explain this relationship, we constructed a Discrete Element Method (DEM) simulation of the epidermal layer of a growing root (∼20,000 cells in 1 cm), treating the particles of the DEM model as individual cells. Interactions between cells are implemented through bonds with time-dependent equilibrium lengths to enable cell elongation. We implement circumnutation via differential elongation, where cells grow at different speeds to induce curvature, and define the axis of circumnutation as a vector pointing from the fastest to the slowest growing cells. We find that modulating the rotational speed of this axis recapitulates the negative correlation between amplitude and frequency observed in experiment. Our study indicates that modulating a single parameter is sufficient to control multiple aspects of organ-level behaviors.

## Constant and fluctuating cold temperatures increase mitochondrial respiration in birds

*Chidambaram Ramanathan, Sampath Anandan, Chelsi Marolf, Reihane Eric, Leyli Mammedowa, David Swanson, Yufeng Zhang*

Global climate change produces greater variation in winter temperatures, resulting in more frequent cold snaps superimposed upon generally warmer winters. Such fluctuating cold temperatures will require animals to rapidly match their physiology to environmental conditions. Birds typically increase both their basal and maximum cold-induced metabolic rates in winter to cope with low temperatures. However, their adaptation to the fluctuating cold is unknown. Wild house sparrows (Passer domesticus) were captured and separated them into 24°C (constant warm), 3°C (constant cold), and 3°C (fluctuating cold) groups for 6 weeks. In the fluctuating cold treatment group, the birds were exposed to a mean temperature of 3°C, with random temperature fluctuations between -10°C and 17°C every 3 days. After acclimation, mitochondria were isolated from pectoralis and liver to measure organelle respiration using the Seahorse XFe24 Analyzer. We found that both constant and fluctuating cold treatment groups increased the maximal (state 3) and basal (state 4) respiration in isolated pectoralis mitochondria compared to the control group, but no differences were observed between the two cold groups. Interestingly, fluctuating cold groups had the highest hepatic mitochondrial respiration when using complex I substrates compared to both constant cold and warm groups. These data suggest tissue-specific responses to constant and fluctuating cold treatments, with upregulation of mitochondrial respiration in both cold groups in pectoralis but greater upregulation in fluctuating cold in liver.

## Use of body lifting by elongate amphibious fishes to move on mud

*Divya Ramesh, Hongbo Zhang, Dami Kim, Alex Nath, Na Dai, Daniel Collum, Abdulla Ubaydullaev, Chiadika Vincent, Catherine Pollard, Gargi Sadalgekar, Chen Li*

When moving at the water-to-land interface, amphibious fishes encounter mud of varying wetness and strengths challenging locomotion. Almost all previous fish locomotion studies (whether aquatic or terrestrial) focused on the role of body bending plus fin motions, except for one observation of small, local tail lifting in mudskippers on inclined sand. By contrast, many terrestrial animals can bend the body vertically to enhance locomotion. Here, we studied the elongate ropefish (Erpetoichthys calabaricus), which uses lateral bending to move on solid ground, on mud of various strengths. On wetter mud, the animal sank more deeply ($0.03 \pm 0.01$ body length, BL) with minimal length of body lifted ($0.03 \pm 0.03$ BL), and moved slowly ($0.02 \pm 0.01$ BL/s). On drier and hardened mud, it lifts longer body sections ($0.4 \pm 0.1$ BL and $0.33 \pm 0.12$ BL) and moved faster ($0.05 \pm 0.04$ BL/s, $P < 0.05$, ANOVA). This novel use of body lifting may modulate drag on mud, similar to sinus lifting of snakes to modulate friction, though with poorer control as evidenced by larger variation in motion. To understand how body lifting and lateral bending coordinate to cope with sinkage and drag, we are studying a fish robophysical model and extending the granular resistive force theory (developed for dry sand) to mud to calculate modulation of lift and drag forces by body lifting.

## Neural correlates of sleep in *Aedes aegypti*: implications for olfactory processing

*Spruha Rami, Joshua Benoit, Clement Vinauger*

Sleep is a critical behavioral and physiological state for animals to rest and maintain homeostatic levels. Sleep in insects is an active area of research, and work on several species, including Drosophila melanogaster, showed that insects, too, display proper sleep states. However, the role of sleep in disease vector insects such as mosquitoes has mainly been overlooked despite its potential epidemiological implications. A hallmark of sleep-like states across animals is the rise of arousal threshold during sleep. Here, to test whether mosquitoes' prolonged inactivity is associated with changes in sensory integration, we conducted simultaneous electrophysiology and postural recordings in female Aedes aegypti, a highly invasive species capable of transmitting yellow fever, Zika, and Chikungunya viruses. Extracellular recordings of the antennal lobe, the center of olfaction, were taken on tethered mosquitoes, and a concentration ramp of odors was used to determine thresholds at which asleep mosquitoes wake up in response to sensory input. Combined with postural information from tracking the mosquito movements, we can identify neural correlates associated with prolonged inactivity and quantify the sensory characteristics of sleep-like states in mosquitoes. Moving forward, results from this project will be used to examine the effects of sleep deprivation on the sensory and neural processes of mosquitoes.

## Comparing Cold Tolerance in Urban and Non-Urban Caribbean Rain Frogs in the Dominican Republic

*Reveca Ramírez Gómez, Nathalie Alomar, Martha Muñoz, Isabela Hernandez Rodriguez*

The Caribbean region is home to remarkable biodiversity currently threatened by climate change's increasing effects. Ectotherms, such as Caribbean rain frogs (genus Eleutherodactylus), are particularly vulnerable since they depend on environmental temperature to regulate their core temperature and maintain homeostasis. This study investigates cold tolerance (critical thermal minimum) across five species of Eleutherodactylus from both urban and rural areas in the Dominican Republic. This region is home to 37 threatened rain frog species. Urban areas are becoming increasingly dense and warm, leading to an effect known as "heat islands." It is thought that there could be differences between species in urban and rural areas due to higher levels of environmental pollution and elevated temperatures in urban settings. The individuals were collected in Los Haitises National Park (non-urban) and the city of Santo Domingo (urban), both coastal and warm areas that share 2 (of the 5) species included in this study. We examine how urbanization and temperature variability influence cold tolerance by comparing populations from the heat islands of Santo Domingo with those in the more thermally stable Los Haitises National Park. This research contributes to our understanding of the thermal properties of highly vulnerable species and moves us closer to developing more comprehensive conservation measures as climate change marches on.

## Carbon storage across a depositional gradient among eelgrass beds in False Bay, WA

*Marisol Ramirez-Buckles, Kendall Valentine, Sandy Wyllie-Echeverria, Bruce Finney, Andrea Ogston*

Seagrass meadows are crucial for estuarine productivity and provide habitat for many invertebrate species and fish, and their decline thus has serious consequences within their ecosystem. Moreover, their large potential to store carbon, acting as a 'blue carbon' solution, makes them important weapons against global warming and ocean acidification. Seagrasses, specifically Zostera marina, are declining at several sites in the San Juan Archipelago region of Washington state. The cause for this decline remains unknown, however, investigation of sediment grain size and organic composition may indicate the spatial distribution of extant populations. In this study, we sampled six cores along a transect in False Bay, San Juan Islands, WA, where Z. marina was historically present, and analyzed variation of sediment grain size in these samples. Then by computing Loss on Ignition values, we found a low amount of organic matter on average across all the cores and their horizons (1.58 – 0.69%). Our grain size results demonstrated that mud content generally increased within surface sediment along the transect from the sea to the shore. Additionally, more landward cores displayed gravel-like consistencies toward the deeper depths and included larger rocks and shells. The cores taken further from land were more consistently sandy. Our results will help determine the role of seagrass in carbon storage across a depositional gradient in False Bay.

## Comparison of the Environmental Temperature Heterogeneity and Model Bee Temperature System in Vitex

*Marco Ramirez-Ramirez, John Hranitz, Victor Gonzalez, Michael Dillon, John Barthell*

Studies of microhabitat heterogeneity and thermal ecology of bees are needed to understand how climate change will impact floral resources visited by bees. Increased environmental temperatures increase the significance of plants offering high microhabitat heterogeneity. Such plants offer more opportunities for behavioral thermoregulation and thermal refugia than plants with low microhabitat heterogeneity. We compared thermal microhabitats and model bee temperatures of two plants, Vitex agnus-castus ("Vitex") and Centaurea solstitialis L. ("YST"). Past studies show these plants differ in nectar reward and, we predicted, in thermal heterogeneity. To measure ambient plant temperatures, we recorded temperatures (5-minute intervals for 48 h) at each cardinal direction of plants. To model bee body temperatures, we recorded temperatures (5 min./48 h) of two clay models, small and large, exposed to sun and shade. Probability density distributions revealed lower ($P < 0.001$) thermal microhabitat heterogeneity in YST than in Vitex. Probability density distributions for bee model temperatures similarly differed ($P < 0 .001$) among large versus small bee models in shade and sun exposure on both plants. Vitex provides superior microhabitat thermal heterogeneity as an excellent nectar resource. These results suggest Vitex shrubs are important for bee pollinators in Mediterranean scrub habitats. Our results corroborate potential mechanisms for recent findings, based on a megadrought in California, that shrubs are important foundational plants providing resources for plants and animals in scrub communities.

## Effect of temperature and cross type on early development of Ascidia sp.

*Dorhkas Ramos, Ivon Ramirez, Itzel Chavarria, C. Sarah Cohen*

Fouling communities experience space competition across thermal regimes, therefore early life stages are essential for population establishment. Early developmental stages may have an important role in competition as these stages can be most sensitive to environmental stressors, although they may also show flexibility. Here, we investigate flexibility in reproductive and developmental timing of solitary tunicates at different temperatures, and in comparison to field environmental conditions on the central California coast. In the lab, we are carrying out self- and cross-fertilizations to compare variation in timing and success at early developmental stages. In Ascidia sp, crosses and selfing at higher temperatures (14°C and 20°C) showed greater success of initial cleaving while the lowest temperature (10°C) demonstrated significant delay. In crosses scored at 2 hours post-fertilization (hpf), the majority of the embryos were at 2-cell stage at 14°C, beyond 2- cell at 20°C and mostly uncleaved at 10°C. With self-fertilization, the majority of embryos at higher temperatures demonstrated initial cleaving at ∼4-5 hpf and some individuals at the lowest temperature (10°C) appeared unsuccessful at fertilization up to 5 hours. We show that early developmental stages are sensitive to low and high temperature effects within the ranges found in their current habitat. Variation in temperature responses early in life could impact establishment of new populations in both introduced and native regions.

## Identifying common sex-specific aging markers across species in RNA-seq data

*Eric Randolph, Yifei Fang, Jingyue Duan, Peggy Biga, Nicole Riddle*

Lifespan differences between sexes are observed in many animal species. Differences in lifespan between sexes are indicators of underlying sex specificity in aging, raising the question of whether sex-specific aging markers can be identified, and whether they are unique to each species or common enough to span multiple clades.

To address these questions, sex-specific next-generation sequencing transcriptome data (RNA-seq) from young and old individuals were collected from multiple species. The initial species investigated for common sex-specific aging markers were Xiphophorus maculatus and Drosophila melanogaster. These species were chosen due to their distant evolutionary relationship as D. melanogaster are members of the protostome lineage and X. maculatus are deuterostomes.

In both species, increased age was associated with the significant downregulation of genes that encode for sarcoplasmic/endoplasmic reticulum Ca(2+)-ATPase (SERCA) proteins in females from these species, not males. The downregulation of SERCA indicates muscle atrophy and weakening. Moreover, weighted gene co-expression network analysis (WGCNA) modules that were significantly and positively correlated to old females in both species contained the enriched KEGG pathway for amyotrophic lateral sclerosis, a disease that causes muscle weakening. These results suggest that muscle atrophy and weakening with age is a female-specific trait shared between these two distantly related species. Furthermore, these results address our initial question by confirming that sex-specific aging markers can be identified and that some are common across multiple clades.

## Characterizing drivers of marine community calcification under ocean acidification and warming

*Racine Rangel, Kristy Kroeker, Matthew Bracken, Luke Miller, Cascade Sorte*

Global environmental change can lead to alterations in ecosystem functions through multiple biological mechanisms. This study employed a novel, in situ factorial field-manipulation of pH and temperature on net ecosystem calcification (NEC) in a coastal marine system over a 6-month period. We examined individual- and population-level mechanisms driving changes in NEC. Our results indicate that the relationship between metabolic rates of the calcifying mussel Mytilus trossulus and NEC was dependent on $CO_2$: higher metabolic rates were associated with higher NEC except when individuals were exposed to elevated $CO_2$, in which case, increased metabolic rates were associated with decreased NEC. While increased calcifier abundance generally enhanced NEC, this relationship was reversed under elevated CO2. These findings suggest further changes in these drivers will primarily affect NEC through individual metabolism until physiological limits are exceeded. Beyond this point, population-level dynamics including survival and recruitment will likely play a more significant role. Individual- and population-level responses are likely to act on different time scales to influence ecosystem functioning. Understanding these complex interactions within a changing climate is crucial for predicting the vulnerability of ecosystem function across levels of biological organization.

## Postcranial validation of a novel algorithmic approach to resolving muscle fascicle architecture

*Aleksandra Ratkiewicz, Alana DiMartino, Avarie Rembert, Michael Deutsch, Alexandra Abrams, Connor McDowell, Michael Granatosky, Edwin Dickinson*

Muscle fascicle architecture serves as a key anatomical indicator of muscle function, providing insights into muscle stretch and force production. Traditional methods for assessing fascicle architecture, such as gross dissection, have been increasingly complemented by advanced imaging techniques that enable non-destructive, in situ analysis and three-dimensional mapping of fascicles within their natural context. Typically, three-dimensional fascicle mapping is conducted manually by tracing from CT images. However, algorithmic methods using density recognition software are now emerging as alternatives. While these automated methods have been validated for masticatory muscles, their applicability to postcranial musculature remains uncertain. To explore this, we compared gross dissection, manual digital dissection, and algorithmic methods in analyzing the hindlimb musculature of long-tailed macaques (Macaca fascicularis). Left legs were dissected, while right legs were stained with Lugol's Iodine and scanned with a Nikon XTH225ST CT scanner. Fascicle mapping was automated using the XFiber extension in Amira across ten hindlimb muscles per specimen. Our findings reveal that algorithmic methods can successfully resolve physiologically feasible fascicle parameters across various body sizes and anatomical systems. This study represents the first application of automated fascicle reconstruction in postcranial muscles, underscoring its potential for comparative anatomical research. However, discrepancies between dissection and digital methods were noted, suggesting that further investigation is needed to understand the sources of disagreement between gross dissection, manual segmentation, and XFiber-generated reconstructions.

## Screening H3 histone acetylation in a wild bird, the house sparrow (Passer domesticus)

*Daniella Ray, Marty Martin, Aaron Schrey, Elizabeth Sheldon, Cédric Zimmer*

House sparrows (Passer domesticus) are one of the most widely distributed species in the world. Part of this success has been attributed to DNA methylation and its role in regulating gene expression. Another epigenetic mechanism, histone modification, likely also plays a role in the success of introduced species, but is largely understudied in ecological epigenetics studies. There are a limited number of histone acetylation studies on non-model organisms, yet those that exist show that it can impact gene expression and phenotypic plasticity. Here, we measure histone acetylation in house sparrows that had been previously collected for a study on house sparrow response to Salmonella infection (Sheldon et al. 2023). We detected high variance in histone acetylation among individuals in both liver and spleen tissue. Additionally, house sparrows with higher epigenetic potential in the Toll Like Receptor-4 (TLR-4) promoter (i.e., CpG content) had higher histone acetylation in liver. Also, there was a negative correlation between histone acetylation in spleen and TLR-4 expression. We verify that a commercially available assay that was developed for mammals can be used in house sparrows. This study also shows that histone acetylation varies in an ecologically relevant way, adding a new study option for ecological epigenetics.

## Predicting disease outcomes in spatially and temporally dynamic host communities

*Nadia Raytselis, David Civitello, Alexander Strauss, Maya Risin, Jane Miller, Layla Steinbock, Ta'Nyia Heard, Christopher Bradon, Stephanie Guitierrez, Isaac Wood, Andrew Sieben, Jakob Scholeno, Kevin Xie*

When species are abruptly gained or lost from communities, non-equilibrium or transient dynamics can become more important to predicting ecological outcomes. Here we illustrate the potential for dynamic coexistence of a fish predator, copepod prey, and the latter's nematode parasite to affect the transmission dynamics of Guinea worm (GW). The GW parasite is the causative agent of Dracunculiasis (GWD), a disabling, neglected tropical disease slated for eradication in several African nations. We hypothesize an episodic overlap in the habitat occupancy of copepods and fish due to seasonal changes in precipitation, water body connectivity, and fishing pressure. Using experimental mesocosms and state space modeling, we show that the degree of fish predation pressure has significant impacts on copepod population dynamics with downstream disease implications. Using model simulations that periodize fish presence/absence over a fish abundance gradient, we also identify specific scenarios that could lead to increased infections in the ecosystem. Understanding the seasonal dynamic coexistence of these species will allow us to predict when infection risk is elevated, allowing for more targeted public health responses.

## Divergence in bill morphology after a migratory drop-off

*M. Emilia Rebollo, Bryam Mateus-Aguilar, Diego Tuero, Alex Jahn, Carlos Cadena, Valentina Gómez-Bahamón*

The morphology of bird bills is mainly associated with feeding adaptations, but bill size and shape can also influence other aspects, such as thermoregulation and song attributes. Thus, switching feeding strategies during the divergence process of a species can lead to correlated evolution in communication signals and physiological traits. The Fork-tailed Flycatcher (Tyrannus savana) has an austral migratory subspecies that breeds in southern South America and shares its non-breeding grounds in northern South America with a subspecies that diverged after losing migration in the wintering grounds. In theory, migratory and non-migratory strategies require different energetic and nutritional demands. Given that migration is an energetically expensive endeavor, and non-migratory birds have a longer breeding season, diet preferences potentially differ. If this is the case, we expect bill morphology to vary accordingly. We measured bill length, height, and width of 353 individuals of T. s. savana (migratory) and 75 individuals of T. s. monachus (non-migratory) from 2014 to 2022. We found that migrants have significantly smaller bills of a thinner and more elongated shape than non-migrants. These differences may indicate a partitioning of the feeding niche due to the different selective pressures they face when co-occurring, or differences reflecting ecological needs throughout their lifecycles. Future directions involve comparatively addressing aspects of diet preference and feeding behavior in relation to the variation of bill morphology.

## Ramp up to touch-down: synchronous ankle antagonist muscle function during drop-landing descent

*Brandon Reder, Dan Bartlett, Andrew Biewener, Nicolai Konow*

Falling animals must contend with impact forces or incur injury. Turkey drop-landings have shown that lateral gastrocnemius (LG) consistently activates at fall-onset and ramps up force development to prepare for ground impact. How this limb extensor generates significant force without counteraction remained unclear and we hypothesized that an antagonist must act in opposition. Electromyography studies on human drop-landing show that tibialis anterior (TA), the major antagonist of LG, is concurrently active during falls. However, direct measurements of TA and LG force during falls were not available. We hypothesized that TA is a significant force producing antagonist to the LG during falls. We predicted concurrent activation and force ramp up of LG and TA at fall onset. We tested our hypothesis in guinea fowl (Numida meleagris) using force buckles on both tendons, and electromyography electrodes in each muscle belly. Using a harness, rope, and pulley system we dropped the birds from 2x, 3x, and 4x center of mass (CoM) height. Our hypothesis was supported by near-synchronous muscle activation and force production onset at fall initiation across heights (ANOVA: $p=0.525$). Interestingly, we saw significantly greater force production rate and magnitude in TA (Paired t-test: all $< 0.01$), potentially matching the force output of LG and its synergist medial gastrocnemius. Our findings demonstrate the importance of coordination between antagonists in providing a means to prevent injury.

## The gut immunology of Eisenia fetida responds to differences in dietary organic matter

*Sarah Redmond, Aiden Bridge*

Eisenia fetida (commonly known as red wiggler earthworms) and their associated gut microbiota facilitate soil remediation by increasing hydrocarbon degradation rates, accumulating heavy metals, increasing soil respiration, and fostering microbial growth. Studies of vermiremediation progress report impacts associated with feedstuffs and microbial cotreatments, such as livestock manure, brewers grains, Bacillus megaterium, and Rhizophagus irregularis. E. fetida mortality and reproduction are common metrics for viability of vermiremediation, however the gut and coelomic environments and host-microbe interactions are critical factors that have received little attention. This study aimed to characterize the immunological environment in the earthworm gut and assess the viability of E. fetida secretions for fostering microbial communities outside the earthworm gut. Mature E. fetida provided with sterile feedstuffs (brewers grains, melon pulp, or spent coffee grounds) were assessed for changes in casting microbial population, coelomic fluid, and mucus proteins before and after a 28-day feeding period. The coffee grounds treatment groups showed a significant increase in oxidative activity and pattern recognition proteins. The watermelon and brewers grain treatments showed lower levels of oxidative stress. These results indicate that differences in non-contaminated organic matter affect host-microbe interactions, which could impact the effectiveness of vermiremediation projects.

## Evolution of an animal signal in relation to group size

*Hannah Reeb, Matthew Toomey, Charles Brown*

The cliff swallow (Petrochelidon pyrrhonota) is a colonial bird known to live within a highly variable social environment– colony sizes range from 2 to 6000 nests. Adult cliff swallows feature a prominent white forehead patch, which we hypothesize is a signal of nest occupancy, useful in mitigating costly nest intrusion interactions within dense social environments. We predicted that more extensive patches (i.e. brighter, larger) should enhance this function and be associated with birds that nest in larger colonies, or that spend more time in the nest. Additionally, given the general ecological trend towards higher frequencies of large colonies, and the known heritable propensity for colony size in this species, we predicted that the signal should be selected for and inherited over time. To test these predictions, I measured both the brightness and size of the forehead patch in 234 preserved specimens in relation to the sex, colony size, and year of collection of the birds. I used reflectance spectroscopy to quantify the brightness of the forehead patch and discern the contrast between adjacent plumage pigments, and imaging software to quantify the size and shape of the patch. Our findings place signal evolution in the context of a variably social colonial species, revealing an interesting facet of social evolution in birds.

## Multimodal communication during hierarchy resolution in a sexually plastic fish

*Makenzie Reed, Beverlly Victoria, Ashley Cantin, Devaleena Pradhan*

Hierarchy resolution is prevalent among social animals, especially those that can undergo sex change. The size advantage hypothesis, stating that larger individuals will achieve a higher status than smaller individuals, is commonly used to predict the winner of an aggressive encounter. However, many conspecific interactions are more complex than merely overall size, potentially including subtle morphological and behavioral variation across individuals. The goal of this study is to determine the importance of multimodal characteristics during hierarchy resolution. Bluebanded gobies, Lythrypnus dalli, are bidirectional sexually plastic fish in which the size hypothesis has been reliably used to predict the dominant fish. However, fish with smaller standard lengths can also achieve the highest status. We hypothesize that multiple cues are used by individuals to assess their opponents. For example, the dorsal fin raise is a low intensity gestural aggressive display that emphasizes the length of the dorsal fins with respect to body length. Here, we created two social environments to either stimulate protandrous (male to female) or protogynous (female to male) sex change. Overall, in 50% of groups, a larger fish with a longer dorsal fin obtained the dominant role, while a smaller fish with a bigger dorsal fin in about 10% of groups. Multidimensional statistical analysis will be used to further untangle the trends and relationships between morphology and behavior and its influence in hierarchy formation.

## Evolution of transmissible cancers: an adaptive, plastic strategy of selfish genetic elements?

*Kern Reeve, David Pfennig*

A growing number of studies have applied evolutionary and ecological principles to understanding cancer. However, few such studies have examined whether phenotypic plasticity––the ability of a single individual or genome to respond differently to different environmental circumstances––can impact the origin and spread of cancer. We propose the adaptive horizontal transmission hypothesis to explain how flexible decision-making by selfish genetic elements can cause them to spread from the genome of their original host into the genomes of other hosts through the evolution of transmissible cancers. We hypothesize that such cancers appear when the likelihood of successful vertical transmission is sufficiently low relative to the likelihood of successful horizontal transmission. This talk describes this hypothesis, highlights empirical findings that support it, and offers suggestions for future research. Generally, phenotypically plastic selfish genetic elements might play an important role in the evolution of transmissible cancers specifically and cancers more generally.

## Effects of habitat characteristics on spatial distribution and fitness of collared lizards

*Jaclyn Reifeiss, Matthew Gifford*

Human-induced climate change and habitat degradation have increasingly burdened ectothermic species, such as the Eastern Collared Lizard (Crotaphytus collaris), by elevating the costs associated with behavioral thermoregulation. These lizards rely on a range of microhabitats within glades, including basking sites and refuges, to regulate their body temperature. However, habitat degradation can disrupt the availability and distribution of these critical resources, potentially altering social dynamics and reproductive success. We explored how variation in glade characteristics – specifically thermal homogeneity, visibility, and refuge availability – affected the spatial distribution and potential fitness of individuals in a population of C. collaris residing on a glade in the Arkansas Ozarks. Through intensive mark-recapture techniques and repeated censuses, home range estimates were constructed for every active individual throughout the reproductive period. A drone was deployed throughout the season at varying times of day to estimate substrate temperature and visibility within each lizard's home range. As an initial proxy for fitness, we used home range overlap to gauge the influence of these physical characteristics on reproductive success. Spacing patterns in isolated populations may be affected by physical glade characteristics, thereby impacting total genetic diversity. These data may identify key habitat characteristics linked to spatial alterations and therefore inform more efficient restoration techniques.

## Male songbirds alter characteristics of own song in response to syntax of rival song

*Emma Reinhardt, Keith Sockman*

Unraveling complexity in animal communication systems is an ongoing discovery. Syntax, for example, occurs if the order of unbroken acoustic elements in a vocal signal elicits a response in receivers. Trill performance reflects the rapid repetition of a song syllable at high frequency bandwidth. Lincoln's sparrows (Melospiza lincolnii) produce several trills per song and modulate trill performance in response to randomized ordering of syllable types in rival songs. In Lincoln's sparrows, the center frequency almost always increases from the first to the second trill. This suggests a more specific syntax present in songs, such that there is signal value not merely in the order of syllable types, but specifically in the order of the first two syllable types' characteristics. We conducted a field playback experiment where each subject was exposed to songs with all trills in a species-typical order as well as with the first two trills swapped. We found no differences between treatments in subjects' agonistic responses, but, compared to control treatments, males responding to the alternative syllable order performed their fourth trills at a higher center frequency, suggesting the order of the first two trills may be salient to receivers. While it's unclear if the center frequency or another trill component is driving this response, these findings support the importance and specificity of complex syllable ordering in this communication system.

## Effects of road de-icers on key ion-regulating organs in *Chironomous riparius*

*Amber Reinsborough, Andrew Donini*

Chironomous riparius is a chironomid species that resides in freshwater ecosystems within the Northern hemisphere where they contribute to a healthy ecosystem and act as bioindicators of water quality. The use of road de-icers is resulting in salinization of these habitats. A common de-icer is NaCl, which has negative effects on freshwater organisms and their ion-regulation. To mitigate these effects, new de-icing agent beet juice brine has been implemented as an eco-friendlier alternative. The effects of beet-juice brine (BBJD) on the osmoregulation of freshwater animals is not understood. This study examined effects of a 24hr exposure to 7g/L NaCl and 2% BBJD on C. riparius larvae with a focus on ion-absorptive organs, the anal papillae (APs) and ion secretory organs, Malpighian tubules (MTs). Haemolymph [$Na^+$] increased in NaCl and BBJD exposed larvae and BBJD exposed larvae had lower body moisture. $Na^+$ and $K^+$ ions were absorbed by APs in FW conditions. BBJD exposure decreased absorption of $Na^+$ and $K^+$ and NaCl exposure resulted in secretion of $Na^+$ and decreased $K^+$ absorption. MTs of BBJD exposed larvae had higher rates of fluid secretion and the secreted fluid contained higher levels of $K^+$. The data suggest that functional modulation of APs may be particularly important for larvae exposed to NaCl while MTs may be more important for larvae exposed to BBJD.

## Scaling Muscle Strength in Primates: Age-Related Changes in Fiber Size and Density

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As animals grow, they face a unique physiological challenge: while body weight increases volumetrically, the ability to support this weight through muscular force generation scales with muscle cross-sectional area (i.e., body mass2/3). This suggests that infant and juvenile animals should be relatively stronger than their adult counterparts. However, experimental evidence indicates that relative force-generating potential peaks during reproductive-age. It remains uncertain whether this relative increase in force-generating potential is due to a higher number of muscle fibers or an enlargement of individual fiber cross-sectional area. This study examines ontogenetic scaling patterns of physiological cross-sectional area, fiber length, density, and diameter in five primate species. For each species, five to ten specimens were available, ranging in age from stillborns to adults. Within each individual, four muscles (two forelimb, two hindlimb) were analyzed. On one side of the body, gross dissection and chemical digestion were used to determine fiber length and calculate physiological cross-sectional area. On the opposite side, histological staining was employed to measure fiber density and diameter. Overall, we observed that older individuals tend to have larger relative physiological cross-sectional areas, driven by a tendency for both greater fiber densities and larger fibers compared to younger individuals. This pattern was consistent across species and sexes. These data reveal differential growth patterns within a species, enabling greater force-generating potential than what body mass alone would predict.

## Molecular mechanisms of maternal care in a mouthbrooding cichlid fish

*Susan Renn*

Parental care in Astatotilapia burtoni entails females protecting eggs and developing fry in a specialized buccal cavity in the mouth. During this mouthbrooding behavior, which can last 2–3 weeks, mothers undergo voluntary fasting accompanied by loss of body mass and major metabolic changes. Following release of fry, females resume normal feeding behavior and quickly recover body mass as they become reproductively active once again. In order to investigate the molecular underpinnings of such dramatic behavioral and metabolic changes, we sequenced whole-brain transcriptomes from females at four time points throughout their reproductive cycle: 2 days after the start of mouthbrooding, 14 days after the start of mouthbrooding, 2 days after the release of fry and 14 days after the release of fry. Differential expression analysis and clustering of expression profiles revealed a number of neuropeptides and hormones, including the strong candidate gene neurotensin, suggesting that molecular mechanisms underlying parental behaviors may be common across vertebrates despite de novo evolution of parental care in these lineages. In addition, oxygen transport pathways were found to be dramatically downregulated, particularly later in the mouthbrooding stage, while certain neuroprotective pathways were upregulated, possibly to mitigate negative consequences of metabolic depression brought about by fasting. Our results offer new insights into the evolution of parental behavior as well as revealing candidate genes that would be of interest for the study of hypoxic ischemia and eating disorders.

## Potency, plasticity, and diversity of stem cells in the rat tapeworm, Hymenolepis diminuta

*Corey Rennolds, Tania Rozario*

Tapeworms are successful parasites due in part to their rapid growth, shedding of reproductive segments called proglottids, and subsequent regeneration of proglottids. The cellular and molecular basis of such continuous, large scale tissue turnover remains poorly understood. The rat tapeworm, Hymenolepis diminuta, contains a sole population of proliferative cells with body-wide distribution that are required for growth and regeneration, like planarian neoblasts, indicative of stem cells (SCs). Unlike planarians, H. diminuta regeneration is not body-wide, consisting only of proglottid regeneration from the neck. Understanding this regenerative ability requires isolating and characterizing the SCs, including determining their potency, diversity, and developmental relationships. We are conducting parallel approaches to isolate SCs. First, we are using basic stains and fluorescence activated cell sorting (FACS) to enrich for SCs. We have found three populations of cells differing in nuclear DNA content, possibly corresponding roughly to cell cycle stages, and we plan to use single-cell RNA-seq (scRNA-seq) of the putative 4N cells to distinguish SC subpopulations, including any pluripotent cells and lineage-restricted progenitors that may exist. Second, we are using existing scRNA-seq datasets to discover SC markers, including cell surface receptors that may serve as antibody targets for FACS. We anticipate that these approaches will yield novel insights regarding the composition of tapeworm SCs and facilitate further work to understand SC function, potency, and plasticity in the context of development.

## Sound in sediment - effects of bioturbation on acoustical properties of sediments

*Semyra Reus, Jennifer Duncan, Kelly Dorgan*

Abundant and diverse infaunal organisms inhabit marine sediments, yet current methods to sample and characterize the impacts of these organisms are time-consuming and have low spatial and temporal resolution. Burrowing infauna modify the physical properties of marine sediments, and these changes translate to changes in geoacoustic properties, enabling use of acoustics to characterize infaunal impacts to near-surface sediments. Specifically, we hypothesized that heterogeneity caused by infauna can cause increased attenuation, and burrowing activities can reduce bulk density and therefore decrease sound speed. To test these hypotheses, we isolated brittlestars, large-bodied, active burrowers that we expected to strongly impact sediment mixing in the area. After placing brittlestars into pre-measured sediment cores collected from Mobile Bay, AL, we measured sound speed and attenuation repeatedly over the course of one month. Changes in geoacoustic properties highlight the potential use of acoustics to characterize infaunal activities on higher spatial and temporal scales than traditional methods of sampling.

## Parental care response to breeding pool water level change in *Ranitomeya imitator*

*Michael Reynolds*

The mimic poison dart frog Ranitomeya imitator is well known for raising its young in small arboreal pools, and for its unique reproductive system of providing biparental care to eggs and tadpoles. The pools R. imitator raise their offspring in are ephemeral and small in volume, making them vulnerable to desiccation.To examine the behavioral responses of adults and the physiological responses of tadpoles of Ranitomeya imitator to water-level decrease in the breeding pool, we exposed captive pairs of frogs to three different treatment levels of water-level change. Water was kept constant at 25 ml, decreased by 2.5 ml weekly, or decreased by 5 ml weekly. Adults were recorded attending to their tadpoles, and the proportion of time spent on parental care behaviors was compared between treatments. After tadpoles achieved metamorphosis, they were weighed and measured. Parental care behaviors did not significantly differ in proportion between treatment groups. Significant differences between treatment groups were found in tadpole snout-vent length, weight in grams, and larval stage duration, with the most significant differences found between the fast and control treatment groups. These results suggest that R. imitator tadpoles experiencing water scarcity are selected to optimize the trade-off between body mass and larval duration. This plasticity in growth may be an adaptation to the ephemerality of phytotelmata, aiding tadpoles in escape from a diminishing aquatic environment.

## Adaptation and constraint in colubrid snake jaws

*Daniel Rhoda, Kenneth Angielczyk*

Natural selection operates on phenotypic variation within populations, but this variation is structured unevenly. Responses to selection (changes in mean phenotype between generations) will be biased towards directions with greater variation, and it has been shown that these biases at the microevolutionary level may drive patterns recovered at the macroevolutionary level. However, empirical analyses that simultaneously consider within-population variation, interspecific variation, and estimates of the adaptive landscape are uncommon. Using a morphometric dataset including functional performance estimates of 346 species of colubrid snakes, 78 of which include data to estimate within-species variation, we show that ontogenetic allometry and intraspecific variation are highly conserved and orientated in the direction of a functional trade-off between gape size and prey handling. We first demonstrate that this alignment facilitates an ontogenetic dietary niche shift in the genus Nerodia, North American Water Snakes. Repeating these analyses on a series of successively more inclusive clades, we further show that this alignment is preserved within most colubrid snakes. This analysis highlights the importance of the interaction between the structure of variation and direction of selection, and builds upon the growing empirical literature suggesting that microevolutionary processes play a central role in the assembly of macroevolutionary patterns.

## Measuring mitochondrial performance in closely related migrant and non-migrant avian species

*Emma Rhodes, Geoffrey Hill, Wendy Hood*

Until recently, the role of mitochondria in migration physiology and energetics has been mostly unstudied. The migratory phenotype consists of whole-organism to subcellular adaptations although a paucity of information exists on how organelles within the cell may play a critical role. Our research has focused on two-study comparisons of closely related migrants and non-migrants, in the family Mimidae and genus Zonotrichia. Here, we discuss our mitochondrial respiratory performance results between our study groups by measuring mitochondrial respiration using high-resolution respirometry. Additionally, we discuss other important variables and measurements that were collected that allow us to examine oxygen-carrying capacity, fuel usage, and whole-organism performance. Our initial study on migratory and non-migratory, White-crowned Sparrows (Zonotrichia leucophyrs), demonstrated evidence of seasonal upregulation of mitochondrial performance related to migration. However, our Mimidae results did not. We discuss potential explanations for these patterns and how we are currently working to understand the mechanisms underlying our results. Lastly, we discuss our current work on expanding to other Zonotrichia groups to control for relatedness in our study.

## Tuning of wing flexibility to intraspecific variance in body size in the mango stem borer

*Gal Ribak, Ori Stearns, Kiruthika Sundararajan, Duvall Dickerson-Evans, Roi Gurka*

The adult body size of insects is often dependent on environmental conditions during larval growth. In the mango stem borer (Batocera rufomaculata) variance in these conditions can lead to a sevenfold intraspecific difference in body mass and a twofold difference in wing length between flying adults. We studied the effect of such variation in body size on flight aerodynamics. The wings of small, and large individuals scale with body mass according to geometrical similarity implying higher wingloading for larger beetles. When tested in a revolving wing set-up to measure aerodynamic performance, the small wings performed as well or better than larger ones. We show that this was due to hypermetric scaling of wing stiffness leading to smaller wings deforming to a larger extent when aerodynamic loads are applied on them. At large angles of attacks (40°-50°) the deformations increase wing twist and camber improving flow attachment to the wing, as evident by a PIV study of the flow in the wake of the revolving wing. The hypermetric scaling of wing stiffness is partially achieved by anisotropic growth of wing vein cross-section leading to increased resistance of larger wings to chordwise and spanwise bending. Thus, wing mechanical properties are tuned to match the structural and aerodynamic needs associated with the high variance in body mass in these beetles

## Wearable wireless system for continuous glucose and heart rate monitoring in house sparrows

*Rachel Riccio, Cihan Asci, Atul Sharma, Sameer Sonkusale, L. Michael Romero*

A key to understanding an animal's ability to survive is by assessing the physiological and behavioral responses to stressors. In assessing the stress response, multiple biomarkers should be considered. In the past, logistical challenges of sampling multiple biomarkers within free-living animals have limited our capacity to capture the full dynamics of the stress response. Integration of novel miniaturized multiplexed sensing devices is a critical next step. In this work, we employed our novel wearable system for real-time monitoring of heart rate and glucose fluctuations for a model species, the house sparrow. We functionalized conductive threads that occupy a small skin area for non-invasive heart rate monitoring and a small sensing suture under the skin for glucose monitoring. We obtained real-time heart rate measurements, and a continuous glucose measurement from house sparrows under anesthesia. For these preliminary validation experiments, our system measured a heart rate of 614 ± 22.8 beats per minute and an expected increase in current value from a spike in glucose injected subcutaneously in fasted birds under anesthesia. Future use of this device to study the house sparrow response to stressors will aid in expanding our knowledge of the physiological response to stress of wildlife in natural environments.

## Innovations and changes in artificial vagina designs

*Jacquline Rich, Dara Orbach*

Artificial insemination is used to support conservation, livestock production, and captive breeding programs across domestic and exotic species. Semen is collected for artificial insemination through distinct techniques that vary by species, application, and individual animal. While artificial vaginas (AVs) generally collect high quality semen from most livestock species, semen quality varies widely when collected by AVs in other mammalian species. AVs vary in size, shape, and construction. The goal of this study was to assess changes in AV designs over time across all non-human, vertebrate species. A comprehensive literature review was conducted by searching the term "artificial vagina" in the Web of Science and Google Scholar databases. A total of 18,291 articles were reviewed and AV shape, material, and elasticity were recorded. AV design innovations, such as the inclusion of a warmed bladder or imitation cervix, were also recorded. A nominal logistic regression was used to analyze changes in AV designs over time. While variation exists in AVs among species, AV designs have not changed in shape, material, or elasticity. The most common design innovation was a warmed bladder. Some species-specific AV design innovations have been developed based on anatomy and copulatory behaviors, yet the vast diversity in vertebrate reproductive anatomy has been overlooked. To improve semen quality at the time of collection, future research could explore bioinspired AV designs based on taxa-specific reproductive anatomy.

## The wind niche: Organismal responses to wind speed, convection, and boundary layers

*Eric Riddell*

Species distribution models (SDMs) rely on the fundamental niche as the philosophical basis for predicting responses to environmental change. Some SDMs use correlations between environmental variables and species' presences to estimate the fundamental niche, while others couple biophysical simulations and physiological performance. Regardless of the approach, most niche-based analyses focus primarily on the thermal and hydric environment. However, wind can also have a major influence on the rate of energy transfer between organisms and their environment, thereby shaping organismal performance. Here, I will couple behavioral and ecological observations with biophysical simulations to demonstrate the physiological consequences of daily and seasonal variation in wind speed in terrestrial endotherms and ectotherms. I also use biophysical simulations to forecast the physiological consequences of changes in wind speed under future climate change scenarios. In endotherms, simulations indicate that the effects of wind speed on heat transfer can be just as impactful as temperature. Similarly, wind speed can restrict activity in ectotherms by increasing water loss by disrupting boundary layers. Under future warming scenarios, including changes in wind speed can worsen the effect of warming temperatures on endothermic and ectothermic performance. I conclude by defining the challenges in simulating wind speed and highlighting evidence that terrestrial organisms exhibit distinct ecological niches related to wind.

## Identifying ZYG11A, HS6ST1, and DIO2 gene expression in green anole lizards (Anolis carolinensis)

*Emma Rieper, Anna Wilcox, Eleanor Malone, Rachel Cohen*

Green anole lizards (Anolis carolinensis) exemplify behavioral changes depending on whether they are in their breeding or non-breeding season. During the breeding season, these lizards display reproductive behaviors such as head bobbing and flashing their dewlap and these behaviors do not occur during the non-breeding season. Our question is to determine at the gene level what might contribute to these seasonal behavioral changes. We tested three candidate genes, ZYG11A, HS6ST1, and DIO2 for their expression during the breeding and non-breeding season in the anole brain. ZYG11A encodes a protein that is involved in the ubiquitination pathway. HS6ST1 promotes angiogenesis and neuronal development. DIO2 converts thyroid hormone into the active version. We designed specific primers for our genes and tested them via PCR and gel electrophoresis. We compared expression in breeding and non-breeding male and female lizard brains using quantitative PCR and normalized to beta actin. We found that ZYG11A, HS6ST1, and DIO2 mRNA expression did not differ across groups ($p>0.136$, $n=6$). Future work could examine expression in specific areas of the brain that regulate changes in behavior. Overall, this contributes to a better understanding of the seasonal control of the drastic behavioral changes in these animals.

## Under the weather: interactions between stress physiology and storms in wild passerines

*Annie Riffee, Jason Davis*

Birds that undergo yearly migration have evolutionary adaptations to deal with challenges beyond just the physical strain of their flight distance–they must be equipped to respond to less predictable variables, i.e. weather, as well. Previous studies have shown that some species of songbirds can respond to weather changes far in advance of migration. This study aims to observe the interplay between stress profiles of various migratory songbirds and potentially correlating past, present, and future weather conditions, with consideration of other demographic and environmental factors as well. To do this, we have sampled their blood not only for corticosterone, but for a range of catecholamine metabolites that may provide insight into recent levels of epinephrine/norepinephrine.

## Olfaction in the Anthropocene: atmospheric pollutants negatively impacts floral scent and nocturnal pollination

*Jeff Riffell, J. Chan, J. Thornton*

There is growing concern about sensory pollutants impacting ecological communities. This is particularly true for plant-pollinator systems, where pollinators fly long distances to locate patches of flowers and use their olfactory system to detect floral odor plumes. Anthropogenic pollutants, including oxidants like ozone and nitrate radicals ($O_3$ and $NO_3$, respectively) rapidly degrade floral scents, potentially reducing pollinator attraction to flowers. However, the neurophysiological and behavioral impacts on pollinators and plant fitness are unknown. Using a nocturnal flower-moth system, we find that atmospherically relevant concentrations of $NO_3$, and not $O_3$, eliminate flower visitation by moths, and it is the reaction of $NO_3$ to a subset of monoterpenes that reduces the scent's attractiveness. The elimination of behavioral attraction to the degraded scent was mediated by the changes in excitatory-inhibitory balance in the primary olfactory region of the moth brain, the antennal lobe (AL). Changes in the proportion of the key monoterpenes in floral scent altered the encoding and scent representation by the AL projection neurons. Atmospheric modeling studies were conducted to understand whether these impacts could alter plant-pollinator systems in other areas of the world. Global atmospheric models of floral scent oxidation reveal that pollinators in certain urban areas may have a reduced ability to perceive and navigate to flowers. These results illustrate the impact of anthropogenic pollutants on an animal's olfactory ability and indicate that such pollutants may be critical regulators of global pollination.

## Arboreal navigation: corn snakes produce stable vertical motion through geometric matching

*Calvin Riiska, Michelle Lee, Joseph Mendelson, Jennifer Rieser*

Some snake species navigate diverse arboreal habitats with ease, propelling their limbless bodies while contending with tree trunks and branches of varying diameters, flexibility, and surface roughness. To investigate climbing strategies used by corn snakes (Pantherophis guttatus), we created an experimental apparatus consisting of a smooth, vertical wall. Evenly spaced force-sensing pegs protrude from the wall and serve as the only useable features available for the generation of propulsive forces. Combining time-resolved 2D force data with 3D kinematics for vertical ascents and descents, we analyzed how body shapes and distributions of applied forces vary with the length and spacing of surface features. With short pegs, reminiscent of bark texture, we find that snakes use small lateral bends and move via a combination of lateral undulation and concertina-like movements that produce force patterns with large fluctuations. In contrast, when presented with longer pegs mimicking small branches or large bark protrusions, snakes use larger laterally undulating bends that vary with peg spacing and produce steadier propulsive forces. We use geometric calculations to explore the space of allowed shapes; surprisingly, a simple feed-forward robotic model reveals that geometry-matching can produce stable vertical movements. We develop a computational model to compare performance across allowed shapes and explore tradeoffs between speed and stability across peg configurations. Future work will investigate the effect of species specialization on the success of climbing.

## Paternal deprivation affects offspring care and offspring adult stress-induced corticosterone levels

*Angela Riley, Jennifer Grindstaff*

The development of the hypothalamic-pituitary-adrenal (HPA) axis is sensitive to early life perturbations, including decreased parental care. In this study, we sought to answer the questions of how paternal deprivation might affect the HPA axis development of offspring and how parental behaviors might be affected by paternal deprivation. To do this, we used captive zebra finches (Taeniopygia guttata) and set up two paternal deprivation treatment groups in which we removed the father at hatching or at fledging. We then measured offspring nestling and adult baseline corticosterone and adult isolation-induced corticosterone. We also quantified the effects of paternal deprivation on parental care and offspring growth. We found that mothers increased feedings to match the combined feedings of mothers and fathers in biparental nests but were not able to match the amount of time spent in contact with offspring, and nestling growth was not affected by paternal deprivation. Additionally, we found that offspring that experienced paternal deprivation from hatching had higher corticosterone levels relative to their baseline corticosterone levels after experiencing social isolation, which is reflective of a hyper-responsive stress response. This suggests that the HPA axis of offspring does not develop the same when fathers are absent from hatching and that these effects are possibly driven by decreased parental contact rather than nutritional constraint.

## The genetic architecture of pollution adaptation in Atlantic killifish

*Carolina Rios, Bryan Clark, Sibel Karchner, Neel Aluru, Andrew Whitehead, Mark Hahn*

Rapid and drastic environmental change, including pollution, is characteristic of urban environments and presents fitness challenges to urban organisms. The likelihood of evolving resistance to urban pollutants is dependent on the nature of pollutants and characteristics of species. Understanding the complexity of the genetic architecture underlying adapted traits is important for understanding a species' capacity for adaptation to urban environments. Atlantic killifish populations inhabit urban estuaries that are highly polluted with persistent organic pollutants (POPs) and have rapidly and repeatedly evolved reduced sensitivity to exposure-induced developmental cardiac defects. We utilize comparative physiology and functional genomics, as well as quantitative genetics experiments to reveal the molecular mechanisms and genetic architecture underlying adaption to pollution. In response to one class of POPs, our results show that exposure-induced aryl hydrocarbon receptor (AHR) activation is desensitized in pollution adapted urban populations, and that pollution-adaptation in cardiovascular developmental toxicity is underpinned by a few loci of large effect. These results suggest that adaptive responses to developmental cardiac toxicity caused by one class of pollutant have a simple genetic architecture. However, organisms in urban environments often encounter complex mixtures of pollutants with differing mechanisms of action, and exposure histories vary greatly between urban sites. Ongoing experiments are testing whether the genetic architecture that underlies pollution adaptation is shared or unique across multiple adapted genetic backgrounds and to different classes of contaminants.

## Effects of Heavy Metals on BMP4 in frogs (Lithobates hecksheri)

*Rafael Rios, Sofia Barajas, Matthew Gross, John Phillips, Christopher Heesy, Leigha Lynch*

Through experiments on model organisms, it is understood that heavy metals alter development of the central nervous system, including through alteration of the genetic structure of DNA. Yet we know little about how heavy metals affect genes that regulate brain development in wild populations. We add to the understanding of the effects of heavy metal exposures on brain development by testing for DNA damage in BMP4, which regulates neural and glial cell development. We collected 37 samples from the species Lithobates hecksheri from Georgia; 19 from a heavy metal contaminated site and 18 from a pristine site. We assembled and aligned BMP4 sequences against Rana temporaria consensus sequence from Genbank. There were no significant differences in GC-content between contaminated and pristine populations ($p=0.80$). Calculations showed genetic distances for the contaminated group of 0.04 and < 0 .01; pristine group of 0.02 and 0.04; and between group of 0.03 and 0.02. We found no significant neutral ($p=1,0.88,0.39$), positive ($p=1,0.44,1$), or negative ($p=1,1,0.19$) selection for contaminated, pristine, and both groups. The populations together and the pristine population showed significant neutral ($p=0.02$) and negative ($p=0.01$) but no positive ($p=1$) selection. The contaminated group showed no evidence of selection ($p=1,1,1$). These results suggest that heavy metal contamination is not damaging this developmental gene but influences selection. The absence of selection on BMP4 in exposed frogs may impact evolutionary brain development.

## Bioaccumulation in insects according to feeding strategy

*Phoebe Riser, Jelagat Cheruiyot*

Due to human activity, heavy metals have become much more available to organisms, causing bioaccumulation in many systems as the concentration of metals increases as they move up trophic levels. While many factors determine the extent of bioaccumulation in predators, an understudied variable is the feeding method that an organism uses. In insects, hematophages partially digest their prey externally, then consume the liquids from their corpse. We analyzed the amount of bioaccumulation in hematophagous insects with insects that use mastication to consume the entire body of their prey. We did this by recreating a previous study on the hematophage Podisus maculiventris that analyzed the bioaccumulation of Ni, Co, Cu, and Zn, using the praying mantis Tendera sinensis instead. Herbivorous Spodoptera exigua larvae were fed diets with the minimum sublethal dose or lethal dose of Ni, Co, Cu, or Zn, or a control diet, were then fed to Tendera sinensis. The bioaccumulation factor of each experimental group was found and compared to the concentrations previously found in Podisus maculiventris. These data show bioaccumulation might change due to the feeding method in these two insect predators.

## How do wild nestlings respond to repeated heat exposure? An integrative approach

*Atalanta Ritter, Emily Levy, Kimberly Rosvall*

Climate change is increasing the likelihood and intensity of heat waves. Endotherms can acclimate to short-term temperature changes via a suite of physiological and behavioral responses; however, mounting these responses may be costly, especially when repeated over multiple days. Physiological performance is thus likely to change over successive thermal challenges, but this process is underexplored in wild endotherms. To begin addressing this gap, we exposed tree swallow nestlings (Tachycineta bicolor) to sublethal heat for 4 hours on two subsequent afternoons, when nestlings were 12 and 13 days old. By this age, nestlings have developed their own thermoregulation but are still confined to the nest. After each heat trial, we measured nestling body mass and wing length. We also sampled blood from at least one individual per nest to assay gene expression of HSP90AA1, a key mediator of heat-induced damage and repair. We will integrate across these physiological and morphological traits to determine how thermal responses act over multiple days of heat, and whether this affects overall organismal performance. By measuring real-time responses to an ecologically relevant thermal challenge, we can better predict how wild birds will fare under climate change.

## The seasonally dynamic foraging landscape: impacts on honey bees, wild bees, and their interactions

*Clare Rittschof*

I will review projects related to our integrative work on honey bee (Apis mellifera) foraging strategies and their response to the seasonally dynamic floral landscape. In times of floral resource shortage, honey bees shift to an aggressive honey robbing tactic and attack other colonies. We have assessed the factors that cause increased aggression in honey robbing bees, including the role of competitive interactions with other honey bees, and whether neuroactive plant phytochemicals in nectar versus honey can explain behavioral shifts. Ongoing work is investigating how colony foraging recruitment behavior (the balance of signals that promote and suppress recruitment to dangerous food resources) changes seasonally with floral resource dearth and honey robbing risk. Finally, we are investigating how seasonal shifts in honey bee aggression and honey robbing activity (prompted by the lack of floral resources and increased honey bee – on – honey bee aggression) impacts direct competition with non-honey bee pollinators on a shared floral resource, white clover. We chose this flower because it has two major bloom periods, one in June (low honey robbing risk and honey bee aggression) and one in August (high honey robbing risk and aggression). This series of studies combines perspectives from ecology, behavior, and insect and plant physiology to understand how honey bees behaviorally respond to seasonally dynamic floral landscapes, and how these changes could impact non-honey bee pollinators.

## From jars to data: transforming natural history collections into research assets

*Alana Rivera*

Natural history collections are much more than just jars of specimens. Collection staff work to connect the dots between each specimen and its broader context. In the Invertebrate Zoology Department at the Museum of Comparative Zoology we increase the research value of our specimens by capturing as much detail as possible. This involves referencing expedition field notes, finding photos of the specimen when it was alive, or researching a historic figure to pinpoint the island and valley a specimen came from.

All of this effort reduces the amount of “dark data” - information that is hidden or underutilized - in collections. This is often collaborative problem solving involving archives, libraries, other museums, and experts in the research community. Much of the work involves sleuthing through history, but while many of our specimens range from 1860 to 2024, we have entered the modern era with our capabilities. We also document our specimens in media. Detailed photographs and scans, as well as video and models of our specimens are important for many research inquiries. Explore the benefits of vouchered material and ways the collection enhances research. Whether data points coming from a larger aggregator, or minute details of a single crustacean specimen, a natural history collection has a lot to offer.

## Deducing the Evolution of Allorecognition and Primordial Immunity in Cnidarians

*Alberto Rivera, Andy Baxevanis*

The allorecognition system of the hydroid Hydractinia symbiolongicarpus plays an essential role in mediating self vs. non-self recognition in cnidarian colonies, which is analogous to the role of the major histocompatibility complex (MHC) in bilaterian immune systems. Both complexes have contiguous stretches of similar, highly duplicated genes, suggesting a homologous relationship between the ARC and MHC. Protein structural prediction methods, such as AlphaFold2 also indicate structural similarity between the proteins encoded within the Hydractinia ARC and the MHC. We have deduced the structure of the ARC in the related hydrozoan Podocoryna to determine the conservation of the cnidarian allorecognition complex. Genome annotation software and protein structural prediction methods have revealed a number of candidate Podocoryna allorecognition proteins that form a long contiguous complex. Phylogenies suggest homology between cnidarian allorecognition genes, as well as syntenic conservation of this gene complex across cnidarians. We are currently applying these methods to analyze the high-quality whole-genome sequence of the basal bilaterian Branchiostoma to identify potential ALR orthologs. We have also begun identifying homologous regions in other bilaterian species to determine likely ALR homologs. Future comparative genomics work with other basal chordates and vertebrates will be focused on determining the relationship between the ARC and the bilaterian MHC, to help elucidate the evolution of the immune system in early vertebrate history.

## Mitochondrial plasticity varies with season and reproductive status in island dwarf lizards

*Danielle Rivera, Corban Muthiah, Aaron Wong, Eric Reyes, Sagar Bhowmik, David Miller, Amanda Sparkman, Tonia Schwartz*

The "island rule" is a well-documented evolutionary phenomenon where animals isolated on islands often evolve to be either larger or smaller compared to their mainland counterparts. The Southern Alligator Lizard, Elgaria multicarinata, which inhabits both the California mainland and Channel Islands, exhibits ∼16% reduction in body size on the islands versus the mainland. While resource limitation hypotheses offer explanations for the occurrence of island dwarfism, the molecular mechanisms—such as the genes, hormones, and cell signaling pathways involved—remain unclear. Mitochondria play a critical role in supporting animal performance, as they produce over 90% of the energy required for cellular activities. Variation in mitochondrial function and density (i.e., the number of mitochondria per cell) are believed to contribute to individual differences in health and overall fitness. Because an individual's energy requirements vary it is expected that mitochondrial function and density exhibit plasticity in response to resource availability and life stage such as growth and reproduction. In this study, we investigate mitochondrial genome density (as a proxy for mitochondrial density and performance) in the blood cells of these the alligator lizard between island and mainland populations and test their association with blood glucose, morphology, reproductive status, and season. Results from this work will provide significant insights into the link between mitochondrial function and energetic demands in wild populations in relation to body-size evolution in this island dwarf system.

## Multiple pathways to modulate bite performance in Sceloporus lizards

*Julio Rivera, Israel Solano-Zavaleta, José Jaime Zúñiga Vega, Emilia Martins*

Biting performance can differ across taxa through independent changes in head morphology that ultimately lead to differences in performance capabilities. Here, we explore biting performance and its morphological correlates in six closely related lizard species, Sceloporus, and asks whether the species share the same morphological correlates or whether they have found unique, independent solutions to modulate biting performance. We found that species differed in head dimension but only head height correlated with performance differences in half the species. We did not find a single morphological trait that correlated with bite performance for the remaining species, however, these species possessed overall larger heads and stronger biting performance. Additionally, all species shared a mechanical advantage of less than one indicating that their jaws are designed to close quickly rather than producing strong bites. These results suggests that head morphology may be under different selective pressures so that some species require large heads to produce strong bites to eat hard prey items, like beetles, or for intraspecific interactions while other species have flat heads for predator avoidance, which leads to weaker biting performance.

## Genomic analysis of gamete recognition proteins in a broadcast spawning echinoderm

*Pearl Rivers Key, Darin Rokyta, Yueling Hao, Don Levitan*

Gamete recognition proteins are proteins expressed on the surface of sperm and eggs which mediate interactions between gametes. In marine species that reproduce by releasing gametes into the water column for external fertilization (i.e., broadcast spawning), gamete recognition proteins play key roles in determining intraspecific reproductive success under variable levels of sperm availability and reproductive isolation among sympatric species. Using a de novo genome assembly and transcriptome for the red sea urchin (Mesocentrotus franciscanus), we investigated the genomic structure and expression of two putative egg receptor genes, EBR1 and HSP110. Variation in EBR1 relates to gamete binding affinity in the red sea urchin, while the role of HSP110 in gamete recognition is less understood and has not yet been directly tested in M. franciscanus. We found that EBR1 is a large and repetitive gene spanning a ∼115kB region of the genome, while HSP110 spans only ∼26kB. RNAseq analysis of male and female gonads and gametes confirmed that EBR1 is expressed only in female gonads and eggs. HSP110 was equally expressed in male and female gonads and gametes, suggesting ambiguity in this protein being an egg receptor for sperm in red sea urchins. Resolving the genomic structure of genes encoding gamete recognition proteins enables deeper investigation into the evolution of variation in gamete recognition proteins under conditions with high risk of polyspermy or heterospecific mating.

## Using a mark-resight model to elucidate population estimation and habitat usage in lined seahorses

*Emma Robbins, Rose Gaetano, Megan Sims, Emily Rose, Heather Mason*

Seahorse National Park's Sweetings Pond is an anchialine system, a saltwater lake fed by the ocean through the ground, located in Eleuthera, The Bahamas. This habitat is home to an isolated population of lined seahorses, Hippocampus erectus, that exhibit nocturnal behaviors and are morphologically distinct. To conduct a mark-resight study in the southern end of the lake, a 25m x 25m grid broken into 5m x 5m cells was established and sampled thirteen times between August 2018 to March 2020. Each occasion consisted of a daytime marking event with seahorses being photographed, marked with individual heterogeneity using elastomer tags during their first daytime capture event, and georeferenced, with 4 nighttime resighting events and a mean resampling time of 51(9.5) days between occasions. Throughout the bimonthly sampling events, we marked 243 seahorses and had 149 recapture events. Identification of individuals through a combination of recapture confirmation using the unique tag codes on each seahorse, along with variation in facial features and body patterning, will strengthen capture histories for Mark's immigration-emigration mixed-logit normal mark resight model and habitat usage analysis. Population estimates generated from the Mark model and individual seahorse movement data are essential components for the development of Seahorse National Park's management plan and the vital conservation plan for this Bahamian seahorse population.

## Landmark-free morphometrics reveals extreme shape variation in the limb bones of domestic dogs

*Lucy Roberts, James Charles, Eithne Comerford, Karl Bates, Anjali Goswami*

Millenia of artificial selection have made domestic dogs (Canis familiaris) one the most morphologically diverse species on Earth, providing the opportunity to test evolutionary, developmental and functional mechanisms underlying morphological variation. Skull shape is well studied and demonstrates that morphological disparity in domestic dog skulls exceeds that of all other carnivorans collectively. The postcranial skeleton is much less well understood, partly due to the relative paucity of homologous landmark positions in limb bones. Here we present the first landmark-free Deterministic Atlas Analysis of limb bone shape across Canini, sampling the humerus, radius, ulna, femur, tibia and fibula of 10 species across the clade, including 13 breeds of domestic dog. We find that every sampled limb bone in domestic dogs occupies an order of magnitude larger morphospace than all other sampled species. The degree of morphological difference from the sister taxon to domestic dogs, the wolf, Canis lupus, varies between dog breeds. Shape differences are most extreme in dachshunds, which have shorter and thicker limb bones. Dachshund fibulae are markedly curved, and femora have pronounced and laterally-extending greater trochanters, potentially related to the biomechanical impact of proportionally short legs. Conversely, greyhounds consistently occupy the same morphospace as other sampled species. These results present the opportunity to inform breed-specific musculoskeletal health in domestic dogs, and elucidate the relationships between postcranial morphology, development and biomechanics across canine phylogeny.

## If not pharyngognathy, then what? The role of ecology and hybridization in cichlid diversification

*Alexus Roberts Hugghis, Ole Seehausen*

Modifications to the pharyngeal jaws – a prey processing system located posterior to the mouth cavity – have classically been regarded as a key innovation that drives diversification in cichlids, damselfishes, wrasses, and a few other fish lineages through increased evolutionary decoupling of the oral and pharyngeal jaws. Opposing long-held predictions, recent studies revealed that these musculoskeletal alterations are associated with greater evolutionary integration of the two jaw systems. This tightened coevolution among feeding structures likely constrains phenotypic diversification as pharyngognathous fishes also displayed reduced morphological and functional disparity and slower rates of functional evolution. Thus, despite supporting elevated transition rates to feeding on hard prey, the modified pharyngeal jaw also restricts phenotypic diversification. These results highlight the urgent need to consider the role of other factors in the adaptive diversification of cichlid fishes, especially those found in African Rift Lakes. Leveraging functional morphological data and phylogenetic comparative methods, we contrast patterns of disparity, rates of evolution, and evolutionary integration in the continental radiation of Neotropical cichlids and African lacustrine cichlid radiations to begin disentangling the influence of morphological, ecological, and genetic factors on rate, direction, and extent of phenotypic diversification in these prominent pharyngognathous fish clades.

## Effects of climate change on body size and melanin in *Polyphylla diffracta*

*Colton Roberts-Zaffiro, Amanda Carter*

In many regions, climate change is increasing the frequency and intensity of heatwaves and drought. These events likely act as intense selective forces on both thermoregulation and water balance across taxa. In insects, two traits that have outsized impacts on thermal biology and water balance, are body size and melanin. Body size can affect rates of heat and water loss through surface area to volume ratios. Whereas, melanin – a dark, hydrophobic pigment– can increase heat gain and reduce water loss when deposited in the cuticle. We wanted to know if body size and melanin are shifting with climate change in a species of beetle, Polyphylla diffracta. P. diffracta is a large, nocturnal beetle with striking black and white stripes that vary across individuals. Using museum collections, we measured body size and melanin deposition in 290 specimens of P. diffracta collected in northern Arizona between 1944-2024. Using ImageJ, we measured body size as elytral length and quantified melanin as the percent of black pigmentation on both elytra. Preliminary results suggest that body size is decreasing over time, and though analyses of melanin are ongoing, we predict that melanin deposition will increase to resist desiccation. Our results will help inform how insects might respond to multiple aspects of climate change and enhance our ability to predict future loss of biodiversity.

## Teamwork in the torrent: collective behaviors of flood survival in social insects

*Andrew Robertson, Daniel Goldman, Michael Goodisman*

Flooding presents an immediate danger to terrestrial animals, especially those that nest underground. Strategies to avoid this danger include specialized morphology, behavior, or both. Fire ants are well-known for their collective success surviving intense flooding by linking together to form a living raft. However, the proximate causes of rafting success are yet to be fully determined. We investigated how developmental stage, caste, and worker size affected colony survival during flood conditions in the Red Imported Fire Ant, Solenopsis invicta. Ants were allowed to form rafts under experimental, flooding conditions. The caste and stage composition of rafts was experimentally varied in order to determine how the demographic makeup of rafts affected raft survival. Rafts were recorded by video for up to twenty days or until rafts failed. We found that rafts made up of large workers lasted much longer on average than control rafts. Surprisingly, we also found that the duration of rafts with larvae or reproductive castes included showed no difference to controls, in contrast to expectations. Analyses further suggest that rafts last longer when fire ants remain in a low-activity state. This research further reveals how individual traits and collective behavior can each contribute to colony survival. Our results challenge previous hypotheses regarding causes of success in fire ant rafting and extend our overall knowledge of collective survival during extreme environmental challenges.

## The evolution of hormonally mediated gene expression in Sceloporus lizards

*Christopher Robinson, Matthew Hale, Christian Cox, Henry John-Alder, Robert Cox*

The evolution of sexual dimorphism is predicted to occur partly through changes in the effects of sex steroids on organismal phenotypes, but the underlying evolution of hormonally regulated gene expression remains poorly understood. To address this issue, we used hormone implants to chronically elevate testosterone levels in juveniles of three Sceloporus lizard species prior to natural sexual divergence in circulating testosterone. We then characterized sex- and species-specific transcriptomic responses in the liver, a tissue that is hypothesized to regulate sex- and species-specific patterns of growth and sexual size dimorphism. In each species, transcriptomic responses to exogenous testosterone were highly concordant between juvenile females and males, with no genes exhibiting siginificant sex-by-treatment interactions. By contrast, hundreds of genes exhibited significant species-by-treatment interactions, particularly when comparing distantly related species with opposing patterns of sexual size dimorphism. This result indicates considerable evolutionary lability in the regulation of gene expression by testosterone. We discuss this "evolutionary potential" in the context of theory in evolutionary endocrinology and our ongoing efforts to link the evolution of hormonally mediated gene expression to natural sex and species difference in transcriptomes and organismal phenotypes.

## Effect of attachment on exertion capacity in the green anole (Anolis carolinensis)

*Natalie Robinson, Benjamin Wasiljew, Austin Garner*

Climbing animals must effectively interact with surfaces to generate enough force to induce locomotion and resist gravity. Anolis lizards accomplish this using specialized attachment systems (subdigital pads and claws) to navigate complex, three-dimensional environments with variable substrate properties. Substrate properties can directly impact attachment ability which can lead to substantial effects on various aspects of locomotor performance (e.g., speed, acceleration, and jump distance). However, the effect of attachment ability on the duration a claw- and pad-bearing lizard can maintain maximal sprint performance (i.e., exertion capacity) has been relatively unexplored. Here we studied the relationship between attachment ability and exertion capacity in the green anole by measuring exertion capacity on a custom-built treadmill. The treadmill was outfitted with three sandpaper substrates to vary attachment ability and set at three different inclines to vary reliance on attachment. The results of this study not only enhance our understanding of how attachment directly affects locomotor performance in scansorial lizards but also how they effectively move in ecologically-relevant conditions.

## Using ultrasonography to evaluate morphological changes in the mammary gland of bottlenose dolphins

*Maria Jose Robles Malagamba, Mason Dean*

Mammary glands are fundamental organs for offspring survival due to their role in lactation. However, in veterinary medicine, these organs are not included in routine clinical examinations, unless abnormalities are detected. Therefore, the influence of significant reproductive processes, such as pregnancy and lactation, on the morphological characteristics of mammary glands is relatively limited. This is particularly evident in marine mammal medicine, due to their unique aquatic environment and associated logistical challenges of studying species such as bottlenose dolphins (Tursiops truncatus). Our research project uses B-mode and color Doppler ultrasonography to evaluate mammary gland morphology and vascularity across a large sample of female Atlantic bottlenose dolphins of different reproductive stages under human care. Our approach allowed us to visualize major anatomical changes that occur in the mammary gland across different reproductive stages (i.e. sexually immature, pregnant, and lactating animals), especially with regard to gland and border thickness, diameter of mammary ducts, and vascularity. In particular, lactation heavily influences mammary gland morphology, with vascularity only visible in lactating dolphins. This study, by providing the first comprehensive ultrasonographic assessment of mammary gland development in healthy dolphins, provides a baseline for guiding reproductive health assessments in this and other small cetaceans, while offering critical insights for conservation of wild populations, many of which are endangered or vulnerable.

## Spatiotemporal stride and tail kinematic comparisons between wetland-adapted and generalist rodents

*Dulce Robles Martinez, Diego Sustaita*

The terrestrial locomotor abilities of the endangered salt marsh harvest mouse (Reithrodontomys raviventris) have historically been inferred based on its preferred microhabitat within the San Francisco Bay Estuary and anecdotes from the field. The mouse remains in areas affected by temporal tidal inundation, likely surviving by climbing emergent vegetation. A reliance on climbing should be reflected in the mouse's climbing performance. We investigated the locomotor capabilities of the salt marsh harvest mouse, the congeneric western harvest mouse, and the invasive house mouse. We measured spatiotemporal variables including velocity, stride length and frequency as mice traversed dowels of varying sizes and orientations. We quantified the mice's tail angular position and its derivatives during horizontal locomotion. The salt marsh harvest mouse employed slower velocities and modulated velocity more via stride frequency than stride length. When not using the tail for grasping support, the salt marsh harvest mouse held its tail at more depressed angles and did not seem to modulate stabilizing angular momentum to the same extent as the house mouse even though both species demonstrated increasing tail angular amplitudes as velocity increased. The salt marsh harvest mouse exhibited fewer slips than the other two species on the same substrates. These results suggest the salt marsh harvest mouse successfully navigates the same substrates as the other mice by making greater use of static stability.

## Motor learning of a new gravity level transfers to other motor and cognitive tasks

*Chase Rock, Hyorim Kim, Tushar Singh, Young-Hui Chang*

Many animals are experts at moving through their physical environments. One way expertise is achieved is through transfer of learning about the world around them: information learned in one context can improve performance in another context. In this series of experiments, we studied human subjects as a tractable model to test the extent of far transfer of learning between dissimilar tasks. We studied adaptation to novel gravity levels because gravity dominates many tasks performed by different bodily systems. Before and after participants adapted to jumping in simulated hypogravity, we tested their ability to do two gravity-related tasks that did not involve jumping: vertical arm movements and cognitive assessments of projectile motion. We hypothesized that novel gravity information learned during jumping would transfer to the arm and cognitive tasks, such that performance on these tasks would reflect the expectation of hypogravity. We found that performance on the arm and cognitive tasks were both significantly impacted by the recent experience of jumping in simulated hypogravity. Surprisingly, following adaptation to hypogravity jumping, vertical arm movements at 1g resembled movements made in hypergravity environments rather than hypogravity. Similarly, the cognitive task revealed an expectation of hypergravity instead of hypogravity. These aftereffects can be explained by an updated expectation of altered gravity that is learned from jumping and then affects dissimilar tasks, providing evidence of far transfer of gravity-related learning.

## Rising to the Occasion: The Role of Fish Dorsal Fin Kinematics During Rapid Turning Maneuvers

*Jason Rodgers, Bradford Gemmell, Nils Tack, Chase McGuire*

Fish locomotion research has a rich history in the literature and has proven helpful in the development of biomimetic underwater vehicles. There are however knowledge gaps in the functional role of the dorsal fin during rapid turning. For instance, most research has focused on the force contributions of the body and caudal fin. However, our comparative work on >100 species of bony fishes during rapid turning maneuvers has shown that the dorsal fin is consistently employed during this behavior. During C-start turns, the dorsal fin rapidly expands in 14.2±3.1ms at the onset of the turn and then retracts immediately upon linear acceleration. The goal of this study is to determine the function of the fin and its relative torque contribution during turning. We used locally collected Pinfish (Lagodon rhomboides, SL=11.67±0.93cm) and measured their hydrodynamics while performing C-start turns using high speed, high resolution 2D PIV. Thirty turns were recorded measuring the pressures along the outline of both the midline of the fish body and the dorsal fin. The mean stage one turn rate was 2.96±0.67°/ms with a mean total turn angle of 107° (range: 43°-239°). We found that the relative torque contribution of the spiny dorsal fin was 14% of the torque produced by the fish body. Implications of this additional torque are discussed in the context form/function relationships as well as for potential bio-inspired design applications.

## The effects of complex nest environments on embryo development and hatchling phenotypes of the brown

*John Rodgers, Daniel Warner, Mike Norris*

The influence of the nest environment on offspring phenotypes and survival is well described for a variety of oviparous (i.e., egg-laying) species. Much of this previous work has focused on replicating natural incubation environments in the laboratory, based on the characteristics of maternally chosen nest sites in the wild. Although several environmental factors affect offspring phenotypes (e.g., substrate type, soil moisture, temperature), most studies do not assess the relative contribution of each factor to variation in offspring phenotype. To understand how multiple nest characteristics interact to affect offspring phenotypic variation, we studied the brown anole lizard (Anolis sagrei). We performed a full factorial experiment that decoupled the effects of nest temperature, moisture, and substrate to quantify the independent and interactive effects of these factors on embryo development and offspring phenotypes. We found that nest temperature drives most of the variation in developmental rate, and moisture conditions generate most of the variation in egg water uptake and hatchling body size. Substrate explains very little, if any, variation in developmental and offspring variables. Interactive effects of these factors were not statistically supported for any phenotype measured. Overall, these results illustrate the complex effects of different environmental factors experienced by developing embryos and have implications for understanding how environmental change will impact this early life stage.

## ROVs and Dynamic Positioning: How do they work together?

*Quinn Rodriguez*

This project investigates the relationship between a research vessel's Dynamic Positioning System (DPS) and a Remote Operate Vehicle (ROV)'s navigation system. By examining how each system works separately, we aim to understand their relationships relative to one another with the goal of maximizing efficiency and gaining an understanding of how ROV Pilots and DPS Officer (DPO) can work together more effectively. In looking into how ROVs and how they navigate, we hope to gain an understanding of how they triangulate relative to the ships they are deployed from, particularly when handling rough weather, and how they are controlled particularly when diving to secure samples from the bottom of the ocean. An area of particular interest is how DPOs work with the ROV Pilots in the case of high winds, strong current, and system failure in the case of the DPS and it's backup systems.

## Using wild songbirds to study interval timing in vocal communication

*Carlos Rodriguez-Saltos*

Using wild songbirds to study interval timing in vocal communication

Research on mechanisms of behavior has still much to benefit from work on Neotropical species. Using scaly-breasted wrens (Microcerculus marginatus), I study the evolution and mechanisms of interval timing and rhythm in vocal communication. These wrens time the notes in their song with a precision that can be as high as that of a professional musician. Both wrens and musicians are vocal learners, and just as musicians do, wrens may learn to time their songs. In support of this idea, we found dialects in the timing of the song of M. marginatus. Birds living in Central America produce a sequence of intervals with increasing duration and plateaus at both ends of the sequence. In contrast, birds living in South America continuously increase the durations without a plateau. Little is known about the adaptive value of interval timing in vocal communication. I propose that the production of long and precise intervals of silence is related to predator avoidance and sexual selection. To test these hypotheses, we are researching the detectability of this song to potential predators and are testing for sexual dimorphism in interval timing. Overall, this Neotropical wren has the potential to become a model organism in the integrative study of interval timing in vocal communication.

## The influence of temperature and nectar volume on pollinator visitation for *Vitex agnus-castus*

*Avery Roe, Anna Dreusicke, Brendon Blake, Ashley Lee, Kiara Lopez, Edgar Nickols, Marco Ramirez-Ramirez, Victor Gonzalez, John Hranitz, John Barthell, Charlotte Simmons, Theodora Petanidou*

Given the inherent interdependency of bees and flowering plants, understanding how the relationships between these two groups will respond to changing temperature conditions and impact the ecosystem service of pollination is critical. Nectar is an important incentive for pollination, and some studies have linked nectar production to temperature, suggesting potential trade-offs between nectar volume and energy conservation for plants at high ambient temperatures. Building on work focused on pollinator thermal tolerance, behavioral thermoregulation, and plasticity in plant responses to temperature, this project explores the relationship between temperature and nectar volume for Vitex agnus-castus and observes their combined influence on plant-pollinator interactions on the island of Lesvos, Greece. We established a belt transect consisting of 16 bushes and simultaneously collected data on pollinator interactions, nectar flow and standing crop volume, plant surface temperature, and internal and external flower temperature from dawn (05:00) to dusk (21:00) on June 28th, 2024. We found evidence suggesting V. agnus-castus modulates nectar production through the reabsorption of nectar volume throughout the day and that honey bee visitation is associated with nectar volume. Non-Apis bees come out in high numbers in the heat of the day when nectar volume decreases. These findings suggest the relationships between nectar volume, honey bee and non-Apis bee visitation, and temperature are dynamic and interrelated, and possible thermal foraging niches exist for bee species.

## Mastering the manu: how humans create large splashes

*Pankaj Rohilla, Daehyun Choi, Halley Wallace, Kai Lauren Yung, Atharva Lele, Juhi Deora, Saad Bhamla*

Manu jumping, a popular diving style amongst Māori people in New Zealand, focuses on creating large splashes. Divers perform aerial maneuvers such as "utkatasana" pose, entering the water in a V-shape, and executing underwater maneuvers to maximize the height and size of the splash. Our study investigates the fluid dynamics of this jumping style by studying the water entry of both passive solid objects and an active robot (manubot), analyzing their cavity dynamics and resulting splash sizes. The key to creating the biggest splash lies in the dynamics of the air cavity in water and its pinch-off to create a Worthington jet. The active robot mimics the aerial and underwater maneuvers to maximize the size of the cavity and the splash. In addition to evaluating the biomechanics and performance of human manu jumpers, we investigate how the size, shape, and impact speed of both active and passive bodies influence the Worthington jet dynamics. Drawing from our experimental findings on manu jumping, we propose the optimal parameters and techniques to pop the largest manu splashes.

## Escaping like Naruto: Rapid locomotion in semi-aquatic insects using Marangoni propulsion

*Pankaj Rohilla, Jace Holmes, Atharva Lele, Sarah Bender, Saad Bhamla*

Semiaquatic insects such as Microvelia eject surfactant fluids at the air-water interface to quickly escape the predators or to locomote on water. Microvelia can achieve up to 100 body speeds during Marangoni propulsion, higher than their normal locomotion speed. While many Marangoni propulsion-inspired robots have been developed and studied, the fluid dynamics of surfactant ejection in Microvelia and its interaction with water remain relatively unexplored. When threatened, Microvelia quickly escapes across the water leveraging surface tension gradients, while leaving their legs loose in a backward direction like Naruto's running motion. In this study, we investigate the biomechanics of Microvelia during Marangoni propulsion, the morphology of its proboscis, and the fluid-ejection mechanism through its proboscis. Our study will provide insights for designing untethered self-propulsive and faster micro-robots locomoting at the air-water interface.

## The effect of venipuncture site on hematology in bats: implications for comparative analyses

*Alicia Roistacher, Bret Demory, Daniel Becker*

Disease ecologists and ecoimmunologists have used hematology to assess the response of the cellular immune system to intrinsic and extrinsic factors and consequent health impacts in wild bats for both conservation and zoonotic risk applications. However, protocols for bat peripheral blood collection for these assays are not standardized across research groups. Lack of standardized blood sampling protocols increases the probability of misled inference and introduction of confounding variables for comparative studies. We evaluated the effect of propatagial and intrafemoral venipuncture sites on hematology profiles of two sympatric bat species, the Mexican free-tailed bat (Tadarida brasiliensis) and cave myotis (Myotis velifer). Bats (n=30) were captured from two colonies between 2023–2024 in western Oklahoma. General linear mixed effect models were used to test the effect of venipuncture site on complete blood count measures. Preliminary results suggest a significant effect of vein site on lymphocyte count in both bat species as well as a significant interaction between vein site and bat species on reticulocyte count. The results of this study quantify the bias in existing and future bat hematology data, and these results should be taken into account when conducting comparative studies involving multiple venipuncture sites. Future validation studies should be conducted with bats on other veins and for additional immunological assays such as -omics approaches.

## Use of annelid parapodia in cylindrical burrow formation and irrigation during burrowing

*Moey Rojas, Kelly Dorgan*

Annelids possess “foot-like” appendages called parapodia that are used in swimming and walking on the sediment surface. How parapodia are utilized during burrowing has not been explored due to the challenges of visualizing burrowing animals. To observe how parapodia are involved in burrowing, we developed an “Ant Farm” tank that reduces wall effects while allowing visualization of burrowing animals. A vertical layer of mud is held between two layers of clear gelatin that mimic the soft elastic properties of muddy sediments. Alitta virens primarily locomotes at depth via metachronal motion of successive parapodia, which can be combined with both peristaltic and undulatory muscle contractions. However, during burrowing, concurrent extension of successive parapodia can occur. Synchrony of peristaltic contractions and concurrent parapodial extension serves to expand and compact the burrow walls. During a pharynx eversion, the expansion and compaction is amplified as anchored parapodia slip backwards and scrape the burrow walls. We also observed worms “walking in place” with their parapodia, further compacting the burrow walls. We posit parapodial motions while burrowing facilitate transforming a crack propagated after a pharynx eversion into a cylindrical burrow. While worms are irrigating, parapodia are oriented to increase the exposure of the worm’s vascularized dorsal lamellae to the ventilatory current. Our work indicates that parapodia are dynamic appendages with roles in burrowing and irrigation.

## Senescence and vestibular-ocular decline in the octopus

*Amanda Rokicky, Z Yan Wang*

Octopuses typically reproduce only once before death and undergo pronounced physiological and behavioral changes at the end of their lives. After reproduction, octopuses progress through periods of feeding, fasting, and rapid senescence. The dysregulated posture, self-injurious locomotion, and loss of pupil orientation exhibited by older, post-reproductive octopuses suggest deficits in the vestibular sensing and ocular motor control systems. Recent methodological and analytical tools have accelerated octopus neuroscience research. However, little remains known about the mechanisms that drive the loss of posture, gait, and pupillary orientation in older, post-reproductive octopuses, or whether these mechanisms are shared with what is known in vertebrates. To address this question, we performed histological analyses of key brain lobes of the octopus vestibulo-ocular system to determine whether older, post-reproductive individuals demonstrate increased rates of cellular death, a hallmark of aging in senescing vertebrates. Our initial results suggest that the molecular features of aging in the octopus nervous system differ from what has been identified in vertebrates. Ultimately, results from our study will facilitate the comparison of aging processes in the octopus with those of other organisms and a deeper understanding of the evolutionary roots and fundamental building blocks of nervous system aging. A future research priority includes investigating the molecular and functional changes of hair cells in the vestibular sensing system as octopuses age.

## CNTNAP2 is consistently expressed during the song learning period in zebra and bengalese finches

*Mallie Roley, Riley Dodd, Nicole Baran*

Songbirds are excellent models for studying vocal learning and associated genetic factors due to their sophisticated vocal learning systems. This study compares expression levels of the autism risk gene Contactin Associated Protein 2 (CNTNAP2) in two songbird species: the zebra finch (T. guttata) and the Bengalese finch (L. striata domestica), which differ in their song learning. Compared to zebra finches, Bengalese finches sing a more syntactically complex song that remains more plastic throughout life. We analyze CNTNAP2 expression in the auditory forebrain at two developmental stages (day 60 and day 80 post-hatch) in both sexes of each species using quantitative PCR. We hypothesize that CNTNAP2 levels will be higher in zebra finches than Bengalese finches, and will be higher in male birds than female birds. We also hypothesize that CNTNAP2 levels will be higher on day 80 rather than day 60. Previous work found that CNTNAP2 levels were differentially expressed between zebra finch males and females across development in other song nuclei, including the robust nucleus of the arcopallium (RA) and HVC. Thus, this work lays the foundation for a novel interspecies comparison, as well as the future goal of analysis in cross-fostered and hybrid songbirds.

## Host-microbiome interactions as moderators of disease-diversity relationships

*Kristen Rosamond, Kevin Matson*

By directly and indirectly influencing health and susceptibility to infection and disease, microbiomes are integral to organismal functioning. Despite this, many studies in disease ecology focus only on higher levels of biological organization (e.g., populations or communities of hosts or whole ecosystems). Often overlooked are the pathways through which microbiome composition and diversity can impact host competence for pathogens and parasites, and thereby affect relationships between diversity and disease risk or incidence at larger scales. Thus, microbiomes of wildlife, which are understudied compared to those of laboratory animals, are important to consider in studies of disease ecology. Here, we examine how the microbiome might interact with pathogen and parasite transmission and other processes related to infection and disease at various scales of biological organization. We also explore avenues for future work and suggest how a better understanding of wildlife microbiomes could be utilized in disease management strategies. Going forward, a fuller consideration of within-individual biodiversity in the form of the microbiome can both challenge and enrich our understanding of disease-diversity relationships and disease ecology more generally.

## Combining morphological survey approaches to identify phenotypic variation in seahorses (H. erectus)

*Emily Rose, Graham Short, Hannah Holland, Heather Mason*

The conservation of species with broad geographic ranges presents significant challenges, particularly in identifying distinct genetic lineages and capturing genetic and phenotypic variation. The lined seahorse's (Hippocampus erectus) range extends from Nova Scotia to south of the equator in Brazil, with a well-documented genetic split between North and South American populations. To better understand phenotypic and morphometric variation in H. erectus, we combined data from field surveys, CT scans, and citizen science photographs. By comparing 3D and 2D images, we aimed to examine differences in body segment proportions and other key morphological characters, such as the crown structure, spine variation, and coloration patterns. This comprehensive approach revealed valuable insights, including island dwarfism in isolated populations, the evolution of sexually dimorphic traits potentially driven by sexual selection, and possible trait introgression from past hybridization events. Our findings highlight the need for conservation strategies that account for the species' genetic and phenotypic diversity across its broad range. Isolated populations, such as the identified Bahamian seahorses displaying island dwarfism, may require targeted protection. Understanding sexually dimorphic trait evolution can inform breeding and restocking programs to maintain natural variation. Additionally, recognizing potential introgression from historical hybridization is crucial for preserving the genetic integrity of distinct populations. These insights underscore the importance of a tailored, multi-faceted conservation approach to ensure effective management of H. erectus throughout its extensive range.

## Body shape diversification in Betta fishes

*Luke Rose, Matt Friedman, Matthew Kolmann*

Anabantiformes, also known as labyrinth fishes, are a diverse group of percomorphs characterized by parasphenoid teeth and a vascularized cranial air-breathing structure, called the "labyrinth organ." The most diverse anabantiform genus is Betta, which contains 76 species native to Southeast Asia. Betta species (or 'bettas') are small-bodied and garishly-colored, with many showing complicated behaviors relating to mating and parental care. For example, many Betta species build nests using bubbles ("bubble nests") while others have evolved mouthbrooding as a spawning behavior. However, whether these behaviors correlate with high lineage diversification in the genus is still unexplored, as is whether high lineage diversification is paralleled by extensive phenotypic diversification. We radiographed species from the genus Betta (along with the immediate outgroups, Parosphromenus and Trichopsis), and then used 2D geometric morphometrics to characterize body shape diversity in these fishes. We then tested whether mouthbrooding or bubble-nesting lineages exhibited higher rates of lineage and phenotypic diversification using phylogenetic comparative tools as well as assessed whether morphospace occupation differed between bubble-nesting and mouthbrooding lineages. We expect that Betta, relative to outgroups, will show some indications of an early burst in body shape disparity, particularly among insular species, and that bubble-nesters will occupy expanded regions of morphospace relative to mouthbrooders, reflecting constraints on cranial shape in mouthbrooding species. This work was supported by the National Science Foundation awards DEB-2333683 and DEB-2333684.

## Don't keep me in (jaw) suspen(sion): open-source tool for hyomandibula form & function in CVA

*Jack Rosen, Matthew Kolmann*

Comparative Vertebrate Anatomy (CVA) courses instruct learners in the evolution, systematics, morphology, and physiology of all chordates. A core competency for learners in CVA is their ability to relate structure to function and understanding anatomical orientation in three dimensions, traditionally taught through gross dissection. We present a workflow for tackling some of these core competencies using iodine-stained, micro-computed tomography (μCT) scans of organisms (and requisite software) instead. The hyomandibula has been an exemplar structure in CVA for decades, as a model for understanding how function can change but structures across organisms remain homologous. We bring this tradition into the digital age, using the 3D structure and function of hyomandibulae, including their associated muscles and innervation, as a means for demonstrating to learners how function evolves in homologous morphologies. For most undergraduate students, particularly those in smaller or more rural universities, μCT data has been inaccessible due to cost. Our μCT data are freely available and we demonstrate how an open-source platform (3DSlicer) can be used to bring cutting-edge comparative anatomy resources to anyone who wants to use it. This is possible only through association with a broad network of collaborators to generate an open-access, annotated 3D anatomical library for the classic fish models (ratfish, bowfin, lungfish) referenced in comparative anatomy. This work was supported by the National Science Foundation awards DBI-2301406.

## The use of biomedical tools in marine frontiers; Immunity and stem cell transplantation for corals

*Benyamin Rosental*

We will present how we transformed biomedical research into two projects in Hexacorallia.

The first project will describe our cellular and functional characterization of coral and anemone immune cells, focusing on the phagocytic cell population. We demonstrate that corals and anemones have immune phagocytic cells, which are different from digestive and pinocytosis cells. Our data demonstrate that immune activity is upregulated in heat stress. With the increase in temperature, there was a simultaneous increase in phagocytic activity. Suggesting the immune system at the base of the bleaching effect.

The second project is the development of stem cell transplantation for Hexacorallians. Our aim is to develop the transformation of resilience through stem cell therapy, using stem cell transplantation. We currently succeed in Nematostella vectensis as a model. Using this, we could follow in vivo mCherry-positive cells in transplanted animals for up to 2 months. Using confocal microscopy and flow cytometry, we showed the integration and proliferation of the transplanted cells into the tissue. Additionally, we showed cell integration using PCR and qPCR. Using serial transplantation, we showed the longevity of our candidate-enriched stem cells. We show classical stem cell gene expression and differentiation on the molecular level. Finally, we showed that the candidate stem cell transplantation can rescue animals from a leather chemotherapy treatment.

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## Addressing continuous and discrete morphological variation in computational anatomy

*Rachel Roston, Sara Rolfe, Maddie Bell, Di Mao, Murat Maga*

One of the central questions in evolutionary-developmental biology is how developmental-genetic processes generate different types of continuous and discontinuous (novel) morphological variation. Studies of genetic knockouts provide insights on how genes influence morphology and have traditionally focused on overt, qualitative phenotypes. High-throughput 3D imaging and computational anatomy methods have the potential to rapidly screen for and identify quantitative phenotypic differences. But, knockout phenotypes often include both qualitative (i.e., discrete) and quantitative (i.e., continuous) differences, even within a single embryo. Our lab has generated over 200 diceCT scans of E15.5 mouse embryos representing more than eight genetic knockout strains. To analyze these data, we are developing a high-throughput, semi-automated pipeline using registration-based and deep learning-based approaches. Accounting for the wide variety of morphological variation in our dataset is challenging: image registration maps an embryo to a reference (average) image and requires a certain level of morphological similarity while deep learning requires a large training dataset of correctly labeled embryo images. One approach we are taking to address the diversity in our dataset is experimenting with using regions of interest (ROIs) in multiple steps of our pipeline to individually analyze body regions. Preliminary results using principal component analysis and tensor-based morphometry on real and simulated diceCT data show that ROIs enhance interpretability and increase statistical power.

## Modifications of microbiome diversity & digestive efficiency in an omnivorous lizard, *P. grandis*

*Angela Roth, Infinity Alvarez, Charles Watson*

Many organisms exhibit physiological and morphological adaptations, along with symbiotic relationships with specialized gut microbes, to enhance their digestive efficiency. Omnivores, especially those that consume arthropods and plant material, face the challenge of digesting both chitin and cellulose—compounds that typically require symbiotic gut bacteria to break down. This investigation explores how dietary changes acutely and chronically affect digestive efficiency in the gastrointestinal tracts of a reptilian omnivore. A sample of day geckos (Phelsuma grandis) was provided with three distinct dietary regimens: arthropod-only, fruit-only, and a combination of both. Here, we present short-term and long-term differences in digestive efficiency and microbiome diversity across these treatments. This study not only enhances our understanding of reptilian digestive physiology but also highlights the complex interactions among diet, gut microbiota, and overall digestive efficiency in these organisms.

## Mechanisms of S-Phase Arrest and Survival in Anoxia-Tolerant Killifish Cells

*Riley Roth-Carter, Jason Podrabsky*

Complete and faithful replication of the genome is a requirement for cell survival and proliferation, with errors in this process potentially leading to dysregulation, disease, or cell death. Standard DNA replication has been heavily studied, but exploration of this process during exposure to genotoxic stressors, such as hypoxia and irradiation, is leading to the discovery of novel processes involved in maintenance and repair of DNA. The use of extremophiles to study replication during exposure to stressful conditions can lead to a better understanding of this process. The embryos of the annual killifish, Austrofundulus limnaeus, are tolerant to a variety of known genotoxic stressors such as long-term anoxia, ionizing radiation, and 3% H202. Using Quantitative Image Based Cytometry (QIBC) we quantified cell cycle dynamics and patterns of DNA damage in the anoxia tolerant WS40NE cell line isolated from A. limnaeus. Preliminary data suggests the cells arrest in early-S phase of the cell cycle (DNA replication) after 24 hours of exposure to anoxia. Arrest during replication often leads to cell death in vertebrate cells, but WS40NE cells can survive for weeks in this state. We hypothesize that WS40NE cells possess a mechanism that allows them to resume replication and return to a normal cell-cycle after arrest in S-phase. The molecular basis of this capability is currently under investigation.

## Characterizing thermal microhabitat selection across sites and seasons in a *Plethodontid* salamander

*Dellen Roush, Alyssa Baxter, Genevieve Paulick, Athena Vakaleris, William Peterman, Meaghan Gade, Ariana Brown, Brooklyn Upp, Eric Gangloff*

Thermal environments are critical in setting the limits of species distributions for terrestrial ectotherms across broad geographic scales. This is evident for plethodontid salamanders, being lungless, desiccation-vulnerable ectotherms that have low metabolic rates. Despite the ubiquitous impact of temperature heterogeneity on physiology and ecology, there are still many open questions regarding salamander thermal biology at a fine scale. We have yet to distinguish how salamanders utilize localized variation in temperature, how this varies across populations, and the impact of thermal landscape heterogeneity on population dynamics. To address this deficit, we conducted coverboard surveys of Plethodon cinereus (eastern red-backed salamander) across four arrays, spanning two Central Ohio forests. We used infrared thermography to characterize thermal landscapes at the coverboard level, within and across arrays. Utilizing data on activity and salamander body temperature, we tested the hypothesis that salamanders exhibit evidence of microhabitat selection based on available temperatures. Given that Plethodon cinereus behavior is highly seasonal, we tested whether thermoregulatory behaviors differ temporally between spring and fall, when salamanders increase surface activity and breed. Plethodon cinereus also demonstrates physiological variation among populations, which suggests the potential for plasticity or local adaptation to shape thermoregulatory behavior. Characterizing plethodontid thermoregulatory behavior at fine spatial scales will produce valuable insights for generating predictions regarding salamander population dynamics and the effects of anthropogenic environmental change on terrestrial Plethodontid ecology.

## Variation in shell thickness along shell length in the gastropod Neoterebra dislocata

*Alexa Ruberte, Luigi Queirolo Williams, Elizabeth Shea, Janice Krumm*

Characteristics of gastropod shells have been widely studied to increase our understanding of shell structure and their role in providing defense from predation. A greater understanding of how shells change as snails grow and develop is a key step in our understanding of predator-prey dynamics over the life of the snail. In this comparative study we examine how shell shape changes with growth in five morphologically distinct species of gastropods. We measured shells from the Delaware Museum of Nature and Science collection to describe how shell shape changes with growth along a continuum of small to very large adult snail sizes. We measured shell length, shell width, aperture length, aperture width and shell weight in the snails Conus virgo, Fasciolaria hunteria, Neoterebra dislocata, Sinistrofulgur perversum, and Triplofusus giganteus. For all 5 species, shell length and shell width were significantly correlated ($p<0.0001$). However, preliminary analyses suggest the slopes of these correlations differ between species. Our results highlight general trends in shell growth across species and contribute to our broader understanding of the evolutionary pressures on shell morphology.

## Patterns and drivers of iridescence across a highly speciose butterfly family (*Nymphalidae*)

*Juliette Rubin, Leo Tomás Camino, Yanileth Lopez, Akito Kawahara, W. Owen McMillan*

Iridescence – changes in hue across viewing angle – creates striking visual displays with diverse biological functions that have fascinated humans for millennia. Butterflies with iridescent wings can create particularly salient visual signals, as the iridescent dorsal surface is alternatively hidden and revealed in a flashing pattern. This visual signaling likely plays a role in mating, as well as anti-predator defense. Our work shows the successful development of the wing scale nanostructures underlying iridescence requires certain environmental conditions. Despite its longstanding intrigue, the tension between these constraints and the selective forces that have shaped the tempo and mode of iridescence have not been revealed on phylogeny. Here, using visual analyses from museum specimens, we map the presence or absence of iridescence across a 2600-species family tree of Nymphalidae. To quantify iridescence, we measured reflectance from multiple angles of each specimen using a spectrophotometer and explore patterns across subfamilies. We then take a macroevolutionary perspective to query the evolutionary drivers of this trait. We hypothesize that the presence of iridescence has been shaped by insectivorous bird predation pressure and constrained by environmental variability in lineages where it evolved. By focusing on a structurally complex, visually conspicuous trait in a globally distributed group, we provide insight into the evolutionary conflict that drives trait diversity.

## Thermal stress during pupal development induces changes in iridescence of *Morpho butterflies*

*Juliette Rubin, Leo Tomás Camino, Yanileth Lopez, W. Owen McMillan*

Butterfly coloration is essential for mating success and predator avoidance but may be vulnerable to temperature changes during development. While pigments usually determine butterfly coloration, iridescent butterflies have wing scale nanostructures consisting of a latticework of ridges and crossribs that together produce vivid hues. Previous research has shown that pigmentary colors can change under different thermal conditions, but the effect of temperature on iridescent scales remains unclear. The common blue morpho (Morpho helenor theodorus) displays large iridescent blue patches on its wings and inhabits Neotropical environments that generally have stable temperatures. To test if iridescent scale development is susceptible to thermal stress, we exposed Morpho butterfly pupae to three different thermal conditions: control (28°C), hot (35°C days, 28°C nights), and cold (28°C days, 14°C nights). We photographed the butterflies to measure the color and size of the iridescent patch. To understand changes in the quality of iridescence, we used a spectrophotometer to measure reflectance at multiple angles. Finally, using scanning electron microscopy, we measured the wing scale nanostructures of our thermal treatments. We found that different thermal environments led to significant color differences, likely due to alterations in scale ridge and crossrib nanostructures. These findings suggest that temperature-induced changes in the iridescent scales of Morpho butterflies could disrupt their mating displays and anti-predator efficacy, posing a significant threat to their survival in a warming climate.

## Gene expression analysis following the establishment of clownfish association with an atypical host

*Wyatt Rudd, Coral Tolman, Sofiia Kuklina, Jason Macrander*

Mutualistic symbiosis sees two distinct organisms coexisting in close proximity benefiting one another. This mutualistic interaction is especially unique in clownfish hosting anemones because they are the only venomous organisms that co-evolved to live with potential food rather than kill it. This symbiotic link has independently evolved three times within Cnidaria, indicating that given the right conditions, this beneficial association could evolve multiple times if conditions are right. For this study we used Stichodactyla helianthus, a Caribbean species known to host clownfish in aquariums, to examine toxin gene expression shifts as an atypical hosting anemone acquires a clownfish symbiont. RNA sequencing, transcriptome assembly, and gene quantification data were used from anemone tentacles prior to association, 12 hours, and 48+ hours post-association. Notably, 16 toxin candidates across 7 protein families exhibited a >2-fold or greater decrease in gene expression post-association. These protein families include AChRl, Actinoporin, NaTX, NEP 6, SCRiP, Type I KTx, and Type II KTx, some of which are prominent venom components. Conversely, 9 toxin gene candidates across 4 protein families increased expression, albeit modestly, particularly cysteine-rich neurotoxins, which may function as housekeeping genes. These findings underscore the potential influence of clownfish on toxin gene expression, particularly in establishing associations with atypical hosts, suggesting symbiont association as a vital ecological mechanism regulating toxin expression for mutualistic associations.

## Rapid phenotypic change in wing color and shape in invasive spotted lanternfly

*Gaia Rueda Moreno, Kristin Winchell, Fallon(Fang) Meng*

The recent invasion of the Spotted Lanternfly (L. delicatula) into the United States poses a significant threat to agricultural and ecological systems alike, motivating a plethora of research in order to combat this emerging invasive. Current research has linked L. delicatula dispersal to human activity, but our understanding of the underlying traits which drive their dispersal is lacking. Moreover, while their red coloration has been well understood to play a role in predator deterrence and mate selection, its variation is also poorly understood. We sampled 228 individuals from both their native (China) and invasive (USA) ranges, and collected data on wing shape and color. Our results show wing coloration differs between countries and across land cover types. Moreover, wing shape differs across countries and with wing area, although not with increasing urbanization. Overall, both wing shape and coloration exhibited greater variability in the US than in China, which suggests a release from selection pressure in L. delicatula's invasive range. Our results suggest that evolutionary change may play a role in the invasion pathway of L. delicatula. Cities can drive accelerated evolutionary change in the physiology and morphology of organisms within, due to the variety of novel stressors and opportunities they provide.

## A function-valued approach for the comparative analysis of color evolution

*Nicholas Ruffolo, Michael Alfaro, Marc Suchard*

Many models of continuous trait evolution characterize a trait as a singular value that can diffuse under a Brownian process. However, many traits are better described as continuous functions, where trait changes follow processes that are more complex than a simple Brownian motion. One such example are reflectance spectra: the percentage of light reflected from an object over a range of wavelengths. For any given visual system, reflectance data can be used to determine color, but much of the reflectance spectrum is discarded for most evolutionary analyses of color, relying instead on one or more spectrum-derived colorspace parameters. Here, we introduce a new function-valued comparative approach for spectral data based upon the Brownian diffusion of splines. We fit natural and cubic splines to reflectance spectra and allow the spline coefficients to undergo Brownian diffusion. We tested this approach on an empirical data set of tanager (Thraupidae) color patches and explored the impact of changing spline parameters on spline fit. Our approach provides a new means of identifying the regions of the reflectance spectra that show accelerated and constrained evolution. We also compare our approach to traditional comparative analyses on the Brownian diffusion of color parameters in other color spaces. Our function-valued trait evolution model can be broadly applied to other continuous traits, offering new insights into the development and diversification of complex biological systems.

## Thermal treatment and specificity affect symbiont colonization and coral development

*Maria Ruggeri, Samuel Bedgood, Jun Cai, Jennifer Qian, Federica Montesanto, Mark McCauley, Saki Harii, Sandra Loesgen, Virginia Weis*

The foundation of coral reef ecosystems is facilitated by the nutritional relationship between coral and algal symbionts. Though obligatory for coral hosts, many species re-establish this symbiosis each generation, and the cellular mechanisms underlying successful symbiont colonization and host development are poorly understood. Here, we explored the effect of algal partner and manipulation on symbiont and host cell proliferation by offering Acropora tenuis larvae one of four algal species pre-exposed to elevated or ambient temperature. Further, we characterized the cell-surface glycome of each symbiont-temperature combination to understand its role in symbiont recognition and proliferation. We found that thermal pre-treatment did not affect colonization, but did affect host development in a symbiont-specific manner. Thermal pre-treatment of Breviolum minutum and Durusdinium trenchii negatively affected host cell proliferation, potentially driven by glycan profiles which converged following thermal treatment. However, thermal pre-treatment of Symbiodinium microadriaticum had the opposite effect, increasing host proliferation with only minor shifts in glycan classes. As S. microadriaticum typically dominates early life stages of A. tenuis, maintenance of host cell proliferation following algal manipulation could also indicate that specificity promotes development, whereas colonization of alternative, manipulated partners are costly. Overall, this study shows that there is an interaction between symbiont partner and environment on coral development, potentially driven by specificity and glycan-lectin interactions, providing important insight into the mechanisms and constraints of coral symbiosis establishment.

## Effects of point mutations on protein stability in heat-resistant algae

*Devin Ruppe, Michael Cato, Geoffrey Mitchell*

Coral maintain symbiotic relationships with intracellular algae (zooxanthellae) that provide them with energy derived from photosynthesis. Coral bleaching, in which the algal symbionts are expelled by their coral hosts, lead to the deaths of said hosts, devastating regional biodiversity and local fisheries. Several environmental factors are suspected to contribute to these events, with rising ocean temperatures being the primary cause. Chakravarti et al. (2017) raised $\sim 80$ generations of cultured zooxanthellae at elevated temperatures. The resulting offspring showed normal cellular activity at higher temperatures, while wild-type algae failed to grow and reproduce. Follow-up transcriptional studies by the same group (2020) identified differentially responsive genes via transcriptional analysis, but the mutations underlying these effects remain unexplored. We hypothesize that the single nucleotide polymorphisms (SNPs) in heat-resistant algae alter the thermal stability of associated proteins. We used a protein structure prediction software (ColabFold) coupled with several computational tools that assess effects of SNPs on protein $\delta\delta G$. Out of 618 proteins assessed, several were predicted to be stabilized and destabilized by their associated mutation(s). We are currently using molecular dynamics simulations and in vitro methods to verify the effects of the most stabilizing and destabilizing SNPs. Our work provides a unique insight into the molecular mechanisms that may confer heat resistance to algae and may introduce new algal proteins that could be targeted to combat coral bleaching.

## The diversity, structure, and bacterial-fungal interactions of herpetofauna gut microbiomes

*Alexander Rurik, Jason Dallas, Chloe Cummins, Mitra Ghotbi, N. Reed Alexander, Kaitlyn Murphy, Lluvia Vargas-Gastélum, Joseph Spatafora, Kerry McPhail, Jason E Stajich, Donald Walker*

Herpetofauna (reptiles and amphibians) are among the most threatened vertebrate groups. The gut microbiome is a crucial element of herpetofauna conservation approaches, as dysbiosis in the microbiome may cause adverse health effects for the host. Understanding the complexity of stable fungal-bacterial interactions in the gut microbiome can help to establish a baseline of knowledge to inform conservation strategies, however, relatively little work has been done to characterize the gut microbiomes of herpetofauna. Previous research has determined that filamentous fungi (genus Basidiobolus) are dominant members of the herpetofauna microbiome and that Basidiobolus diversity shapes the bacterial community. By examining the bacterial and fungal assemblages in the herpetofauna gut across space, host phylogeny, and life history, we aim to better understand the unique role that ubiquitous members like Basidiobolus play in the herpetofauna gut. To date, we have characterized bacterial and fungal assemblages using metabarcoding and amplicon sequencing of 16S rRNA and ITS1 rDNA in 150 herpetofauna species, many of which have never had their gut microbiome studied and/or are species of conservation concern. Results will include the taxonomic characterization of the gut fungal and bacterial assemblages of over 150 host species, comparisons of alpha and beta diversity, an investigation of the co-occurrence of Basidiobolus and other microbial taxa, and an exploration of co-diversification utilizing comparative phylogenetic methods.

## Ecological and evolutionarily consequences of buzz pollination

*Avery Russell*

Buzz pollination, a type of interaction between bees that can vibrate flowers to collect pollen and flowers that conceal their pollen within tube-like (poricidal) flower morphology, involves more than half of all bee species and 10 percent of all angiosperm species. The evolution and diversification of both buzzing bees and buzz pollinated plant species is thought to be strongly affected by this interaction. Yet global ecological and evolutionary consequences are poorly characterized. We discuss our work on the evolution of buzzing behavior and drivers of the global distribution of buzzing bee taxa, and the evolution and distributional patterns of buzz pollinated flowers. Overall, we find that buzzing has been lost and gained repeatedly and may be a key driver of bee diversification. Drivers of buzzing bee biogeography also differ from those of non-buzzing taxa and are closely associated with poricidal plant biogeography. Altogether, buzz pollination occurs across 87 plant families and more than 635 genera, with on average 200 independent gains and 150 independent losses. We find that buzzing in bees evolved alongside the earliest radiations of buzz pollinated plant species, but is generally not associated with increased plant diversification. Finally, we present alternative hypotheses for the functional significance of poricidal flowers.

## Assessing the capabilities of biohybrid robotic jellyfish for vertical ocean profiling

*Kelsi Rutledge, John Dabiri*

In light of a changing climate, monitoring ocean health is more vital than ever. Recent technology has demonstrated the ability to robotically control the unidirectional swimming of moon jellyfish. Here, we assess the potential of biohybrid robot jellyfish to act as vertical ocean profilers, similar to buoyancy-controlled Argo floats routinely used for ocean sampling. Biohybrid jellyfish equipped with positively buoyant microcontrollers and ballasts were deployed in a vertical tank and tracked swimming repeated vertical profiles (1 profile = swim down, float up). Descent speed was found to generally correlate with jellyfish volume. Biohybrid jellyfish were also tested in a coastal ocean environment, equipped with a temperature sensor to monitor the surrounding environment during profiles. The successful demonstration of vertical-profiling biohybrid robot jellyfish is an important first step toward realizing this new ocean monitoring platform. Additionally, this platform would address many of the limitations of current sensing technology due to its low cost, global availability, small size, minimal power demand, and potential scalability.

## DNA Methylation Variation Between Native and Introduced Populations of a Model Cnidarian

*Auston Rutlekowski, Adam Reitzel*

Anthozoans (corals, sea anemones) have been shown to change the amount and location of DNA methylation when moved to different habitats in their native range. However, little is known about how anthozoans may change methylation when introduced to new, non-native environments. Here we compared the DNA methylation profiles of field populations of the model anthozoan Nematostella vectensis both in their native range along the Atlantic coast of North America as well as in introduced populations on the Pacific coast. Using Oxford Nanopore Technology we sequenced DNA for 48 individuals from three different populations on both the Pacific and Atlantic Coast of North America, and compared genome methylation profiles for individuals from each population. Our comparisons are the first to quantitatively compare variation in DNA methylation between native and introduced populations of a cnidarian, as well as the first to look at variation of different N. vectensis individuals from the same location and different populations along the same coast. Our analysis shows differential methylation not only between coasts, but within individual populations. Understanding how different populations vary in DNA methylation and other epigenetic strategies may provide insight into how individuals acclimate and adapt to their local environments, improving our understanding of how species can occupy non-native habitats and how they may fare in the face of ongoing climate change.

## Evidence for extensive gene loss in the genome of a pelagic tunicate, Dolioletta gegenbauri

*Joseph Ryan, C. J. Pickett, Leandra Toledo, Adolfo Lara, Cohen Manges, Bradley Davidson*

Polymorphic organisms generate numerous morphologically distinct body plans within a colony using a single genome. Doliolids, a lineage of pelagic tunicates, are one of a very few polymorphic animal lineages.

To gain insight on how doliolids made the transition to a polymorphic lifestyle, we sequenced the genome and transcriptomes of several distinct morphs of the doliolid, Dolioletta gegenbauri. From our phylogenetic analyses of gene content, we found that D. gegenbauri has lost hundreds of genes that were present in the last common ancestor of tunicates. These include several genes from the following important developmental families/superfamilies: homeobox, Ets, Fox, Wnt, FGF, Nanos, Chordin, and TGFbeta receptors. From these results we conclude that gene loss in the doliolid lineage likely played a major role in the transition from a benthic to holopelagic lifestyle, monomorphic to polymorphic lifestyle, or both. This work contributes to a growing body of research showing that adaptive gene loss is a major engine of evolutionary change.

## Corticosterone modulates social behavior across multiple breeding seasons in tree swallows

*Thomas Ryan, Conor Taff, David Chang van Oordt, Monique Pipkin, Daniel Ardia, Maren Vitousek*

Social interactions can provide critical information that aids reproductive decision making, particularly for organisms encountering challenging environments or events. Variability in the prevailing environment across years may further influence the need for social information gathering and the role of glucocorticoids in mediating this process. Over multiple breeding seasons, we explored how a common social behavior—nest visits by breeding female tree swallows (Tachycineta bicolor)—is affected by experimentally elevated corticosterone levels. In line with our prior results from a single year, we hypothesized that birds facing challenges would invest more in gathering social information, mediated by corticosterone. Additionally, we hypothesized that challenged birds would be visited less frequently due to the reduced value of the information they provide. Corticosterone was administered through a minimally invasive technique– corticosterone dissolved in DMSO gel placed on a fake egg inside the nest. Females treated with exogenous corticosterone made more visits to neighbors' nests and were visited less frequently than controls, particularly when nestlings were young. This effect diminished as nestlings aged. Notably, females engaging more in these social visits fed their own nestlings at a lower rate, indicating a potential tradeoff. First-year breeders were less likely to engage in visits or be influenced by corticosterone manipulation. These results suggest that glucocorticoids likely mediate social information gathering, particularly for older, experienced breeders, and this effect likely varies across years.

## XROMM shows that quadrate motion drives the biomechanics of macrophagy in reticulated pythons

*William Ryerson, Elska Kaczmarek, Robert Cieri, Morgan Turner, JJ Lomax, Elizabeth Brainerd, John Capano*

While it is well known that snakes have highly kinetic skulls, the question of how snakes are capable of swallowing prey many times larger than their head has remained. The anatomical basis of macrophagy has been explored via experimental manipulation of dead snakes, and limited radiographic video and external observations suggest that many snakes use 'pterygoid walking' to advance the upper jaws over the prey during swallowing. However, we have a poor understanding of how snakes produce large gapes in vivo, the roles of the quadrate and mandible during swallowing, and the coordination between the upper and lower jaws. We implanted radiopaque beads in all independently mobile bones of the head and used XROMM to comprehensively investigate the biomechanics of large prey ingestion in reticulated pythons Malayopython reticulatus. We find that pythons use a coordinated and stereotyped set of kinematic patterns to disengage, advance, and reengage the mandibular and upper tooth rows (i.e. maxilla, pterygoid, palatine) independently over the prey. We also find that each of these stereotyped movement patterns are driven by rotation and translation of the quadrate bone relative to the braincase. These findings suggest that evolution of unrestrained quadrate motion was an important step in the origin of macrophagy in snakes and emphasize the value of studying behavior in vivo, in 3D, and beyond what is externally visible.

## Introducing a new comparative vertebrate anatomy text for undergraduate learners

*William Ryerson, Lisa Whitenack, Vanessa Hilliard*

There are limited options for comparative vertebrate anatomy textbooks in the current market. Furthermore, those that are available are out of date, expensive, and often neglect the human element of comparative anatomy - both in terms of anatomy and representation of the people that practice in the field. Although existing texts provide a brief historical overview, these overviews fail to acknowledge the historical and current diversity of scholars in the field. This narrow view carries over to the representation of the organisms featured in anatomy books, which tend to focus on male anatomy and binary sex. Based in part on feedback received from the SICB community at our 2024 poster, we have developed an open-access comparative vertebrate and human anatomy textbook that addresses these issues by including recent work on the systems studied in comparative anatomy and the diverse scholars doing that work, a more complete history of the field, and the impact of the work on people. In addition, our book follows published recommendations for making anatomy more inclusive for marginalized groups. This talk will introduce the SICB community to the new textbook, and outline the scope, content, and pedagogical elements of the book

## A simple, interpretable model for movement simulation with biological limitations and uncertainties

*Hansol Ryu, Manoj Srinivasan*

Simulation models are useful for understanding control mechanisms in biological movement. While previous studies often focused on specific phenomena or single movement types, a model that represents a wide range of motor tasks while accounting for biological limitations would be beneficial. Our aim was to develop a simple, interpretable, and broadly applicable model of biological movement control.

The model consists of a single degree of freedom rotating rigid body, controlled by two muscles representing an antagonist-agonist pair. It simulates goal-directed movements, such as reaching, pointing, and swinging, as well as postural stabilization tasks like standing, balancing, and catching, depending on simulation conditions and constraints. The model is expandable, enabling the integration of complex elements such as muscle and sensor models, an extended Kalman filter for state estimation, and combined feedback and feed-forward control. We also considered uncertainties, including disturbances of unknown timing and amplitude, noise, and delay.

The model reproduces experimental observations, such as the bell-shaped velocity curve, tri-phasic muscle activation pattern during reaching, and anticipatory counter movements in balancing tasks. Optimization results explain the accuracy-velocity trade-off, increased co-contraction with higher accuracy demands, and compensation for decreased sensor signal quality. These findings suggest that seemingly suboptimal strategies, like dead band and co-contraction, might be optimal when accounting for imperfect sensors, muscles, and environment.

## Transient perfusion through a microfluidic dragonfly wing model

*Sangjin Ryu, Haipeng Zhang, Mary Salcedo, Jake Socha, Günther Pass*

Insect wings consist of a complex network of veins and thin membrane. Veins are hollow tubes that are filled with hemolymph (insect blood), supply the sensory organs located on the wing veins with water and nutrients, and enable the removal of waste products. Additionally, the composite material of the wing is hydrated by the hemolymph, which helps to maintain the wing's flexibility. Therefore, the hemolymph flow through the microfluidic vein network is crucial for the functionality of insect wings. However, how perfusion occurs throughout the vein network remains poorly understood. To investigate transient perfusion in wing venation, we developed a microfluidic wing vein model of the forewing of the common green darner dragonfly, Anax junius, using polydimethylsiloxane and soft lithography. Transient perfusion was simulated by injecting a red dye into the microfluidic model pre-filled with clear water. Simulated perfusion suggested that the perfused portion of the vein network logarithmically increased in area with respect to time. A theoretical model of a simplified wing vein network was developed to explain the observed scaling relationship. In addition, visualized perfusion patterns revealed that time differences existed between the arrival of a new substance and the complete removal of an old substance in veins during perfusion. Our microfluidic wing vein model enables systematic investigation into the circulatory system and transport phenomena of the insect wing.

## High cortisol and preservation of lean mass linked with reproductive success in female Weddell seals

*Caroline Rzucidlo, Amy Kirkham, Amy Klink, Jay Rotella, Allyson Hindle, Jennifer Burns, Michelle Shero*

Long-term energy management impacts survival and reproductive success across marine mammals. A >60-yr-long Weddell seals (Leptonychotes weddellii) demographic study in Erebus Bay, Antarctica provides lifetime reproductive histories of individuals. By identifying high- and low-reproductive output females a priori, this study determines mechanisms governing the balance of lipid versus protein use and correlates with lifetime reproductive success in Weddell seals. Females with higher reproductive outputs ('HRO', produced more pups for their age) had significantly higher serum cortisol concentrations throughout lactation (October-December; $n=114$; $F=7.33, p=0.00755$). Higher cortisol levels may increase HRO seals' reliance on lipid stores postpartum, as evidenced by consistently higher serum non-esterified fatty acids (NEFA; $F=12.595, p=0.002819$) even post-weaning (January-February, $n=110$). Taken together, HRO Weddell seals appeared to better defend their lean mass, as loss of muscle poses greater health risks. Preserved protein was later used after females weaned their pups and began breeding, and serum L-amino acids were higher post-ovulation (F=2.25,p=0.024) and in females that became pregnant again for the following year (F=1.95,p=0.054) determined via ultrasound. Even in the relatively few years that HRO females 'skip' pupping, they may utilize the year of reproductive rest more effectively. During 'skip' years, HRO females maintained greater fat stores (as %total body mass) across the austral summer compared with LRO females (F=6.189,p=0.0159). These results suggest that carryover effects of energy allocation 'decisions' influence lifetime reproductive potential in Weddell seals.

## Using robophysical models to study the performance landscape of terrestrial fish locomotion

*Gargi Sadalgekar, Divya Ramesh, Chen Li*

Many amphibious fishes can move on land. Their sustained locomotion falls into three strategies: using body lateral bending (e.g., ropefish), using fins (e.g., mudskipper), and using body lateral bending and fins together (e.g., bichir). Some fishes even transition between these strategies, especially as the substrate changes. Previous research largely focused on quantifying kinematics and muscular control, but the relative advantages of these three strategies across substrates, which depend on how the performance of each strategy is affected by body and fin motions, are not well understood. Here, we created a fish-inspired robot that can use all three strategies as a physical model to explore this. As a first step, we tested the robot on solid ground while systematically varying body and fin actuation parameters. For the "mudskipper gait" using fins only, the robot's forward speed did not change much with fin adduction and supination angles, except a large drop at a small supination angle (20 degrees). For the "ropefish gait" using body bending, forward speed increased with body bending amplitude, and it had an optimum at intermediate wave number (= 1) at high actuation frequencies. Of the two gaits, the "mudskipper gait" was more advantageous in that it maintained speed better as frequency was varied. We are studying the "bichir gait" using body and fins together and will further study on mud of various strengths

## Artist meets architect: color nesting preference of *M. rotundata*

*Gwen Sailer, Ella Eleven, Joshua Rinehart, Joseph Rinehart, Julia Bowsher*

The Alfalfa Leafcutting Bee (Megachile rotundata), are solitary cavity nesting bees that are commercially managed for alfalfa seed production. Farmers use commercial nesting blocks which are manufactured with patterns, shape, color, orientation, and contrast believed to help these bees locate their nest to promote bee productivity. Nesting preference has been studied with regards to cardinal direction, temperature, plant quality, and pattern, but color is underexplored. Establishing nesting preferences for color may increase bee productivity and yields. To observe how color affects the nesting preference of alfalfa leafcutting bees, we painted nest boxes with ten different colors in three different patterns and two different orientations. We found that alfalfa leafcutting bees nested equally in all colors but preferred horizontal orientations of stripes. Cavities painted pink, purple, white, yellow and unpainted experienced higher nesting rates suggesting preference for those colors. The number of uncompleted nests and nest completion time was not affected by color or orientation. This study provides evidence that color plays an important role in nesting preference which could be used to promote solitary bee management and conservation.

## Image classification with YOLO for wildlife monitoring in South San Antonio

*Vivian Salazar, Sean Brandin, Elizabeth Borda, Jose Valdez, Ashley Teufel*

This study investigates wildlife monitoring in a natural area recently acquired by Texas A&M University-San Antonio for research and education. By utilizing camera traps positioned throughout the property, we aimed to identify and catalog the wildlife in the area, while also evaluating fluctuations in species density over time. A common challenge associated with camera traps is their propensity to capture images triggered by non-animal motion, such as movement caused by wind or vegetation. To address this issue, we have developed an image recognition model in Python using the YOLO framework to detect and classify wildlife in the images captured. The effectiveness of our model is assessed based on its ability to identify empty frames and accurately recognize the animals present in each image. We document not only the species observed but also their abundance and occurrence related to time and location. This research, conducted entirely by undergraduate students, highlights the valuable contributions that image recognition can make to biodiversity monitoring.

## The Andes are a driver of physiological diversity in Anolis lizards

*Jhan C. Salazar Salazar, Gustavo Londoño, Martha Muñoz, Donald Miles, Maria del Rosario Castañeda*

The Andes, with its diverse topography and climate, is a renowned cradle for adaptive radiation, particularly for vertebrate ectotherms like lizards. Yet, the role of temperature in promoting physiological specialization in the Andes remains unclear. Aseasonality in the tropics should favor physiological specialization across elevation in lizards, but empirical data are limited and equivocal. Determining how thermal tolerances are geographically and phylogenetically structured, therefore, is a priority, particularly as environments continue to rapidly change. However, there's a gap in our knowledge of thermal limits of species from the Andes, one of the planet's most biodiverse regions. This study focused on 14 anole species from two different anole clades (Dactyloa and Draconura) that independently diversified along elevational gradients in the Andes. We measured critical thermal limits (CTmin and CTmax) and found patterns of thermal tolerance specialization across altitude, both among and within species. Patterns of thermal specialization are similar among anole clades, indicating parallel responses to similar environmental pressures. Specifically, high-elevation anoles tolerate colder temperature and are less heat tolerant than their low elevation counterparts, rendering thermal tolerance breadths stable across elevation. Evolutionary rates of physiological traits were similar, reflecting parallel specialization in heat and cold tolerance across elevation. The adaptive radiation of anole lizards reflects physiological specialization across elevation, and the endemism such specialization likely catalyzed their remarkable diversity in the tropical Andes.

## Top bunk or bottom bunk: rest-site selection and vulnerability to climate change in tropical mammals

*Claudia Saldaña DeCamillis, Ana Breit, Eric Brown, Andrew Alek Tuen, Mohd-Azlan Jayasilan, Danielle Levesque*

Adjusting to high temperatures in an increasingly warming world can come at a high energetic cost for mammals. To counteract, mammals can use different strategies to cool down, whether by evaporative cooling, maintaining higher thermal gradients via facultative hyperthermia, or behavioral changes. We used thermophysiological data obtained in Borneo from nocturnal (Order: Primates, Chiroptera, and Rodentia) and diurnal (Order: Scandentia) small mammals which occupy different resting sites, to assess climate change vulnerability. Thermal profiles, resting metabolic rates, and evaporative water loss were used as a proxy to determine their potential responses to climate warming. Energy and water costs in response to warming can be mitigated by behavioral strategies such as becoming more nocturnal or changing foraging habits, therefore we also assessed the rigidity of activity patterns and nest site selection. We found that some, but not all, nocturnal animals may be more susceptible to climate change than their diurnal counterparts. Nocturnal obligates such as arboreal bats and tarsiers, occupying the most exposed diurnal rest sites, had increases in both energy and water loss at higher temperatures. In contrast, Murid rodents (nocturnal) and treeshrews (diurnal) showed blunted metabolic responses to high temperatures despite occupying different nesting sites and activity periods. Furthermore, the thermally isolated, underground nesting sites of rats make these rodents potentially doubly resistant to changing climates.

## Adult nutrition influences spine injury resistance in a sexually selected weapon

*Christina Salerno, Walter Federle, Christine Miller*

Sexually selected weapons are often highly sensitive to nutritional quality. In arthropods, better juvenile nutrition typically results in enhanced weapons; however, the effects of adult nutrition are not well understood. Here we investigate the effects of adult nutrition on an offensive component of a sexually selected weapon in Narnia femorata (Hemiptera: Coreidae). N. femorata use their spiny hind legs to engage in male-male contests, using the spines to trap and wound opponents. We have found previously that high-quality juvenile nutrition leads to increased weapon size, and that both juvenile and adult nutrition influence exoskeletal thickness and injury resistance in this species. Here, we varied the natural diet of young adult male N. femorata and tested how much force the terminal hind-leg spines could withstand before failure. We found that the spines of insects on a high-quality adult diet could withstand three times more force compared to those with a low-quality adult diet. Nutrition is notoriously variable in the wild, and these results show that regardless of juvenile nutrition, the diet of newly emerged adults strongly affects exoskeletal stability, with likely important consequences for male-male competition and reproductive success. This study and other recent work suggest that the structural integrity of animal weapons may vary drastically within natural populations. Yet, the mechanical properties of weapons, and the factors influencing those properties, have rarely been considered in studies of sexual selection.

## Unraveling the embryotoxicity of salinity and tire wear microplastics on distinct anuran species

*Raquel Salla, Camryn Kritzell, Aaron Devine, Molly Albecker*

Multiple environmental stressors can contribute to amphibian declines worldwide. Among them, significant gaps remain on how increased salinity and automotive tire micro-fragments affect amphibians' health. We evaluated the effects of tire micro-fragments and salinity on anuran species: Hyla squirella (squirrel tree frogs) and Incilius nebulifer (Gulf Coast toads). To perform the "Frog Embryo Teratogenesis Assay Xenopus" we collected several clutches per species in natural ponds around Houston (TX, USA). Early blastula embryos were individually positioned in culture plates (24 wells, 3mL), exposed to environmentally relevant concentrations of tire micro-fragments (50, 200, and 500 ug/L) and increasing salinity (0, 4, 6, and 8 ppt), isolated or in combined mixtures. We assessed survival and hatching rates, heart rate, and frequency of abnormalities.

Embryonic survival and hatching of both species were not affected in freshwater nor 4ppt, however, under 6 ppt (alone or in combination with 200 ug/L fragments) survival of H. squirella was reduced to 48% in 72 hours, and 31.6% in combination of 500 ug/L of fragments, so combined factors maximized the stress conditions, impairing survival. Incilius nebulifer showed lower sensitivity to saltwater, reaching $\sim$70% survival under 6 ppt (alone or in combination with 200 and 500 ug/L fragments). No alterations were observed in heart rate nor morphological abnormalities. Future analysis still needs to address larval stages for both species to enable better comparative conclusions.

## Cycad weevils as a model for multi-modal plant-insect signaling

*Shayla Salzman*

Cycad pollinating beetles provide an excellent opportunity for studies into the ecology and evolution of insect pollination, plant-insect signaling, and the maintenance of mutualisms. Entire lineages of beetles exclusively live on and pollinate this ancient lineage of dioicous gymnosperms in what has been suggested to be a classic case of co-evolution. Specialized cycad-beetle pollination has existed since at least the early Jurassic, predating the ecological dominance of angiosperms and the accompanying diversification of major lineages of pollinators such as butterflies and bees. Cycads produce woody reproductive cones without the overt visual signals commonly employed by angiosperms and must rely on other signals and cues for communication with their insect partners. As such, they are thermogenic plants, producing internal heat that in turn alters the carbon dioxide, humidity, and scent of the cones within which the insects live. All plant-produced metabolites that are perceived by pollinators are used in decision making, yet primary metabolites such as temperature, humidity and CO2 are rarely studied, even though they are widely produced by plants and universally perceived by insects. A thorough understanding of signaling in the highly specialized cycad-beetle mutualism provides insights into the maintenance of mutualism and pollination in a changing climate. I will discuss multi-modal signaling in an ecological and evolutionary framework to understand the evolution, maintenance, and success of these pollination mutualists.

## Mesial drift observed across varying levels of dental specialization in African pigs

*Alexandria Sambrano, Ashley Hammond, Deming Yang*

Dental wear progressively hinders the teeth's ability to efficiently chew, therefore many vertebrates display adaptations that increase the durability of their teeth against dental wear. Among African suids, warthogs (Phacochoeurs) have abrasive diets and have evolved high-crowned (hypsodont) and elongated third molars that drift mesially to compensate for the shedding of other teeth and preserve their chewing surface for longer. The giant forest hog (Hylochoerus) and the African bushpig / red river hog (Potamochoerus) have lower-crowned molars and more generalized diets. This study examines how the progression of dental wear and mesial drift are correlated in these suids with different levels of dental specialization. Photographs were taken of upper and lower dental arcades for the three genera (Hylochoerus, n = 36; Phacochoerus, n = 59; Potamochoerus, n = 60). Dental wear was scored by a rubric established for this study. Mesial drift was calculated using landmark data in ImageJ/FIJI. Correlations between wear scores and mesial drift measurements were evaluated using linear models. Results confirmed that mesial drift is the most pronounced in the dentally specialized Phacochoerus. We found less pronounced but similar rates of mesial drift in the other two genera. This indicates that mesial drift accompanies all types of dentition in African suids and is not just restricted to high-crowned suids needing to mitigate dental wear.

## Evaluating reproductive parameters of the dwarf seahorse (*Hippocampus zosterae*)

*Dalila Sanchez, Darshi Patel, Emily Baker, Emily Rose*

Dwarf seahorses (Hippocampus zosterae) are a flagship species for threatened seagrass ecosystems. By following 25 broods of lab-born dwarf seahorses, we examined multiple reproductive parameters, including brood sizes, juvenile growth, and juvenile survivorship rates in a lab setting. Offspring from wild caught adult seahorses mated in the lab were divided equally into three treatments to measure lengths, weights, and a control group to evaluate effects of animal handling from different measurement techniques. Growth rates were calculated using lengths measured via photographs and documented weights every eight days, while survivorship was monitored every four days. Average brood size was 31.7 ± 3.4 offspring per brood ranging from 8 to 70 offspring across the 25 broods. Average offspring length and weight were 10.15 ± 0.052 mm (n=25 broods, 238 offspring) and 2.07 ± 0.045 mg (n=25 broods, 243 offspring) across all broods at birth. The longest offspring reached 40.632 mm on day 96, while the largest mass was recorded on day 80 at 6.72 mg. Within the first 30 days after birth, trends show a relatively high survivorship with a decline after that timepoint. Preliminary results at day 100 show a 20% survival in all treatments, suggesting no difference from animal handling. These results are applicable for rare or endangered species of seahorses with similar smaller reproductive outputs, allowing for enhanced conservation practices in the wild.

## Schooling and Shoaling Patterns of Swimming Sharks

*Danna Valentina Sanchez Hernandez, A-bel Gong, Heidy Martinez, Taemur Daud, Andrew Nosal, Brooke Flammang*

Quantifying shark schooling and shoaling behaviors is crucial for understanding the hydrodynamic advantages that these formations may provide to individual sharks and the group as a whole. To further understand the varying benefits to schooling and shoaling, this research aims to quantify group behavior and determine repeated positional patterns by analyzing the k-nearest neighbors (k-NN) algorithms of schooling blacktip (Carcharhinus limbatus) and shoaling leopard (Triakis semifasciata) sharks. We analyzed overhead unmanned aerial vehicle (UAV) video footage of aggregating sharks using object detection models such as YOLO, implemented in Python, to extract distance metrics. These schooling and shoaling data were compared using statistical t-tests to identify behavioral differences. Using schooling-specific distance, we performed two-dimensional hydrodynamic analyses to explore the behavior patterns that may enhance efficiency. This study has the potential to reveal insights into the energy efficiency, predator avoidance, and social interactions within shark schools, which can inform broader ecological and conservation efforts.

## Plug and play: using vinegar flies to generate decoder systems for insect odorant receptors

*Clara Sandberg, Roeskva Torhalsdottir, Gregory Pask, Lisa Brady, Tobias Ziemke*

To navigate and sense the world, insects utilize odorant receptors (ORs) to detect salient molecules and drive important behaviors. Insect ORs are expressed in odorant receptor neurons (ORNs), where each ORN typically expresses a single OR plus Orco, the odorant receptor co-receptor. Advances in genomic tools continue to improve the identification of OR genes, but understanding their function (i.e. what odorants activate them) can be challenging. Here, we develop and validate a new system to decode insect ORs using an “empty neuron” model, which adds to the existing toolkit and enables several options for researchers’ efforts in OR characterization. Using Drosophila melanogaster for its genetic tractability, we created a CRISPR knock-in line that disrupted the native Or59b gene with an inserted GAL4 coding sequence. We confirmed the GAL4 functionality by utilizing existing UAS constructs (UAS-GFP and UAS-Kir.2) and by expressing previously decoded insect ORs. The development of this new decoder system provides researchers a tractable and reliable option for studying the ever-increasing amount of insect ORs from agricultural pests, disease vectors, and evolutionary models.

## Water relations of invasive Burmese pythons (*Python bivitattus*) in Florida

*Mark Sandfoss, Eleanor Lane, Christina Romagosa, Amanda Kissel, Amy Yackel Adams*

Understanding the physiological tolerance of invasive species is important for predicting their potential to invade and persist in a novel environment. The Burmese python is an invasive species in Florida and much about their physiology remains unknown. To better understand their water requirements, we measured hydration status of free-ranging pythons in the field and conducted three laboratory trials on drinking behavior of hatchling pythons. Between 2019 to 2023 we measured the osmolality of plasma from pythons (n = 322) in the Greater Everglades Ecosystem to characterize hydration state. We found considerable variation in hydration state throughout the year. Results of our first drinking experiment measuring thirst in hatchling pythons (n = 52) found individuals drank shortly after emergence, within 0.66 ± 0.9 days, and ingested 4.63 ± 4.3% of their body mass. We then measured thirst threshold and found hatchling pythons drank after losing on average 2.15 ± 1.1% of their body mass and returned to their original body mass plus 1.25 $\pm$ 2.6%. Finally, we measured saline drinking behavior of hatchlings when in a dehydrated state despite anticipated long-term deleterious effects to their hydration budget. Several drank saline water while others refused. Collectively, these results show pythons drink often and will voluntarily ingest saline water which matches the evolutionary history of the species and suggests coastal habitats are less suitable than freshwater habitats.

## Expanding bacteria-killing assays to be more functionally relevant in a reptile host

*Franziska Sandmeier, Christopher Hall, Bec Reynolds, Mariah Painter*

Bacteria-killing assays (BKA) are frequently used in ecoimmunology, with Escherichia coli and other common pathogens. In an effort to increase the applicability and interpretation of such assays in our study organism, the Mojave desert tortoise (Gopherus agassizii), we focused on expanding assays to more closely reflect natural host-microbe dynamics. We used a commensal microbe (Pasteurella testudinis) as well as E. coli, ran assays across a range of potential body temperatures, and used both isolated white blood cells and plasma separately in assays to understand the difference between cellular and humoral components of the blood. We first quantified growing conditions of P. testudinis across a range of incubation temperatures (13-40°C). We collected blood samples from 18 captive animals in summer and ran cell-based killing assays immediately after we separated cells from plasma, across incubation temperatures. We repeated a similar killing assay, using only plasma. We found that cell-based assays had much higher rates of killing than plasma-based assays, but that killing was lower for P. testudinis in these cell-based assays. These data suggest that important recognition happens during cell-recognition of microbes that mediate killing responses. We recommend that cell-based BKA should be used in tandem with plasma-based BKA, to better understand immune function and regulation of commensal and pathogenic bacteria in animal hosts.

## Fall migratory photoperiod responses in a facultative migrant, the Anna's hummingbird (*Calypte anna*)

*Sam Sandoval, Chelsea Johnson, Jesus Ovalle, Derrick Groom*

There are two main types of bird migration, obligate migration, where birds move spatially and temporally in a predictable manner and is signaled by changing daylength, and facultative migration, where the movements are less predictable. The major drivers of obligate migration is a relatively well studied phenomenon, but the biology of facultative migration is less understood. Because day length is one of the strongest environmental drivers of migratory behavior and physiology in obligate migrants, it may also be an important environmental regulator in facultative migrants. This research focuses on the behavior of Anna's hummingbirds (Calypte anna), a facultative migrant, in response to a migratory photoperiod. We predict that Anna's Hummingbirds will show stereotypical migratory behaviors under a migratory photoperiod, as seen in an obligant migrant. This includes an increase in activity, foraging effort, and increased food intake. Thirteen individuals were placed under two different photoperiods that simulated long days and fall migration. Food was provided ad libitum to prevent any effect of food availability on the migratory phenotype. Perch-mounted scales and video recordings monitored changes in activity levels, while feeders outfitted with sensors monitored feeding frequency and duration. By studying avian facultative migrants, we will deepen our understanding of migration diversity and evolution. This knowledge can help us identify common environmental drivers of migration across the avian clade.

## Systemic effects of pesticides on insectivorous bats: a proteomics approach

*Natalia Sandoval Herrera, Linda Lara-Jacobo, Paul Faure, Denina Simmons, Kenneth Welch*

Bats play a critical role controlling agricultural pests, yet foraging in croplands exposes them to hazardous pesticides. Even at low doses, these chemicals pose significant risks for bats by impairing immune function, locomotion, and cognition, thus jeopardizing their survival and ecological role. Here, we used proteomics—a powerful, yet underused, tool in ecotoxicology—to examine the systemic effects of Chlorpyrifos (CPF), a commonly used insecticide, on big brown bats (Eptesicus fuscus). We exposed bats through their diet to an environmentally relevant concentration of CPF for three and seven consecutive days and took plasma samples before and after exposure for non-targeted proteomics. We identified over 100 proteins with significant abundance changes before and after exposure to the pesticide. Exposure to CPF altered a wide range of molecular processes including cell communication, cell metabolism, and DNA maintenance. Remarkably, we found changes in key proteins involved in immune response, T cell activation, and inflammation. These effects could reduce bat's immune response, increasing their susceptibility to viral infections and intensifying the risk of shedding and transmitting pathogens to other species. Our results provide new insights into the toxicity of pesticides and suggest broader implications for bat and human health, considering the role of bats as reservoirs for numerous zoonotic pathogens. Our results also highlight the utility of proteomics for assessing toxicant effects in understudied and vulnerable species like bats.

## Phylogenetic relationships within the Anolis cybotes group from the Caribbean Island of Hispaniola

*Bianka Sanó, Nathalie Alomar, Isabela Hernandez Rodriguez, Sina Rometsch, Martha Muñoz*

Anoles are a lineage of primarily arboreal lizards distinguished by their adhesive toepads, extensible throat flap, and a remarkable range of diversity in both size and shape. In this study, we focus on the Anolis cybotes group, a clade of trunk-ground anoles native to the Dominican Republic and Haiti. This anole clade exhibits a wide diversity of species and can be found throughout the whole; this is why anoles from this group have been frequently used as a model organism for several ecology and evolution studies. Owing to their highly similar morphology and overlap in geographic distribution ranges, the taxonomy delimitation of this group has been complex. Previous phylogenetic studies conducted in this group are based on Sanger sequencing, which only targets specific genes. Even when combining several different sequenced genes for phylogenetic analyses, resolution is often too low for reliable species delimitation, increasing the chance of biased results. In this project, we built a high-resolution phylogenetic tree using 3RAD sequencing. This next generation sequencing technique allows us to detect many variants across the genome, leading to a highly accurate phylogenetic tree that reflects the true relationships among these species. This approach enabled us to create a robust and reliable phylogenetic tree, facilitating a more precise systematic delimitation of species within the cybotes group.

## 3D reconstructions of peptidergic terminals suggest synaptic pruning in an adult molluscan brain

*Harshada Sant (she/her), Sarah DeAmicis, Alexzander Cook, Srimaan Sridharan, Sanmadhi Periyasamy, Yuelong Wu, Richard Schalek, Jeff Lichtman, Paul Katz*

Synaptic pruning is a crucial process during the development of the nervous system and has been extensively studied in young animals. Glial cells play an important role in synapse elimination by engulfing synaptic boutons. Here, we found evidence of synaptic pruning in the rhinophore ganglion (rhg) of an adult nudibranch mollusc Berghia stephanieae. The rhg contains approximately 9,000 somata and ultrastructurally distinct neuropil regions. The Lateral Rhinophore Ganglion Neuropil (LRhN), is composed primarily of the axon terminals of peptidergic neurons. In this study, we performed 3D reconstructions of neurons and glial cells from a volume electron microscopy (vEM) dataset with $4 \times 4 \times 30$ nm resolution. Axon terminal arbors that branched extensively within this neuropil region were reconstructed. They featured numerous vesicle-filled varicosities, which are likely sites of peptide release. Neighboring axon boutons made membrane-to-membrane contact without postsynaptic specializations. Among the axon terminals were novel structures: independent vesicle-filled boutons unattached to axons. Some of these independent boutons were either surrounded or completely engulfed by glial cells, indicating potential degradation. At least one was surrounded only by other axonal boutons. These independent boutons likely budded off a nearby axon and may subsequently be engulfed by glial cells. Thus, the independent boutons could represent an example of synaptic pruning in the neuropil of an adult animal.

## Testing for evidence of positive selection using a consensus approach

*Scott Santagata, Joseph Ryan*

Statistically robust investigations of positive selection are often hindered by the effects of numerous factors such as sequence quality, orthogroup evaluation, underlying codon models, number of background and foreground taxa, rate heterogeneity, estimations of dN/dS ratios (omega), and degree of divergence among the included species. Previously, we have demonstrated how our SELECTINGS pipeline facilitates the usage of comparable phylogenetic selection-based methods available from PAML and HyPhy on large datasets encompassing species with diverse evolutionary relationships. Here, we use our pipeline on newly generated and publicly available transcriptomic datasets of 38 Antarctic and 34 non-Antarctic bryozoan species to investigate the effects of above factors on the results gathered from several site- and branch-based tests. Our initial findings include statistically significant evidence of positive selection in a number of genes (orthology groups). Importantly, we identify several genes with significant results using tests from both PAML and HyPHy packages. However, we also find that PAML and HyPHy often produce different sets of significant genes, even for those found to be significant between multiple methods within the same package. Some of the variability in our results are linked to methodological differences (e.g., codon frequency models used and rate calculations for omega). Going forward, we will use our pipeline and results to inform on a set of guidelines for using existing and potentially improving comparable tests for positive Darwinian selection.

## Investigating acute stress effects on skeletal muscle myogenesis pathways in black rockfish

*Julianne Santos, Eva Claussen, Zoey Dale, Janae Shew, Sean Lema*

Elevated cortisol can impair somatic growth in teleost fishes. While such growth-reducing effects of cortisol are likely to be mediated in part by changes in skeletal muscle growth, mechanisms of cortisol action on muscle growth in fishes remain unclear. In this study, black rockfish (Sebastes melanops) were exposed to an acute stressor to test for stress-induced changes in skeletal muscle myogenesis and muscle atrophy gene expression pathways. Juvenile rockfish maintained under either a restricted feed amount (0.5% ration: 0.5% dry feed mass per fish mass per day) or an ad lib food ration (6% ration) for 56 d were either: 1) sampled directly for a 'baseline' pre-stressor condition, or 2) netting and handled, returned to their holding tanks, and then sampled 70 min after the initial netting for a 'stressed' condition measure. Rockfish under restricted food failed to increase in body mass over the experimental period, indicating the restricted food ration was insufficient to support positive growth. Food restricted fish showed elevated skeletal muscle mRNAs encoding myostatin1, a negative regulator of muscle growth, as well as slightly elevated expression of the F-box only protein 32 (fbxo32) gene, a ubiquitin ligase gene linked to proteasomal degradation and muscle atrophy. Muscle fbxo32 expression also increased following acute stress in ad lib-fed fish only, suggesting cortisol modulation of muscle atrophy pathways may be dependent on prior feeding status.

## Worm drop: Emergent flow behavior in shape-shifting worm collective

*Paulami Sarkar, Ishant Tiwari, Prathyusha Kokkoorakunnel Ramankutty, Saad Bhamla*

California blackworms (Lumbriculus variegatus) have flexible, slender and elongated polymer-like body. Blackworms can intertwine their bodies to form entangled collectives called the worm blob. These blobs can collectively respond to various stimuli ranging from thermal, electrical and photic. How the blob's collective behaviour changes in semi-dry substrate under acute stresses is still unexplored. We address this question by designing a flow setup which forces the worm blob through a narrow cylindrical channel under gravity. We observe spherical, droplet-like worm structure forming at the tip of the funnel similar to water droplets. We further introduced electric and thermal stresses in the worm-funnel system to understand the effect of increased worm activity on flow profile, increased worm activity led to higher exit-velocity. The same experiment with the funnel tip under water revealed different results, where the worms could escape the system without forming an agglomeration. To further understand the role of activity on flow behaviour, we examine a passive polymer like material in a similar setup, no flow was observed in that case. To understand underlying mechanisms, we employed computer simulations, the worms were modelled as active polymers flowing through a cylindrical channel. Our study improves our understanding of how physiologically slender-elastic bodies of invertebrates allow them to shapeshift and develop interesting flow behaviours, their unique body shapes allowing them to collectively traverse constrained spaces without jamming.

## Comparing traditional and genetic methods for diet characterization in dispersal-stage green turtles

*Chris Sarkis, Brandon Hoenig, Erin Seney, Kate Mansfield, Anna Forsman*

Sea turtle diets vary significantly among species, life stages, and localities, encompassing both plant and animal taxa. Unfortunately, obtaining accurate dietary information for sea turtles through traditional, visual approaches can be challenging due to physical degradation of diet items through digestion. DNA metabarcoding, however, works well despite some tissue degradation by amplifying taxon-specific genetic targets (i.e., DNA barcodes) that are sequenced to identify diet taxa. In this study, we compared DNA metabarcoding of dietary samples to visual identification methods to characterize prey composition of wild green turtles and evaluated the effectiveness of each technique. We collected cloacal swabs and esophageal lavage samples from 24 dispersal-stage green turtles (Chelonia mydas) captured in the Gulf of Mexico and used eukaryotic COI and 18S barcodes to characterize diet from both cloacal and esophageal lavage samples; visual identification was only used for esophageal lavage samples. Illumina reads were processed and analyzed using QIIME2 to classify diet-derived DNA sequences found in green turtle diets. Preliminary results indicate that metabarcoding of lavage DNA identifies more diet taxa than cloacal swab DNA. This outcome highlights the importance of careful sampling design and demonstrates that lavage DNA metabarcoding is an effective complement to visual identification. Our work suggests that methodological considerations are critical for informing ongoing studies on early life history and foraging ecology of federally protected sea turtles.

## Modeling flying fish locomotion as informed by bioinspired RMO experiments

*Valeria Saro-Cortes, Aimy Wissa, Brooke Flammang*

The unique multi-medium locomotion of flying fish, which features "taxiing" on the ocean surface as a precursor to gliding through the air, is hypothesized to both function as an escape mechanism from underwater predators as well as to provide energetic alternatives when traveling long distances. The latter is not well-studied due to the challenges inherent to studying the dynamics of biological organisms, but is critical to forming a complete understanding of flying fish locomotion. In order to investigate this hypothesis, we have developed a model for flying fish locomotion validated by experiments on a robotic model organism (RMO). Specifically, we use the model to investigate 1) the energetic requirements for transitioning from swimming to flying, and 2) the conditions under which it is more energetically favorable to glide or swim a given distance, accounting for the energy required for transition. Dynamics results from experiments performed on a biologically relevant flying fish-inspired RMO are used as inputs for the model. Kinematics inputs are determined by a fluid-structure interaction analysis performed on the caudal fin based on measurements taken from a flying fish sample. The resulting trajectories and energy analysis form the basis for a quantitative discussion on the biological roles of flying fish multimedia locomotion as well as a foundation for bioinspired design based on flying fish locomotion.

## How do frozen crickets maintain mitochondrial function?

*Stefane Saruhashi, Soren Coulson, James Staples, Brent Sinclair*

Internal ice formation is usually lethal, but freeze-tolerant insects withstand internal ice formation. Metabolic rate of the freeze-tolerant spring field cricket, Gryllus veletis, returns to normal – or even increases- after freezing, implying that freeze-tolerant insects either prevent mitochondrial damage during freezing or quickly repair any damage after thawing. We used a highly metabolic active tissue, the Malpighian tubules, to examine how freezing and thawing affect mitochondrial structure and function using high-resolution respirometry and transmission electron microscopy. We compare freeze-intolerant (i.e. control) and freeze-tolerant crickets to identify how acquiring freeze tolerance changes the mitochondria and compared unfrozen with frozen crickets to disentangle the effects of cold and ice formation. Mitochondrial oxidative capacity in freeze-tolerant crickets doesn't differ from freeze-intolerant crickets but acquiring freeze tolerance is accompanied by a morphological change, yielding bigger, rounder mitochondria. After thawing, freeze-intolerant crickets have swollen mitochondria with reduced ATP production, likely associated with a damaged inner mitochondrial membrane. Although mitochondria of both unfrozen and frozen freeze-tolerant crickets swell, they maintain metabolic function and inner membrane integrity. We conclude that acquiring freeze tolerance requires a fundamental change in the structure and function of mitochondria.

## Behavioral differences in two subspecies of Red Panda (*Ailurus fulgens fulgens and A. f. styani*)

*Zaha Sarwar, Kelly Diamond*

Red pandas (Ailurus fulgens) are divided into two subspecies, the Himalayan red panda (A. f. fulgens) and the Chinese red panda (A. f. styani). These subspecies are geographically isolated in their native ranges, but due to their arboreal habitat, little is known about the behaviors of wild individuals. Behavioral differences might be expected between the two subspecies because of the different altitudes of their native habitats. Previous studies have shown how activity can differ within the same subspecies among different zoos. We are interested in studying how behaviors can differ between the two species while in captivity at the same zoo. To document red panda behavior, interval sampling was used to film each subspecies at the Memphis Zoo during various times of day over 4 weeks. Videos were analyzed to measure the amount of time red pandas spent exhibiting 7 behavioral categories, including resting and locomotive behaviors. We found differences in the time each subspecies spent performing comforting and vigilant behaviors. This study emphasizes that there is a difference in certain behaviors of the two red panda subspecies in captivity. Research like this is important to gain information about this endangered species and to improve husbandry standards and conservation efforts.

## Diel variation in baseline testosterone levels in a diurnal rodent (*Octodon degus*)

*Yuta Sato, Josephine Low, Carolyn Bauer, Tate Garcia*

Testosterone is correlated with various social and reproductive behaviors such as aggression and territory acquisition. However, testosterone tends to vary over a 24-hour cycle, with most species showing peaks during their inactive period. For the common degu (Octodon degus), researchers have found low concentrations and low inter-individual variability of testosterone in both the field and laboratory, however, these samples have exclusively been collected during the active period (daytime). We hypothesized that baseline testosterone levels peak during the inactive period (nighttime) in degus, and also show greater inter-individual variation during the inactive period. Therefore, we measured testosterone levels of captive degus at six different time points across a 24-hour cycle. Gonadotropin-releasing hormone (GnRH) challenges were also performed during the daytime sampling periods to see if peak nighttime baseline testosterone levels could be simulated during the daytime. As expected, baseline testosterone was highest during the inactive period, with a peak 2 hours before lights turned on. However, peak baseline testosterone levels were still much lower than levels two hours after a GnRH challenge. These results expand on research surrounding diel testosterone rhythms and can offer future strategies for examining relationships between testosterone and androgen-mediated behaviors.

## Diverse evolutionary pathways to morphological novelty in coral reef fishes

*Darien Satterfield, Bernice Yin, Samantha Hodges-List, Michael Burns, Peter Wainwright*

Integration and modularity in morphological systems have been implicated as alternative mechanisms for the origin of novel forms. Strong integration facilitates rapid evolution to extremes along axes of trait covariation, while modularity imparts independence of body parts allowing for unusual trait combinations. However, there is no consensus on the relative importance of integration and modularity in the evolution of novel phenotypes. Further, it has been predicted that the evolutionary pathways available to reach extreme morphologies are determined predominantly by the strength of integration. In this study, we use a phylogenetic approach to estimate the contribution of these two pathways in generating novel forms in coral reef fishes. We show that novel reef fishes arose along axes of trait covariation only slightly more often than modular evolution produced extreme forms through novel trait combinations. Simulations of multi-module evolution under Brownian motion reveal that access to novel forms via both integration and modularity is only possible when integration is present but at moderate strengths, as is the case for reef fishes. However, extreme forms have evolved via integration more commonly in reef fishes than predicted by simulations, suggesting that biomechanical constraints might inhibit the exploration of novel trait combinations. Because vertebrate morphological systems are often characterized by intermediate levels of integration it can be anticipated that both evolutionary mechanisms contribute substantially to the evolution of novel forms.

## Diet driven host tolerance to avian conjunctivitis is linked to shifts in global gene expression

*Erin Sauer, Carson Stacy, Weston Perrine, Ashley Love, Jeffrey Lewis, Sarah DuRant*

As humans alter the landscape, wildlife have become increasingly dependent on anthropogenic resources, altering interactions between individuals and subsequently disease transmission dynamics. Further, nutritional quantity and quality greatly impact an individual host's immune capacity and ability to mitigate damage caused by infectious disease. Thus, understanding the impact of dietary nutrition on immune function is critical for predicting disease severity and transmission as human activity both facilitates the dispersal of pathogens and alters dietary options for wildlife. Here, we use transcriptomics to explore the previously unstudied molecular mechanisms underpinning diet-driven differences in pathogen tolerance to Mycoplasma gallisepticum (MG). MG is an ideal model for understanding the dietary drivers of disease as the human supplementation that wild birds commonly rely on, bird feeders, are also an important source for MG transmission. Significant diet-driven differences in the expression of many genes encoding immune response and translational machinery proteins are seen both in the absence of MG and during the recovery period. Prior to infection, protein-fed birds are more transcriptionally primed for infection than lipid-fed birds which translates to greater tolerance in protein-fed birds during the recovery period. Given the significant importance of human supplemented food in wildlife disease systems, the molecular mechanisms by which interactions between diet and infection emerge provide insight into the ecological and immunological consequences of human behavior and wildlife disease.

## Losing the gut feeling: host immunity and infection perturb the bumble bee beneficial gut microbiota

*Logan Sauers, Bryan Sierra Rivera, Toby Bassingthwaite, Benjamin Sadd*

Understanding factors influencing the maintenance and membership of beneficial host-associated microbial communities is central to understanding the ecological, evolutionary, and health consequences of these communities for their hosts. Host immunity is often implicated as a potential regulator of these host-associated microbial communities. This is supported by studies of the adaptive immune system and its ability to selectively surveille and respond to gut microbes. On the other hand, immunity may play a disruptive role, with responses to infection causing collateral damage. Such effects are predicted to be more prominent from innate immune responses, with rapid acting and relatively non-specific components. We quantify changes to the beneficial bumble bee gut microbial community following non-pathogenic immune stimulation treatments in one experiment and following infection with a gut infection trypanosomatid in another. We find immune stimulation alters microbiota colonization and community interactions. Furthermore, infection early during development of the adult bee microbiota also leads to a perturbation core microbiota member abundances. These changes are indicative of immune response and infection induced dysbiosis. Such changes demonstrate outcomes of pathogenic infection may in part be mediated by effects on the host microbiota and that there is a potential for collateral perturbation of beneficial microbial communities by innate immunity. The latter will contribute to the cost and benefit tradeoff for immunity that shapes the evolutionary optimization of immune investment.

## Opsin regeneration in the isolated zebrafish retina

*Aimee Saunders, Jordan Renna*

The retina detects changes in light levels, guiding a variety of complex behaviors. As organisms move in and out of bright light (photopic) and dim light (scotopic) conditions, the photoreceptor opsins regenerate through various pathways. In the zebrafish, the primary pathways of opsin regeneration are through the retinal pigment epithelium (RPE) and through the Müller glial cells within the retina. Here, we dissected out the contributions of each pathway to opsin regeneration by isolating retinae from the eye and removing the RPE of the zebrafish. Retinae were then mounted into a custom 3D-printed ex-vivo electroretinogram (ERG) chamber, dark adapted for various durations, and then subsequently exposed to 300ms single long flashes at 520nm at increasing intensities. Photoreceptor (a-wave) and bipolar cell (b-wave) response amplitudes to light onset were measured as well as response amplitudes to light offset (d-wave).

Retinae that were dark-adapted for 60 minutes post-dissection demonstrated increased photoreceptor and bipolar cell response amplitudes to light onset at scotopic and photopic intensities, but only had increased response amplitudes at scotopic intensities to light offset when compared to tissue dark-adapted for 15 minutes. Response amplitudes that increase were presumably the result of regenerative opsin through glial cells, whereas the responses to light decrements at photopic intensities suggests the RPE is directly involved in regeneration.

## Predicting changes in diatom density through unsteady sinking

*Phoenix Savage, Kevin Du Clos*

Diatoms are the most abundant phytoplankton in many marine ecosystems and contribute 20% of global and 40% of marine primary production. Their silica shells make them dense enough to sink, but they can adjust their sinking speeds gradually in response to light and nutrient conditions and also exhibit sinking speed oscillations over seconds (unsteady sinking) by mechanisms that are not understood. To gain insight into buoyancy control mechanisms, we focused on how a diatom's shape and size impact unsteady sinking and modeled the density changes needed to produce observed speed oscillations. We used high-resolution video to record the sinking of individual diatoms from contrasting-sized cultures of a nearly spherical species, Coscinodiscus wailesii, and a more cylindrical species, Odontella mobiliensis, with dimensions comparable to the smaller C. wailesii culture. When cultured under high nutrient conditions, larger spheroids sank faster on average, while smaller spheroids sank more unsteadily, indicating greater density variability. Smaller spheroids, similar in size to the cylinders, had a slower mean speed but sank more unsteadily. These findings suggest that unsteady sinking in diatoms may be influenced by surface-area-to-volume ratio or that active sinking may not be advantageous in nutrient-rich environments.

## Diverse pneumatizing pulmonary diverticula in birds challenge reconstructions of dinosaur lungs

*Emma Schachner, Aracely Martinez, Stephanie Baumgart, Alexis Slack, Amanda Pineda, Jaeger Johnson, Chloe Huntley, Clinton Grand Pre, Claire Zimmerman, Adam Lawson, Andrew Moore*

Considerable research attention has been devoted to reconstructing the evolutionary origin of an 'avian-style' lung in the extinct archosaurian relatives of birds. This work has relied on putatively universal 'rules' of skeletal pneumatization, whereby specific components of the avian respiratory system invade and aerate particular postcranial skeletal elements, producing pneumatic (i.e., air-filled) bones. However, the universality of these patterns was recently challenged by the discovery of highly heterodox pneumatization patterns in the Common Ostrich (Struthio camelus). Here we evaluate pneumatization patterns in six phylogenetically disparate species: Common Ostrich, Mallard, Red-tailed Hawk, Great Horned Owl, African Grey Parrot, and Zebra Finch. Each specimen was inflated, imaged via microCT/CT, and checked for decay, and then the pulmonary sources of intraosseous diverticula were tracked for each taxon ($n \geq 3$). This method was validated for each species ($n \geq 2$) by full segmentation and 3D modeling of the respiratory system. All six taxa show strongly divergent patterns. The Red-tailed Hawks pneumatize the femora via the abdominal air sacs, whereas the ostriches do so via pelvic diverticula. Contrary to nearly all published reports, most taxa pneumatize their synsacra via pelvic diverticula, not the abdominal sacs. We show that the specific pulmonary tissues pneumatizing different regions of the skeleton are far more variable than previously recognized, indicating that pulmonary reconstructions of avian lungs in dinosaurs should be much more conservative.

## Risk perception and locomotor performance in wild and captive primates

*Nicole Schapker, Lydia Myers, Judith Janisch, Ahmad Matar, Julie Pham, Abdelrahman Boghdady, Liza Shapiro, Jesse Young*

Research on primates' aptitude for navigating fine, compliant, and oblique branches has often focused on their postcranial morphology and locomotor mechanics. Here we aim to understand how primates perceive risk and make informed judgments to move safely. We video-recorded and digitized the locomotion of four lemur species (Ranomafana National Park) and 3 cercopithecoid monkeys (Kibale National Park). We test the general hypothesis that primates should change their gaits and engage in exploratory behaviors – using touch and sight as guides – to increase stability in precarious settings. Augmenting our prior study showing that some lemurs change their locomotion when moving high in the canopy, we present new data on the behavior of wild lemurs and monkeys as they cross gaps between substrates or switch between locomotor modes. They frequently cross gaps and transition between modes without pause, meaning they can accurately gauge their locomotor capacity before moving onto a new substrate. In an investigation on four species of captive lemur (Duke Lemur Center), we examine how variations in substrate diameter, orientation, and compliance influence the paths lemurs choose to take. Preliminary results suggest that lemurs will tend to avoid the most precarious substrates in their paths, and future analysis will examine the role that light availability plays as well. Overall, this research highlights the importance of risk perception for robust locomotor performance while moving in arboreal environments.

## Scratching beneath the surface: forelimb muscle properties in black-tailed prairie dogs

*Luke Scheetz, Carter Burnett, Benjamin Kimble, Michael Butcher*

Black-tailed prairie dogs excavate burrow systems mainly for predatory avoidance and social organization. As such, they have evolved a suite of musculoskeletal traits in their forelimb digging apparatus for scratch-digging. However, the degree to which their muscular anatomy is modified in response to the selective pressures of their semi-fossorial lifestyle is unknown. The functional capacities of the entire forelimb musculature of Cynomys ludovicianus (N=9) were discovered through quantifications limb mechanical advantage, muscle architectural properties, and myosin heavy chain (MHC) isoform content. Forelimb mass distribution was marked by a large investment in scapular and shoulder muscles that accounted for two-thirds of total forelimb muscle mass. The majority of forelimb muscles had long fascicles with high LF/ML ratios and low PCSA/MM ratios. Only the massive m. pectoralis superficialis was capable of high power by its architectural properties, although several other large muscles were modified for large joint torque or torque range, including mm. latissimus dorsi and triceps brachii long head. Mechanical advantage was correspondingly greatest at the shoulder, intermediate at the elbow, and lowest at the wrist. Muscle composition was also surprisingly faster-contracting by moderate expression of fast MHC-2B and low expression of slow MHC-1. The findings suggest that prairie dogs are less-specialized compared with subterranean burrowing rodents due to their preferences for medium soil types, cooperative social behavior, and trade-offs between terrestrial locomotor and digging functions.

## Against the grain: untangling the tangled denticles of basking sharks

*Mike Schindler, Aurora(Tairan) Li, Frederik Mollen, Nick Payne, Shahrouz Amini, Venkata Surapaneni, Ruien Hu, Mason Dean*

In contrast to other sharks, slow swimming basking sharks (Cetorhinus maximus), high-volume suspension feeders, are covered by massive conical denticles. Shark denticles are effectively teeth embedded in the skin, with most examples diminutive (<500μm) and consisting of a wide basal plate, tapering towards an angled pointed crown, often bearing ridges. As a group, denticles are organized in streamlined series on the skin, their cusps pointing towards the tail, reducing drag. In sharp contrast to this canonical pattern, we show that basking shark denticles are densely and focally clumped to form 'paver blocks' separated by unscaled folds. In each block, denticles are radially arranged like floral whorls, their tips pointing toward and interdigitating with denticles of neighboring blocks. The wrinkling resembles the skin of elephants, with folds oriented to prescribe local anisotropic flexibility. Using high-resolution μCT scans, histology, mechanical tests and large-area laser scanning, we characterized how the significant shape and orientation of basking shark denticles differ from other species' and discuss how variations of denticles and skin alignment along the body promote extreme stretching of the head skin for oral volume enlargement during feeding. These investigations provide much-needed insights into basking shark anatomy, for understanding the evolution and ecological constraints of large marine suspension filter feeders and for the design of dynamic bio-inspired textiles.

## Complex environments drive adaptive hunting strategies in mice

*Aidan Schneider, Jacob Amme, Keith Hengen*

An animal's predatory behavior is often uniquely evolved and adapted to its natural environment. However, predators can also persist and adapt in the face of environmental change. Laboratory studies of mice preying on insects offer controlled, mechanistic insights into their hunting dynamics. Yet, these experiments typically occur in barren, unchanging environments. This study investigates how prey capture and search strategies evolve with increasing environmental complexity.

We designed an experimental setup enriched with objects reminiscent of refuse commonly found in cluttered anthropogenic environments where mice and cockroaches may coexist (e.g., a landfill). Mice reared in barren environments were introduced to this complex setting, and their behavioral adaptations were studied. This required specialized computer vision tools to track the animals despite frequent occlusions, as well as novel machine-learning models to classify both brief individual actions and extended behavioral states integral to the hunt.

Our analyses revealed the emergence of new hunting behaviors unique to the complex environment. These include: 1. skillful maneuvering through dense clutter, 2. persistent tracking of prey over extended periods and through uncertainty, 3. discovering and revisiting potential prey hiding locations, and 4. complex, sequential hunting and search strategies. These behaviors, although observed within an enclosure, mirror strategies of wild predators in their native environments, suggesting that animals can adaptively develop novel complex behaviors in response to a changing, complex environment.

## Mechanisms of a novel feeding strategy in chameleons

*Nikole Schneider, Christopher Anderson*

Some organisms have evolved extreme anatomical structures which increase the performance of a specific behavior. However, these structures may be coopted for alternate usages which can also benefit the animal. How these novel behaviors evolve from existing structures remains unanswered in many organisms, including the chameleon. Chameleons have a specialized feeding apparatus which allows them to ballistically project the tongue at high performance up to 250% of their body length. Though tongue projection is their typical feeding strategy, chameleons have also been reported to feed on slow or non-mobile prey items by directly capturing the prey item with their jaws. This direct capture strategy is minimally described in the literature and the basic mechanisms never examined. We compared the kinematics and muscle patterns of tongue projection and direct prey capture between two chameleon species feeding on different prey items to determine whether these strategies utilize the same movements and patterns, or if distinct behaviors can be performed despite the extreme specialization of the feeding apparatus. Preliminary results suggest that these feeding strategies are not constrained to the same kinematics and muscle patterns, and that the direct prey capture strategy is similar between chameleon species. Additionally, future comparisons with an agamid outgroup could help elucidate whether direct prey capture is a co-optation of ballistic projection or a reversion back to the ancestral mode of feeding.

## Conserved anterior-posterior bilaterian features of the adult gut in a marine annelid

*Stephan Schneider, Wahyu Cristine Pinem, Grace Sonia*

A through-gut, a digestive organ with a mouth and anus, is one of the major features of animals with bilateral symmetry, the bilaterians. Vertebrates including humans share this feature with flies and worms suggesting that an inner digestive tube was already established in the last common ancestor most likely a marine invertebrate worm-like creature. To unravel which aspects of the ancestral digestive system are retained in a marine worm and which ones are novel and unique we investigate the molecular make-up of the gut in the marine annelid Platynereis dumerilii. To do so we dissected adult guts and generated bulk RNA-seq data of tissues along the anterior posterior axis that correspond to morphological specializations. This enabled us to identify hundreds of genes encoding digestive enzymes and unravel their mostly restricted expression in distinct sections, a first glimpse of the functional subdivision along the anterior-posterior (ap) axis of the adult gut. Intriguingly, we could also find restricted expression of genes encoding orthologs of developmental gene regulatory networks (GRNs) that are known to be involved in the development and formation of sea urchin and vertebrate guts. In summary, our study revealed the molecular and functional subdivision of the annelid gut, identified markers to describe gut cell types, hints that parts of the embryonic GRNs are being maintained in adult guts, and might be ancestral bilaterian features.

## How single-cell transcriptomics of Hydractinia is informing evolution of cnidarian sensory systems

*Christine Schnitzler, Jingwei Song, Danielle de Jong, Justin Waletich*

For over a century, the colonial cnidarian Hydractinia has been employed as a research organism to study stem cells, germ cells, and regeneration. For the last 70 years, it has also been used in allorecognition research within the field of comparative immunology. Hydractinia colonies are composed of a limited number of repeating structural units, polyps and stolons. Polyps are divided into three major types used for feeding, reproduction, or defense. Clonal lines grown in the lab provide unlimited material from a single genetic unit. Colonies have separate sexes and spawn regularly with exposure to light. Recently, genomic and transcriptomic resources have been released for two species of Hydractinia: H. symbiolongicarpus and H. echinata. Tools for gene expression manipulation have been developed for this organism including CRISPR/Cas9 knockout, shRNA knockdown, and overexpression via synthetic RNA. Fluorescent transgenic reporter lines have been created via random integration of circular DNA plasmids and CRISPR/Cas9-mediated gene knockin. We constructed a single-cell transcriptomic atlas of adult Hydractinia colonies to explore the cellular biology of the animal. We are investigating known and novel cell types and validating spatial expression patterns of cell-type specific markers to enable further understanding of the animal's biology. Hydractinia is poised to become a model for sensory biology research as we can now fully explore their sensory cells and structures and the expression of sense-organ-related genes.

## Larvae in the dark: Meroplankton diversity and ecology during the Polar Night

*Kharis Schrage, Kirstin Meyer-Kaiser*

The Polar Night is a multi-month period of darkness in the high Arctic, meaning there is no primary production to support the pelagic ecosystem. Despite this, studies have found evidence of active feeding, growth, and reproduction of marine animals (benthic organisms, holoplankton, and seabirds) during this period. Little targeted research has focused on the early life history stages of benthic invertebrates, a key stage impacting population and community dynamics on the seafloor. We assessed the taxa richness, reproductive and developmental biology, feeding, and competence of meroplanktonic larvae in January 2023 in Kongsfjorden, Svalbard. Using surface plankton tows, we characterized the meroplankton community in the fjord. We found low densities of meroplankton compared to other times of year, but more taxa than identified in previous studies. Half of these morphotypes were planktotrophic (feeding) larvae. Using laboratory assays and direct observations, we documented feeding in a few of these planktotrophic larvae. Some morphotypes were embryos, suggesting some taxa have active reproduction in the Polar Night. We observed settlement in two polychaete taxa in the laboratory, as well as metamorphosed echinoderms in our samples, showing competency to settle across phyla. Overall, we show that early life-history stages of a diverse range of benthic invertebrates are actively feeding and developing during the Polar Night.

## DNA methylation and epigenetic potential regulate phenotype in House Sparrow

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The house sparrow (Passer domesticus) is one of the world's most successful introduced species. We are conducting a large collaborative investigation of how DNA methylation, epigenetic potential, gene expression, and genetic variation support this success. Here, we report on two aspects of this study: investigating DNA methylation and epigenetic potential in the individual response to infection and linking epigenetic potential to changes in gene expression across house sparrows on a global scale. A previous experiment in house sparrows demonstrated that epigenetic potential is important in an individual's response to infection with a pathogenic Salmonella. Here, we show that DNA methylation is related to epigenetic potential, varies among tissues, and varies over time among the same individuals. We also found individuals with the highest rate of change in DNA methylation had the highest rate of change in Salmonella burden. We have also investigated the patterns of variation in DNA methylation and epigenetic potential at the putative promoter of multiple Toll-like Receptor genes, and their expression among house sparrows collected from nine locations across the globe. Here, we will discuss the relationship between epigenetic potential and gene expression across geographic space and introduction histories, contrasting specific Toll-Like Receptor promoters and different tissues. Together, these results indicate that DNA methylation and epigenetic potential make important contributions to introduced species at both the individual and population level.

## Form-function of biological composites through morphology, mechanics, modeling, and mimicry

*Andrew Schulz*

Muscular hydrostats are thought of as nearly infinite degrees of freedom systems that utilize complex muscle arrangements to accomplish diverse grasping and manipulation behaviors without the need for rigid bones to constrain their locomotion. This versatility has inspired roboticists to inspire different technical solutions based on the thousands of muscles working in union inside the elephant's trunk. As the muscles are adapted to various functions, so is the skin wrapping these muscles and protecting them from external harm. Mammalian skin is a complex biological composite of layers with distinct mechanical properties, morphologies, and mechanosensory capabilities. In this work, we explore a framework to utilize four scientific techniques of morphological characterization, mechanical testing, computational modeling, and bioinspired design to break down skin to determine the trade-offs of individual components of skin complexities. In this work, we describe the current state-of-the-art with each technique and how we can leverage material science, additive manufacturing, and metamaterial physics to systematically study structure-function relationships in biological tissue, such as skin.

## Metamaterials Investigations of Biological Composites in the Elephant Trunk

*Andrew Schulz*

Elephant trunks have been seen bulldozing trees, throwing lions several meters into the air, and picking up a tortilla chip without breaking. These trunks comprise the same foundational structural proteins, collagen, and keratin, that include human fingernails, skin, and muscles. In the elephant trunk, these proteins form complex biological metamaterials. We define a biological metamaterial as a complex organization at the micro or meso-scale that drives macro-scale functional benefits. Elephant skin has metamaterial properties that assist with the duality of mechanical extension while maintaining a protective sheet around these inner muscles that provide the muscular hydrostat namesake. This presentation will discuss some complex metamaterials inside the elephant trunk and how they can lead to mechanical, sensing, or medical benefits. We discuss some tools that can be used to investigate metamaterial mechanics in biological tissues ranging from soft collagenated tissue to heavily keratinized materials. We look forward to what techniques could be used in the future to investigate metamaterials, including muscular hydrostats, and expand to biological composites as a whole.

## Bluegills are stable in horizontal cross-flow vortices without their visual or lateral line systems

*Margot Schwalbe, Hannah Stinson, Kyle Lassen, Jeremy Levin, Reed Connor, Eric Tytell*

Fish swim in complex hydrodynamic environments and may encounter unexpected flow patterns, like horizontal vortices shed by waterfalls. Multiple sensory systems, including vision and the lateral line, likely contribute to a fish's ability to detect such flow and to remain stable through swimming adjustments. To test the role of different sensory systems in stability, bluegills (Lepomis macrochirus) were placed in a flow tank with a custom-made flapper that generated strong up- and downward flows separated by horizontal cross-stream vortices and were recorded with high-speed cameras. Fish positioned behind the flapper experienced one of two flapper frequencies (1, 3 Hz) and flow speeds (low, high), and their visual and lateral line systems were temporarily disabled by performing trials in the light and dark (under infrared light), and with and without their lateral lines (disabled by cobalt treatment). In all cases, fish quickly recovered from the flapper action and even with both sensory systems disabled at the same time, fish were able to hold station. In low flow and at both flapper frequencies, responses were variable and fish changed their movement depending on available sensory systems. Thus, bluegill are relatively stable in horizontal cross-flow vortices, yet input from visual and lateral line systems is important to regain stability. Other sensory modalities may contribute to flow detection in unsteady flows, including mechanosensors in fins, and warrants further study.

## Convergent evolution of hindwing flight in beetles and cockroaches

*Johanna Schwartz*

Polyneopteran insects fly only with their hindwings. Their thickened forewings protect the hind-wing—which is particularly important to clades that spend time in narrow spaces. Yet, this constrains the size of the hindwing, to be able to fit safely underneath the forewing. Numerous clades have solved this by evolving different folding mechanisms in the hind wing. In particular, cockroaches are unique in Polyneoptera in having an apically folding field. Outside of Polyneoptera, beetles (Coleoptera) have independently evolved a similar mechanism. In both groups, the surface area of the hindwing can be greatly expanded depending on the size of this field. To receive the maximum benefit from the wing to body size ratio, we hypothesized that the apical field size is positively correlated with body size. We tested this hypothesis using cockroaches and beetles, two evolutionarily independent datasets. We took wing and body measurements from specimens representing more than 50 beetle families and cockroach genera, calculated the phylogenetic independent contrast, and analyzed them with a multiple linear regression. We found that the apical field composes less of the wing as the hindwing size increases in both taxa. Ancestral state reconstruction indicates that the folded apical field evolved nine times in cockroaches but only once in the common ancestor of all beetles. Major questions remain about the morphological correlates of apical field size, and its functional constraints.

## Tunable moisture loss by spider egg sac design

*Ravi Schwartz, Katherine Karkosiak, Hunter King, Todd Blackledge*

Many organisms undergo sensitive developmental stages in which their immobility makes them vulnerable to both predators and environmental hazards such as thermal fluctuations and desiccation. A common response is to form a protective cocoon-like structure, which offers resistance to advective and diffusive exchange of heat and matter. Spiders present a counterintuitive example across their morphological and geographical diversity: in place of a solid (eg. serosal) membrane to prevent desiccation, they form a highly porous sac of layered silk fibers to loosely surround their egg clutches. A consistent interpretation of the egg sac's role has been lacking, we believe, because previous studies have looked at various aspects of the problem without a cohesive view of the whole system. Here, we present a simple model to relate the resistance to moisture loss of the whole egg sac to its structure and geometry, validating it in experiments with synthetic porous membranes. Experiments with natural samples of three species demonstrate that egg-sac shape, rather than material or structure, plays the dominant role in mediating moisture loss.

## Strategies for self-monitoring dynamic visual appearance

*Lorian Schweikert, Heather Bracken-Grissom, Umut Ayoglu, Sonke Johnsen*

The capacity of animals to rapidly alter their visual appearance is often achieved using either physiological color change or bioluminescence, two distinct behaviors with similar ecological functions (e.g., background-matching camouflage). In general, outputs of these behaviors do not function in binary states, but instead, over a performance spectrum that tunes appearance to changing environmental conditions. Thus, dynamic appearance likely operates under strong selective pressure, as even small errors in performance may have fitness consequences. Other behaviors that are tunable and robust to environmental variation, such as locomotion, often rely on sensory feedback information to optimize performance (i.e., closed-loop control systems). Here, we review emerging studies that reveal how dynamic appearance may also benefit from sensory feedback, using information obtained through the self-assessment of visual appearance via visual means. In this way, diverse animals (such as certain fishes, cephalopods, and shrimps) appear to be "watching themselves" over three central mechanisms: photoreception in color-changing skin, photoreception in light organs, and monitoring of bioluminescence via eye-facing light organs. This visual assessment of self is intriguing from an evolutionary perspective due to: 1) the apparent co-option of visual pathways traditionally understood to only support ocular vision and 2) the widespread nature of this strategy across taxa and between appearance-altering behaviors. The evolutionary significance of convergence upon this strategy is one of several considerations for future study.

## Lizard and snake tongues as muscular hydrostats: comparative morphology and function

*Kurt Schwenk*

Tongue morphology in lizards and snakes (squamates) is highly diverse in shape, papillary form, and muscle fiber architecture. The squamate tongue subserves two disparate functions: feeding and tongue-flicking related to vomeronasal chemoreception, as well as subsidiary functions such as lapping and facial-wiping. Variation in form is largely explicable in terms of the nature and extent of the movement required by each function. However, variation is also broadly correlated with phylogeny. In iguanian lizards, tongue movement is coupled to the hyobranchial skeleton, the lingual process and laryngohyoid ligament extend nearly to the tongue tip, and tongue protrusion for prey capture exhibits little, if any, hydrostatic shape change, as manifested in the muscle fiber architecture. Chameleons are exceptions in exhibiting hydrostatic length change during projection and extensive shape change in the tongue tip during prey capture. In non-iguanian taxa, the lingual process and laryngohyoid ligament fail to extend into foretongue, the tongue is laterally and/or dorsoventrally narrowed, and tongue protrusion is hydrostatic and independent of hyobranchial movement. Gekkotans possess broad, spatulate tongues with multiple longitudinal bundles and intrinsic fiber loops that thin the tongue to maintain a wide surface during protrusion for face- and eye-wiping. Extreme protrusion during tongue-flicking in snakes reflects the basic mechanics of hydrostatic elongation, including an increase in the tongue's resting length, its narrow, cylindrical form, and muscle fiber architecture favoring diameter reduction.

## Bend it like butterflies: Buckling dynamics of ridge grating morphologies in developing wing scales

*Kwi Shan Seah, Shankar Venkataramani, Antonia Monteiro, Vinod Kumar Saranathan*

We report on the development of longitudinal ridges in pupal butterfly wing scales by tracking time-resolved changes in scale cell shape and cuticle deposition. We correlate quantitative measurements of ridge and overall scale cell growth from confocal and electron micrographs with an elastic buckling model that is theoretically investigated in two-dimensions. Our theoretical analysis recapitulates the observed topological changes on the scale surface during development. We further extend our model to plausibly explain how the highly exaggerated ridge lamellae with Christmas-tree cross-sectional profiles found in some nymphalid species (e.g. Morpho spp.) could be an hierarchical elaboration of the buckling process. Our observations provide new insights into how complicated surface morphologies develop in nature. This is highly relevant to current challenges in engineered technologies of soft materials for multifunctional applications, from flexible electronics, photonics and photovoltaics to soft lithography and soft robotics.

## The hydrodynamics of the streamlined body of sea lions

*Sophia Sebo, Frank Fish, Duncan Irschick, Megan Leftwich*

California sea lions (Zalophus californianus) are highly maneuverable and agile marine mammals. The hindflippers act as control surfaces during turning and porpoising maneuvers while the foreflippers aid in propulsion through wing-like oscillation. The streamlined body of otariids maximizes the locomotory efficiency during aquatic propulsion. Based on multiple simultaneous videos of two sea lions (Ariel and Cali) gliding in water (DigitalLife3D) 3D images were reconstructed and physical 3D models were printed. Three versions of the models (body and all flipper, body without foreflippers, and body with no flippers) for both sea lions were tested in a flow tank at speeds 0.5-1.5 m/s in trim at 0 deg. The models were connected to a six-axis force transducer for measurement of drag based on frontal area. The sea lions generally had reduced drag as the flippers on the models were removed. All models exhibited similar patterns in maintaining a minimal drag coefficient (Cd) through the varying speeds. On average at 0.5 m/s the removal of the foreflippers reduced Cd by 22.8% and the removal of all flippers reduced Cd on the body by 32.3%. The body of the sea lion without flippers had a Cd of 0.3. The flippers account for a large percentage of the total drag on the streamlined sea lion body.

## Hydrodynamic roles of fore and hindflippers in harp and harbor seals

*Sophia Sebo, Frank Fish, Megan Leftwich*

The flippers of phocid seals are modified for an aquatic lifestyle. The foreflippers are used mainly as control surfaces for maneuverability, whereas the hindflippers are used mainly for propulsion in a unique alternating motion. Both fore and hindflippers can be abducted (spread) and adducted (collapsed). The fore and hindflippers of harp (Pagophilus groenlandicus) and harbor (Phoca vitulina) seals were examined. Hindflippers were morphologically similar with aspect ratios, ranging from 1.64-2.15 for abducted hindflippers and 2.83-3.49 for adducted hindflippers. Each abducted and adducted flipper was 3D scanned and printed into 3D models of similar scale. The models were hydrodynamically tested in a flow tank at 1 m/s. A six-axis force transducer was used to measure the lift and drag on each flipper at angles of attack (AOA) ranging from -20 to 20 deg. Lift coefficients (CL) for harp and harbor seals of abducted hindflippers ranged from 0.77-0.86, while CL of adducted hindflippers ranged from 0.52-0.74. Lift/Drag (L/D) ratio for the abducted hindflippers was highest for the harbor seal at 7.4 for 12 deg AOA, while harp seal flippers showed a maximum value of 5.1 at 16 deg AOA. No stall was indicated for any model tested. The greater aspect ratio and associated higher L/D of the propulsive hindflippers of the harbor seal will indicate relatively enhanced swimming performance compared to the larger harp seal.

## Does the experience of leaving home trigger magnetic orientation In hatchling sea turtles?

*Isabelle Sechrest, Jadyn Sethna, Stella Sherrill, Catherine Lohmann, Kenneth Lohmann*

As hatchlings, loggerhead sea turtles (Caretta caretta) from the southeastern United States begin a migration to their nursery habitat in and around the North Atlantic Subtropical Gyre. To guide themselves during this migration, turtles respond to positional, or map, information inherent in Earth's magnetic field. In a magnetic displacement assay, in which they are exposed to magnetic fields that they would typically encounter on this migration, turtles respond by swimming in directions that would keep them within the warm waters of the Gyre. Previous anecdotal evidence suggests that hatchlings in this assay do not show magnetic orientation when near their home beach but may only demonstrate magnetic orientation after experiencing a change in the magnetic field. Thus, at the start of the journey, hatchlings may rely on other environmental cues to guide themselves offshore and later switch to using magnetic cues when they experience a sufficient magnetic change. Here, we compare the orientation responses of hatchlings from Jekyll Island, GA, USA that experience no change in magnetic field to responses of hatchlings that experience a change in magnetic field (for example, a change to a magnetic field that exists north of Jekyll Island). Results will provide insight into the circumstances that elicit the use of magnetic cues for navigation.

## The effect of jump spacing on landing pressures in agility dogs

*Brendan Seitz, Rachel Olson, Arielle Markley*

Vertebrate locomotion involves a chain reaction of events that triggers the movement of an organism; this movement could determine whether they satiate their hunger or quickly escape from an enemy. However, for agility dogs, a faster speed results from training, rather than escape from a predator. Agility competition involves high speeds and maximum effort exerted from the dog through a course of different obstacles. With any fast moving and repetitive behavior, the margin for injury likely increases as the repetitions increase. We focused on the forces associated with jumping with various spacing between obstacles (7m, 8m, 9m). Our study quantified the pressure on the leading forelimb during landing using a TekScan-Strideway. Our results showed that leading forelimb pressures at 8 and 9 meters apart was significant for the higher jump heights. Further insights into the affect of scaling and velocity can inform our understanding of peak performance and inform injury risk.

## Moo-ving Mountains: An Agent-Based Exploration of Grazing Terracette Formation

*Benjamin Seleb, Saad Bhamla*

On vegetated hillslopes around the world, one may occasionally observe hillsides adorned with quasi-parallel rows of closely spaced terraced steps, or terracettes, that run along the contour of the slope. Several geological mechanisms, including soil creep and slumping, have been proposed to explain the formation of these patterns. In most cases, however, these landscape features are associated with significant ungulate or livestock activity, suggesting that they arise, at least in part, from the biogenic disturbances caused by grazing animals.

Previous studies have demonstrated strong correlations between terracette landscape topography and ungulate characteristics, such as body size and step dimensions. Although potential mechanisms have been proposed to explain these correlations, no formal model has been developed to explain the generation and evolution of these terracettes. In our research, we develop a simple agent-based model in which agents explore a simulated erodible terrain. By introducing a slope-dependent energetic cost of motion, we are able to generate terracettes that closely resemble those observed in nature while examining the process of pattern formation.

## The muscularized tongue is a key feature of the mammalian feeding system

*Kaleb Sellers, Peishu Li, Courtney Orsbon, Casey Holliday, Callum Ross*

The muscularized tongue is a key feature of the mammalian feeding system. During swallowing, coordinated activity of intrinsic and extrinsic tongue musculature propels the bolus into the alimentary canal. In vivo evidence suggests that tongue base retraction (TBR) is a kinematic feature common to swallowing across mammals with a wide range of hyolingual morphologies, suggesting a deep ancestry for this trait. Emerging evidence suggests that TBR is caused by diverse mechanisms independent of the configuration of the hyolingual apparatus, suggesting lineage-specific adaptations to bring about TBR. Various mechanistic hypotheses have been advanced to explain TBR; however, we know surprisingly little about the comparative anatomy of the muscles driving TBR, challenging our ability to understand this key feature of the mammalian feeding apparatus. Using diffusible iodine-based contrast-enhanced computed tomography (diceCT), we investigated the hyolingual apparatus of mammals with a range of craniofacial morphologies and putatively diverse mechanisms of TBR. We found that animals with relatively anteriorly placed hyoids had relatively superoinferiorly tall tongues. We also found that animals with relatively anteriorly placed hyoids had flexed soft palates relative to the hard palate. We found no clear patterns of relative muscle size, supporting a many-to-one mapping problem of form-function relationships in the hyolingual system. Our results highlight the diversity of lingual myology and suggest that various lineages have experimented with different mechanisms to effect TBR.

## Sea turtle nest sand composition and diversity on the Gulf of Mexico

*Matthew Senecal, Jake Lasala*

Loggerhead sea turtles (Caretta caretta) migrate from their foraging grounds to their natal nesting regions to lay their nests during the nesting season. Loggerheads have strong nest site fidelity, but beach composition can vary within natal regions, even across islands. Nest temperatures impact sea turtle hatchling development, including embryo growth rate, incubation duration, and primary sex ratios. Sand characteristics (albedo, color, particle size, porosity, hydraulic conductivity) have been shown to influence nest temperatures globally. Sarasota County hosts the largest loggerhead nesting aggregation in the Gulf of Mexico, but sand types have not been assessed for this region. Within the county, sand types vary widely including a range of colors and shell content that could impact nest temperatures, nest depth, and hatchling emergence. Sand composition and diversity were explored across 4 beaches in Sarasota County during the 2024 nesting season. Nest temperatures from data loggers, coupled with local weather station data were modeled with sand characteristics and nest measurements to identify which factors influenced hatch and emergence success of loggerhead hatchlings. Hurricane Debby impacted many nests by placing sand over hundreds of nests in 2024. Sand types post storm were also collected and the new sands' impact on these nests will be discussed.

## Self-righting behavior of benthic crabs in freefall

*Yohan Sequeira, Emily Carrington, Jake Socha*

When many animals are inverted on a substrate, they exhibit the dorsoventral righting reflex (DVRR), which enables the animal to reorient. The DVRR is exhibited by a wide range of taxa, including arboreal, terrestrial, and even aquatic species. However, the ability to self-right during free-fall is rarer, characterized in a few species including geckos, insects, and squirrels. These animals live in arboreal environments where falling is potentially injurious, and free-fall righting likely evolved as a recovery mechanism. Similarly, some species of crab also live on exposed rocks or kelp blades where they can be displaced, rotated, and carried into the water column by intermittent flows or other disturbances. To determine if crabs can self-right while falling in water, we inverted and dropped crabs in a seawater tank with a depth of 40 cm. We recorded trials from 39 juvenile crabs of eight different species, with 5-15 trials per individual. Our preliminary analysis suggests that differences in morphology and ecology between crab species may affect both reorientation success rate (varying from $\sim$7% for Petrolisthes eriomerus to $\sim$100% for Scyra acutifrons) and required rotation depth (a minimum of $\sim$4.6 leg lengths for Oregonia gracilis versus $\sim$5.9 leg lengths for Cancer oregonensis). The ability of certain species of crabs to reorient in freefall may enable them to traverse or inhabit more turbulent environments than species without this ability.

## Nest temperature effects on body condition index of loggerhead sea turtles in Sarasota County, FL

*Julia Serra, Jake Lasala*

Nest temperature plays an important role in the development of sea turtle hatchlings; impacting primary sex ratios, size, and locomotion. Multiple papers have expressed that as global temperatures rise, there is a risk for hatchling development to be affected. A previous study on the east coast of Florida found that higher incubation temperatures have the potential to negatively impact hatchling survival rates as they are associated with lower fitness, smaller body size, and dehydration. The study presented here will assess the impact of temperature on the morphometrics and body condition of hatchlings from nests on the Gulf of Mexico. Temperature data loggers were inserted into loggerhead (Caretta caretta) nests from 2021 to 2024 in Sarasota County, Florida. Local weather station data on these beaches will be compared to these data logger nests and then extrapolated to 600+ nests laid during that time frame. Of the hatchlings that were collected from those nests, approximately 20% per nest were measured and weighed before release. Generalized additive models will assess date nest laid, year, average extrapolated incubation temperature, beach placement, and precipitation average during incubation to determine which factors influence hatchling body condition.

## Sea turtle navigation in a moving geomagnetic field:link between maternal age and offspring response

*Jadyn Sethna, Isabelle Sechrest, Stella Sherrill, Catherine Lohmann, Kenneth Lohmann*

Once Loggerhead sea turtles (Caretta caretta) hatch from their nesting beach in the southeastern U.S.A., they immediately begin a multi-year oceanic migration around the North Atlantic Subtropical Gyre. While there are few available navigational cues in the open ocean, hatchling turtles can rely on seemingly innate orientation responses to the Earth's magnetic field. However, because the geomagnetic field gradually drifts over time, a mechanism must exist that enables the loggerhead population to update responses to regional magnetic fields that exist along the migratory route. To investigate how turtles adjust to the changing geomagnetic field, we compared the responses of hatchlings from young mothers, mothers who had completed their own migration through the gyre in the relatively recent past, with the responses of hatchlings from older mothers, mothers who migrated through the gyre decades ago when the magnetic field differed significantly from how it is now. Initial results suggest that the responses of hatchlings from young mothers are better matched to the current magnetic field than the responses of hatchlings from old mothers. How geomagnetic instructions are passed across generations in sea turtles remains enigmatic; both genetic and epigenetic mechanisms appear plausible.

## Habitat- and species-dependent changes of neuronal temperature resilience

*Mackenzie Seymour, Wolfgang Stein*

Temperature fluctuations present major challenges to the nervous systems of poikilothermic animals, which cannot actively regulate their body temperature. Decapod crustaceans, which play crucial roles in marine coastal ecosystems and food webs, are particularly vulnerable to the rising habitat temperatures and heatwaves resulting from global warming. The proper functioning of their nervous systems under these changing conditions is essential for survival, as it controls vital processes such as heartbeat, respiration, digestion, and sensory abilities. This raises the question how resilient the nervous system is against temperature fluctuations, whether resilience is species- and habitat-dependent, and which cellular and circuit mechanisms enable temperature resilience.

We investigate neuronal temperature resilience mechanisms in a comparative approach across decapod crustacean species that live in distinct temperature habitats by using pattern generating circuits that control aspects of feeding. These circuits can be recorded in all species and are generated by homologous neurons.

The measured rhythmic neuronal activity showed habitat- and species-specific differences in temperature resilience: When challenged with high temperatures, rhythmic activity in species from colder and more stable habitats (subtidal and benthic, N=10 each) ceased at significantly lower temperatures than in intertidal species that experience rapid and more frequent habitat temperature fluctuations (N=10 each). Acclimation to higher habitat temperatures shifted the range of temperature resilience in intertidal species. Thus, neuronal temperature resilience correlates with, and responds to, environmental temperature conditions.

## Quantitative Micro-CT Analysis of Murine Bone: Investigating Menopause-Related Osteoporosis

*Mohit Shah, Supriya Baskara, David Matatov, Maria Sepulveda, Akinobu Watanabe*

Menopause marks the cessation of a woman's ability to bear children, and the ovaries decreased capacity to produce hormones such as estrogen and progesterone. Osteoporosis, a pathological condition, has been associated with the post-menopausal state in women. The heightened risk of developing osteoporosis in this population has been linked to reduced estrogen signaling to skeletal muscle following menopause. However, the exact mechanisms through which decreased estrogen contributes to increased risk of osteoporosis remain incompletely understood. To understand the relationship between the post-menopausal state and the development of osteoporosis in humans, it is essential to quantitatively assess how bone structure changes in post-menopausal females. Here, we quantified various attributes of selected bones using menopause-induced mice as a model system. Age and sex were controlled to isolate the quantitative effects of decreased hormonal signaling on bone porosity. Specimens were scanned using micro-computed tomography imaging, and we collected and analyzed data of the cortical and trabecular bone of the L5 and L6 vertebrae, femur, and tibia. The results indicated lower bone volumes and higher porosities in the mice that underwent ovariectomies. These findings align with expectations and corroborate previous studies on the subject. This study provides quantitative bone data that will enhance our understanding of the connection between menopausal females and their increased incidence of osteoporosis.

## Energetics as a gateway to studying adaptations across biological scales

*Anusha Shankar*

Animals need to balance their energetic needs with their energy stores, and adjust this balance according to their environment. Animals such as hummingbirds might maintain very sparse energy stores, and manage this carefully with astonishingly high metabolic rates. Others, such as large mammals, might pack large energy stores as fat, and have lower mass-specific metabolic rates. The mechanisms by which their evolutionary histories and their environment influence this balance can be studied at every biological scale, from how their enzymes are best suited to a particular metabolite, to how their gut microbiota process their diet, to how their organs use and store energy, to their behavioral adaptations and their use of a landscape. My research program integrates data from across biological scales to study animal adaptations to their environment, from allometric scaling at the interspecific level to gene expression in various tissues of a hummingbird in torpor. Moving forward, my lab in India is studying animals such as sunbirds and nightjars and how they adjust their energetic needs to environmental variation and change. Sunbirds are especially interesting in the context of this symposium because they are often sexually dimorphic, and the males sometimes have distinct breeding and non-breeding morphs. How do these morphologies relate to the diet, energetic needs and thermoregulatory strategies of these birds across environmental gradients?

## A Unique Microbiome Supports Photosymbionts in Fraginae Heart Cockles

*Maya Shaulsky, Jingchun Li*

Photosymbiosis is ubiquitous in the marine world and has significant conservation and economic importance. In Photosymbioses, a primary producer (photosymbiont) partners with a heterotrophic host (e.g., coral, mollusk, jellyfish). The photosymbiont provides photosynthates to the host and gains shelter and nutrients, like nitrogen, in return. Research shows that bacterial communities support stable photosymbiosis, yet the composition or roles of bacteria in many non-coral photosymbiotic systems remains unknown. To elucidate this bacterial role, we utilized the Fraginae study system. This bivalve group includes photosymbiotic and non-photosymbiotic species, allowing for direct comparisons between the microbial community in hosts with and without photosymbionts. Using 16S, we assessed the bacterial community composition in three photosymbiotic species and one non-photosymbiotic species for four different tissue types (gill, gut, mantle, foot). Our results revealed a common core microbiome among all bivalves, including the genera SUP05 cluster, Endozoicomonas, and Cryobacterium. Most differentially abundant bacteria we found were more abundant in photosymbiotic bivalves, including individuals from the genera Fangia, HIMB11, and Aquibacter. The genus Endozoicomonas is prevalent across samples with individual ASVs more abundant in both photosymbiotic and non-photosymbiotic bivalves. The different tissue types show significantly different microbial communities, with the gills hosting the most disparate microbiome between species with and without photosymbionts. Understanding the bacterial role in photosymbiotic interactions can inform marine health and the role of symbiosis in broad patterns of evolution.

## Testing the influence of chronic radiation exposure on biological aging trajectories in Medaka fish

*Ethan Shealy, Steven Gardner, Marilyn Mason, Benjamin Parrott*

Recognizing how life history traits are shaped by the environment is critical to understanding the ways in which organisms respond to a changing world. Whereas all organisms share an evolutionary history with ionizing radiation (IR), cumulative doses and exposure risks have increased due to anthropogenic sources. The effects of these exposures on individual life histories are complex; for example, studies have observed exposure to IR both extending and reducing organismal longevity, with effects varying by taxonomic group, dose, and environmental factors. Here, we utilize outdoor mesocosms within a specialized facility to expose Japanese Medaka fish living under semi-natural conditions to four dose rates of ionizing radiation (~0, 5, 50, and 500 mGy/day). To test how IR exposure affects biological aging and organismal health, individuals were sampled at three different timepoints across their natural lifespan. Using data from each of these life stages we assessed organismal growth, histopathology, and developed novel epigenetic aging pipelines to assess biological aging trajectories. Preliminary analyses indicate that IR exposure induced a drastic increase in growth rate and maximum size attained, negatively affected reproductive organs, and accelerated epigenetic markers of aging in fish exposed to 500 mGy/day. Collectively, we use these molecular measures of aging rate along with the associated phenotypes to investigate the potential pathways by which environmental radiation shapes organismal health and its consequences on life history variation.

## Hot or not? The effects of temperature on anuran glucocorticoid regulation

*Eleanor Shell, Cris Ledón-Rettig*

Climate change is emerging as the biggest threat to biodiversity, with amphibians as the most vulnerable vertebrate class. Therefore, a critical question is: how do amphibian species with different environmental histories respond to changing temperatures? Specifically, because many anurans (i.e., frogs) choose mates in the same ponds where their offspring will develop, it is imperative to examine how adult frogs respond to warming water. We hypothesized that adult frogs respond to warming water through an elevated glucocorticoid response (i.e., corticosterone or CORT), but that this response varies across frog species that evolved in different thermal environments. To evaluate the impact of warming water on the adult frog stress axis, we used a non-invasive, waterborne corticosterone (CORT) assay across two species of spadefoot toads (family Scaphiopodidae) that evolved in different thermal environments. Both the mesic-dwelling species, Scaphiopus holbrookii, and the desert-dwelling species, Spea bombifrons, produced more CORT in response to heated water, though these results varied in a sex-dependent manner. Because elevated CORT is associated with changes in behavior, our study suggests that warmer water might modify adult frog behavior across both species, especially in the context of reproduction. Further, our study provides the foundation for future research exploring how differences in adult reproductive behaviors affect offspring quality in a changing climate.

## The effect of temperature variation on tadpole resilience in a desert-adapted frog

*Eleanor Shell, Cris Ledón-Rettig*

In unprecedented times of rapid environmental change, temperature fluctuations are an emerging threat to biodiversity. Amphibians, frogs in particular, are ectothermic organisms that exhibit a complex life cycle, in which both water and air temperature affect their resilience across life stages. Therefore, a crucial question is: how will temperature variation affect early-life frog (i.e., tadpole) resilience? To address this, we raised spadefoot (family Scaphiopodidae) tadpoles under ecologically relevant thermal environments to examine the effects of temperature variation on tadpole resilience, as measured by tadpole performance under heat stress. We hypothesized that tadpoles of desert-adapted frogs reared at warmer temperatures would be more resilient to a heat shock than those raised at cooler temperatures. To evaluate the impact of a heat shock on the tadpole stress axis, we used a non-invasive, waterborne corticosterone (CORT) assay across two species of spadefoot tadpoles (genus Spea). To assess the resilience of early-life behavioral phenotypes, we also measured tadpole performance via swimming speed. We hypothesized that heat-reared tadpoles will develop faster, but at a smaller size, swimming slower, thus performing worse, than cold-reared tadpoles. Results from this study will provide insights into how early-life frog phenotypes may provide a buffer in a rapidly changing environment. Future directions will examine how resilience differences in early-life tadpole phenotypes are shaped by adult frog reproductive behaviors in a changing climate.

## A novel carnivorous diet reduces brain telomere length in spadefoot toads

*Alex Shephard, Cris Ledón-Rettig*

Environmental conditions experienced during organismal development can have profound effects on adult survival or longevity. One well-established correlate of longevity is length of telomeres - noncoding DNA regions that protect chromosomal ends. Dietary stress in the form of nutrient restriction during early development has been associated with reductions in telomere length later in life. Yet, we lack experimental studies of how adult telomere length is affected by a different form of nutritional variation: diet type. Here, we asked how diet type variation during development affects adult telomere length using the Mexican spadefoot (Spea multiplicata), a unique system whose larvae can develop on two qualitatively distinct diet types: an ancestral omnivorous diet of detritus or a more novel diet of live shrimp prey. We tested how larval dietary variation influences post-metamorphic telomere length in multiple somatic tissue types, including muscle, liver, gut, and brain. We found that larvae developing on the novel shrimp diet developed into adults with shorter telomeres in the brain, a structure that is particularly vulnerable to harmful effects of nutritional adversity, such as oxidative stress. Given known links between brain telomere length and neurological health, our study suggests that a dietary transition to carnivory might carry costs in terms of compromised neural integrity later in life. Altogether, this work shows that developmental diet type can have lasting consequences for somatic maintenance and health.

## Muscle shortening and vertebral column curvature during propulsive vertical bending in snakes

*Jacob Sherman, Kelsey Garner, Jessica Tingle, Henry Astley*

While snakes can use lateral bends to propel themselves, recent studies have shown that they can also generate propulsive forces through vertical bending when moving through uneven terrain, either in combination with lateral bending or via a single vertical bend. Given the likely importance of three-dimensional movements during snake locomotion in natural environments, the muscular basis for propulsive vertical undulation can provide a broader understanding of the mechanics of limbless locomotion. To quantify muscular strain, we implanted radio-opaque metal beads into three muscles in four corn snakes (Pantherophis guttatus), and then we recorded X-ray videos to measure muscle length and vertebral column curvature during vertical bending. A preliminary analysis suggests that muscle length change and vertebral column curvature are closely related. Observed muscle shortening patterns during vertical and lateral bending confirm functional predictions from muscle anatomical positions. Additionally, particular combinations of vertical and lateral bending allow certain muscles to remain isometric or near-isometric despite continuous motion. Because overcoming frictional forces is a major requirement for effective limbless locomotion, snakes may benefit from these lower shortening speeds due to increased muscle force output.

## Performing under pressure: How morphology affects locomotion of a sand-swimming skink

*Anya Shevchik, Ethan Livingston, Eric Gangloff*

An animal's morphology directly influences its ability to perform fundamental tasks, which can be vital to its survival and reproduction. This is especially true in harsh or extreme environments, such as The Sahara. Despite being common across a broad geographic range – and an important food source to some human populations – little is known of the natural history of the sandfish skink (Scincus scincus). Building upon our past work on the thermal biology of this sand-dwelling lizard, we conducted an experiment to test how body size and dimensions affect performance at optimum temperatures. We quantified three different types of movement: sprinting (hunting behavior), diving (escape behavior), and sand swimming, a unique form of locomotion for these animals. We measured multiple morphological characters, including toe, leg, head, and body size, using digital calipers. We then tested how this multivariate morphological phenotype impacted performance measures and assessed potential trade-offs. Further, we searched for patterns of sexual dimorphism and how morphology-performance relationships potentially differ between the sexes. Overall, this experiment provides insight into morphology-performance relationships across a number of ecologically important aspects of locomotion in this unique lizard, including the novel measures of swimming speed within the sand. Looking forward, we hope to leverage these data to illuminate ecological drivers of sexual dimorphism and to characterize the unique adaptations that allow this species to flourish under such intense conditions.

## Using a digital endocast to evaluate feeding performance during suckling in mammalian infants

*Hannah Shideler, Thomas Stroud, Emily Volpe, Dylan Anderson, Skyler Wallace, Maressa Kennedy, Ani Smith, Holly Sabato, Shanique Yazzie, Elska Kaczmarek, Christopher Mayerl, Harlow Smith*

Infant suckling is a complex process driven by tongue movements that form a seal around a nipple then generate suction. However, understanding how this is accomplished has remained challenging, particularly due to the complexity of how this muscular hydrostat moves in three-dimensional space. To address this, we surgically implanted radio-opaque beads throughout the oral cavity in infant pigs and filmed them feeding on both a hollow and a ducted nipple using high-speed biplanar videofluorography synchronized with intraoral pressure generation. We then used X-ray Reconstruction of Moving Morphology (XROMM) to reconstruct a dynamic endocast of the oral cavity during suckling and calculated intraoral volume change. We used these data to assess if nipple type affects tongue kinematics, intraoral suck volume, or the relationship between suck volume and suction generation. We found that the differences in suckling kinematics across nipple types varied by individual. We also found that pigs fed on a ducted nipple generated greater suction than when fed on a cisternic nipple, but we saw minimal changes in maximum intraoral suck volume. These results demonstrate that nipple design impacts the relationship between biomechanics and fluid dynamics in feeding, and the mechanism of milk acquisition can vary among individuals within a species.

## Biomechanical underpinnings of directional abscission of dandelion seeds

*Jena Shields, Fiorella Ramirez Esquivel, Aspen Shih, Yukun Sun, Sridhar Ravi, Chris Roh*

The common dandelion (Taraxacum officinale) is a widespread plant which disperses its seeds through wind. Though seed dispersal has historically been seen as a passive process, recent research has shown that plants can influence their seed dispersal through non-random seed detachment, or abscission. It has been known that dandelion seeds abscise more readily on the windward side of the seed head versus the leeward side, but the mechanism through which this occurs has remained unclear. To study this phenomenon, force measurements of seed abscission were taken with forces applied in different directions. These force measurements along with multiple forms of microscopy of the seed and seed head morphology reveal an asymmetry in the structure of the seed attachment which results in significant differences in the abscission force needed relative to the direction of the applied force. We propose a new mechanistic model to explain this directional bias based on morphological parameters of the plant. This improved understanding of seed abscission can be used to create more accurate dispersal models to better study the population dynamics of wind-dispersed plants.

## Don't Fall! Pendular dynamics models for time scale limitations in non-primate mammalian climbing

*Cassie Shriver, David Hu, Young-Hui Chang*

In horizontal terrestrial locomotion, inverted pendulum and spring mass models demonstrate reliance on passive, pendular dynamics to minimize energy expenditure during walking and running. These cost savings are dependent on strategic utilization of gravitational potential energy. In climbing, however, organisms must continuously overcome gravitational forces to move upwards. This additional locomotor challenge is further exacerbated by scaling constraints in larger animals. We have previously shown that non-primate mammals tend to use one of two climbing gaits: a bounding gait, characterized by synchronous contact in the forelimbs and hindlimbs, and a lateral sequence gait, characterized by synchronous contact in diagonal limbs. We now propose novel dynamics models for these two gaits, using pendular dynamics to predict a time scale of falling which climbers must overcome to minimize energetic costs. We calculated theoretical time scale limits using known morphological scaling relationships in non-primate mammals. Experimental data were acquired using videos of animals at Zoo Atlanta and other online sources. When comparing the experimental data to the theoretical bounds of our model, we found that most individuals exhibited time scales at or below the theoretical limits, suggesting these climbers operate within time scales of pendular dynamics. Individuals exceeding these time scale limits appear to instead depend on muscular action to slowly extend their bodies upwards and may be able to afford additional energetic costs due to smaller sizes.

## Genomic tools in veiled chameleon (*Chamaeleo calyptratus*) for the study of left-right patterning

*Natalia Shylo, Zoe Griffin, Andrew Price, Sofia Robb, Paul Trainor*

Squamates (lizards, snakes, and amphisbaenians) represent the largest order of reptiles and their extensive diversification is an extraordinary example of adaptive evolution. Very little however is known about early squamate development, because at the time of egg laying most squamate embryos are well into organogenesis. Veiled chameleons (Chamaeleo calyptratus) breed well in captivity, with pre-gastrula embryos at oviposition. We discovered that unlike most deuterostomes, chameleons use a motile cilia-independent mechanism for left-right (L-R) patterning. Using live imaging we observed a leftward tilt in the posterior neural plate hinge point, and this morphological L-R asymmetry precedes, and likely triggers the asymmetric expression of the Nodal signaling cascade. In parallel, we assembled and annotated the veiled chameleon genome at chromosome scale. Analyses of different genomic regions revealed veiled chameleons possess both ancestral paralogs of the Nodal gene, but have lost Dand5 and several other genes, likely in conjunction with the loss of motile cilia in the node during left-right patterning in reptiles. We are currently establishing CRISPR/Cas9 genome editing in veiled chameleons to elucidate the roles of non-motile cilia in L-R patterning and heart formation, as well as transposon-mediated transgenesis to fluorescently label cells for improved live imaging and cell tracking during L-R patterning and gastrulation. Thus, veiled chameleon is a powerful and tractable model genetic and cellular moder organisms for studying early reptile development and evolution.

## Effects of a thermal gradient on bowfin (Amia spp.) ultimate total length, L∞

*Amy Sibley, Michael Newbrey, Hugo Martín-Abad, Ashley Desensi*

There are no studies on the relationships between a thermal gradient and the age and growth characteristics of Amia spp. We wanted to know if longevity, size at age, maturity, and growth rate are correlated with a thermal gradient, but there are few studies detailing the age and growth of Amia species. Instead, we used state records (recorded "L∞") for length to determine if Amia are responding to a thermal gradient. There are two living bowfin species ranging from Quebec/Minnesota to Florida/Texas. We gathered data from 27 states with public records of the largest recorded bowfin in that state; and of those, 12 states included total length (TL). States records without TL did include weight data and to estimate TL for those states, we used the weight-length expression for bowfin. We used National Oceanic and Atmospheric data for three types of mean annual temperature data; 24-hour (MAT24°C), maximum (MATMax°C), and minimum (MATMin°C), for each state record location. The TL range was 711-980 mm and MAT24°C ranged from 4.8-22.8°C. Using least square regression, we found significant positive relationship between the length (mm) and each MAT24°C, MATMax°C, and MATMin°C. We suggest that bowfin will exhibit correlations between a thermal gradient and their age and growth characteristics. This research also answers a long-standing question in paleontology about why the largest bowfin are only found during ancient, hot climates.

## Bioinspired, modular, hybrid quadruped robot with multifunctional appendages for enhanced underwater

*Abu Nayem Md. Asraf Siddiquee, Yasemin Ozkan-Aydin*

Animals possess multifunctional appendages that serve purposes beyond locomotion, enabling them to perform various tasks to adapt to diverse environments [Yen, 2013]. Inspired by the aquatic walking animals, we developed a modular, multi-legged, soft-rigid bodied, pneumatic robot capable of navigation, manipulation, and transporting objects in underwater settings. We developed a soft appendage with a single actuation chamber that functions as a knee joint, allowing the lower portion of the appendage to bend backward when actuated. We conducted FEA simulations to analyze its bending behavior and generated forces to predict its performance in real-world. Using this appendage, we developed an Arduino-controlled quadruped robot capable of moving forward, backward, and steering left or right, and tested it underwater. Utilizing a lateral-sequence gait, the robot achieved forward movement at 8.39 mm/s and backward movement at 5.19 mm/s, with turning speeds of 0.85°/s to the left and 0.732°/s to the right. Adding the same two appendages as grippers, we further investigated the robot's grasping and transporting capabilities. The robot successfully grasped objects with varying rigidity ranging from eggs to plastic boxes, moving at 5.73 mm/s with an egg (75 g) and 5.19 mm/s with a box (125 g). The robot effectively showcased its maneuverability, object manipulation, and transportation capabilities in an aquatic setting, reinforcing its potential for underwater rescue missions and handling delicate marine creatures.

## Influence of sexual dimorphism on length-tension relationships of the masseter muscle in macaques

*Sacha Sides, Callum Ross, Peishu Li, Nicholas Gidmark*

Relative canine height, an important component of sexual dimorphism in catarrhine primates, is positively related to relative gape. One constraint on gape is masseter muscle fiber length, which affects the relationship between gape and masseter muscle force-generating capacity. In this study, we combined in situ muscle stimulation with XROMM visualization to quantify biting force across gapes in 4 male and 3 female macaques. We quantified isometric masseter force by stimulating the nerve to masseter bilaterally and measuring incisor bite forces across incremental gapes. We hypothesized that male macaques would reach maximum isometric tension at larger gapes than females, allowing males to generate bite force across a wider gape range. We found sex-independent inter-individual variation in masseter length-tension curves, and males did not reach optimum force generating capacity at larger gapes. However, males did exhibit wider gapes and higher bite forces, and they exhibited a larger range of forces across gapes than female conspecifics. Contrary to our hypothesis, wider gapes in males are accommodated by larger muscles and longer jaws, rather than changes in masseter gape-force relationships. In combination with studies in other primates, we argue that the primate jaw elevator muscles are more specialized for high force production during chewing at or near tooth occlusion, rather than at wide gapes during agonistic displays.

## Exploring olfactory development in ants through snRNA-seq

*Kayli Sieber*

Olfaction is the primary means by which ants communicate with one another and glean information from the world around them. Through pheromones and chemical signaling, they are able to work efficiently, maintain appropriate colony structure, and gather crucial information about their surrounding environment. Compared to most other insects, ants have evolved a massively expanded repertoire of odorant receptor genes, possibly aiding in their ability to discriminate more effectively between odorants and in their evolution of advanced eusociality. Despite the clear importance of olfactory sensation in ants, little is known about how the olfactory system develops and matures in these animals. Using single-nucleus RNA-sequencing of pupal antennae, we have explored olfactory development across pupation in the ant species Harpegnathos saltator. By investigating antennal cell populations and gene expression across pupal development, we aim to answer questions about how the ant olfactory system matures and lends itself to the evolutionary success of these animals.

## A computational model to predict muscle spindle firing during passive and active rhythmic movements

*Surabhi Simha, Timothy Cope, Lena Ting*

Muscle spindles are peripheral sensory organs embedded within skeletal muscles and equipped with independent neuromotor drive through gamma motor neurons. Both gamma motor activation and muscle spindle Ia sensory output can show task-dependent modulation. However, due to current technological limitations, we cannot empirically test why such modulation is needed or even how gamma motor activation affects Ia output. Recently, we developed a computational muscle spindle model that simulates muscle spindle Ia sensory output based on cross-bridge dynamics of intrafusal muscle fibers. We combined this model with an extrafusal skeletal muscle model to simulate Ia output during active movement. By modulating only the activations to this model according to literature, we reproduced Ia output observed during passive and active conditions. Using the same rhythmic muscle movements, we show how gamma modulation can result in a wide variety of Ia output. We highlight two behaviorally relevant activation patterns to demonstrate that contextual tuning of the gamma motor neurons for the same muscle kinematics can either result in an initial burst at stretch onset to maintain posture or keep the muscle spindle firing without any initial burst through stretch and shortening during locomotion. These differences in muscle spindle Ia output solely from differing gamma motor activations suggest that we cannot interpret muscle spindle sensory signals without understanding how gamma neuromotor drive sculpts the resulting information.

## The impacts of simultaneous stressors on North American bat cellular immunity

*Molly Simonis, Sarah Ciarrachi, Kristin Dyer, Meagan Allira, Dakota Van Parys, Kimberlee Whitmore, Matthew Chumchal, Catherine Haase, Jeffrey Foster, Daniel Becker*

Intrinsic and extrinsic stressors act simultaneously upon wildlife, impacting health. For example, wildlife undergoing stressful life stages such as reproduction can also be exposed to multiple contaminants and land-use changes in their environment. To better understand how multiple stressors simultaneously impact wildlife health, we initiated a multi-year study in summer 2023 using North American bats from Oklahoma, Arizona, and Tennessee. We collected blood and fur from six bat species to assess bat differential leukocyte counts, Bartonella spp. infection status, micronuclei intensity (representing genotoxic effects of pesticide exposure), and mercury concentrations. We also quantified land-use proportions at capture sites from species-specific home ranges. We fit generalized additive models to determine how bat immunity was influenced by interacting extrinsic (infection, mercury, micronuclei intensities, and land-use) and intrinsic (reproductive status) stressors. We found bats increase neutrophil-to-lymphocyte ratios with micronuclei intensities and reproduction. Additionally, lactating bats were only caught with elevated micronuclei intensities (a single extrinsic stressor). We hypothesize lactating bats may not be able to withstand many extrinsic stressors while at peak reproduction. This project continues to expand by incorporating more locations and extrinsic stressors to better understand how wildlife health varies across spatial gradients. This ongoing research is crucial for protecting wildlife populations and identifying where and when to allocate resources for conservation.

## Testing concentric circular plots using mark-recapture techniques in a coastal marine environment

*Megan Sims, Heather Mason, Emily Rose*

Concentric circular plots (CCPs) are widely used in terrestrial environments but underutilized in marine environments. We tested the feasibility of using CCPs coupled with mark resight and recapture designs within a Tampa Bay coastal marine seagrass bed. Two circular, 20-m diameter sites with four rings each were both sampled during an event to collect adult Gulf pipefish, Syngnathus scovelli, a flagship species for seagrass ecosystems. In August 2022, we conducted a mark resight experiment with 7 sampling events that collected 1,257 adult pipefish (802 marked) and registered 247 recaptures (193 distinct fish) with 2 fish traveling at least 178 m. The immigration-emigration mixed logit-normal Mark model couldn't converge due to its sensitive parameters. In February 2023, we conducted a standard mark-recapture with 6 sampling events that collected 187 adult pipefish (184 marked) and registered 6 recaptures (5 distinct fish). The POPAN Mark model estimated a superpopulation of 1,967 fish surrounding our sites and sampling effort impacted their probability of entry/exit into the area. Based on both models and recapture rates, we can infer Gulf pipefish change how they utilize their environment throughout the year – in August they resided around our sites and in February they were transient through our sites. Overall, our results indicate CCPs are feasible in coastal marine environments and can be coupled with marking techniques to elucidate movement patterns and habitat use.

## Domestication alters signals used by specialist pollinators to detect squash flowers (Cucurbita sp.)

*Avehi Singh, Andrew Myrick, Nathaniel McCartney, Kristen Brochu-De Luca, Swayamjit Ray, Jared Ali, Margarita Lopez-Uribe*

Domesticated crop plants are often profoundly different from wild relatives and these shifts in plant phenotypes may have large impacts on plant-insect interactions. Here, we investigate whether domestication affects floral volatile compounds and whether shifts in volatile profiles impact detection by pollinators. We focused our study on the genus Cucurbita, which contains all species of squash cultivated in North America along with their wild ancestors. Cucurbita plants are visited by both specialist squash bees Xenoglossa pruinosa and generalist bumble bees Bombus impatiens. We used headspace sampling to sample floral volatile blends from five domesticated and wild Cucurbita species. We then identified antennally active compounds within these blends for squash bees and honey bees using a combined gas chromatography-electroantennography setup. We used field trials to test behavioral valence of bees to individual compounds identified. We found that wild plants tended to have more complex volatile blends than domesticated plants and that bees responded to different compounds emitted from flowers of wild and domesticated plants. We found that flowers of all Cucurbita species tested except a basal wild squash produced 1-4-dimethoxybenzene, a compound that strongly influenced bee attraction. The compounds eliciting antennal responses in wild species were lost in the most derived domesticated species. We show that bees are able to respond to cues from both wild and domesticated plants, indicating potential shifts in their olfactory systems.

## Chronic stress results in greater pathology during MG infection in canaries

*Vansh Singhal, Erin Sauer, Kamiah Turner, Salvador Barraza-Del Barco, Sarah DuRant*

Chronic stress is related to a decline in immune function in all living organisms and is known to increase the likelihood of developing chronic non-infectious diseases. However, the role of chronic stress in affecting outcomes of infectious diseases important to individual health and endpoints important to epidemic dynamics are not well understood. In this study we exposed canaries to chronic stress or control conditions after which they were inoculated with Mycoplasma Gallisepticum, a bacterium causing respiratory disease in birds.

Following the chronic stress protocol, the canaries were assessed every day for measures of body condition (body mass and fat score) and disease pathology (eye swelling). Once a week, we also swabbed eye conjunctiva to measure pathogen load and collected blood samples to measure hematocrit. In this system greater eye swelling and higher pathogen loads are associated with greater likelihood of MG transmission.

Preliminary data demonstrate that birds exposed to chronic stress weighed more and had more fat but also had greater disease pathology than control birds. Soon, we will use qPCR to determine canary pathogen load. So far, our data indicates that chronic stress can prolong recovery and may be more likely to transmit MG given that transmission. These findings indicate that wildlife populations experiencing frequent or chronic stress may be more susceptible to disease and experience greater transmission rates than unstressed populations.

## Pollinator Response to Drought-Tolerant Landscape Perennials Under Water Restrictions

*Addison Singleton, Adam Mitchell, Heather Mathewson, Blake Liggett*

Declines in insect pollinators are documented across the globe; contributing factors to this loss include increased urbanization, intensive agriculture, and changes in climate, limiting floral resource availability or quality. Current climate models predict increased frequency and severity of drought events throughout the Southern Great Plains, particularly in North-Central Texas, where increasing urban populations will exacerbate water limitations in combination with drought. Drought-tolerant plants have been identified, yet attractiveness and suitability of these plants to insect pollinators under water deficits remains unknown. The purpose of our study is to determine pollinator response to water restrictions in drought-tolerant landscape perennials in North-Central Texas. We established 4, 8.5 × 14-m plots with 3, 2 × 14-m rows containing 20 perennial plant taxa (n = 20). In 2022, we irrigated plants using evapotranspiration rate and a plant factor (PF) of 0.6 for establishment. In 2023, we implemented 3 irrigation levels within each block: high, PF = 0.6; low, PF = 0.3; and no supplemental irrigation. We conducted weekly observations each year during florescence and recorded pollinator visitors during 60 second observations at each plant. Extreme drought conditions persisted both years for the duration of the growing season. Our findings will aid in identifying floral resources suitable for pollinator conservation where water is limited due to drought and other anthropogenic factors in the Southern Great Plains.

## Effect of Population Density on Epigenetic Aging and Life History in Medaka Fish (Oryzias latipes)

*Gabriela Siqueira Martins, Steven Gardner, Kristen Navara, Benjamin Parrott*

Biological aging in vertebrates is characterized by alterations to the epigenome, resulting in age-dependent changes in DNA methylation patterns ("epigenetic aging"). In humans, epigenetic age is a reliable indicator of biological age and typically correlates closely with chronological age, but adverse life events, such as stress, can cause a discordance between the two. Recent studies in fish indicate that they also undergo age-related changes in the DNA methylome, and exposure to adverse conditions, such as ionizing radiation, can disrupt epigenetic aging, leading to discordance between epigenetic and chronological age. We hypothesized that other environmental stressors, like high population densities, would disrupt epigenetic aging in similar ways. To test this, we exposed medaka fish (Oryzias latipes) to one of two rearing densities (low and high) and assessed DNA methylation patterns, aging markers, and life history traits at three life stages (3, 5, and 9 months old). We anticipated that high population density would accelerate epigenetic aging and shorten longevity. Our analysis suggests that high population density impacts epigenetic aging and life history traits, with effects that grow over time and differ between sexes. This sheds light on how environmental stressors may accelerate biological aging and alter life history trajectories and suggests that sex plays an important role in modulating these effects.

## Hormone-dependent modulation of acoustic communication system in fishes

*Joseph Sisneros*

Acoustic communication is prevalent among fish, the largest extant group of vertebrates, and is vital to the reproductive and social behaviors of many vocal teleost species. Recent research suggests that a fish's internal hormonal state can significantly influence its ability to produce and interpret social acoustic signals. Karen Maruska was renowned for her groundbreaking work in this area, investigating the neural and hormonal mechanisms that drive social behavior and sensory processing in fish. Her research has shed light on how sensory systems, including hearing, vision, and chemoreception, are influenced by the social environment and internal physiological states, particularly hormonal levels. Her research has provided significant insights into how these factors affect communication, reproduction, and aggression in fish, offering a deeper understanding of the neurobiological foundations of behavior in vertebrates. In this talk, the author will highlight the influence of Maruska's research on the ongoing investigations by the Sisneros lab, which shares a focus on understanding the neural and sensory mechanisms underlying communication and behavior in fish. The Sisneros lab investigates auditory neuroscience and behavior in fishes, with a particular emphasis on how fish detect, process, and respond to acoustic signals. Sisneros' research is centered on how hormonal changes, such as those linked to reproductive cycles, affect sensitivity and communication, particularly in the plainfin midshipman (Porichthys notatus).

## Comparative pulmonary anatomy of avian predators: air sacs in Red-tailed Hawks and Great Horned Owls

*Alexis Slack, Jaeger Johnson, Andrew Moore, Claire Zimmerman, Stephanie Baumgart, Aracely Martinez, Emma Schachner*

Both Red-tailed Hawks (Buteo jamaicensis) and Great Horned Owls (Bubo virginianus) are large North American predatory birds occupying the top space in their ecological niche. B. jamaicensis is a well-established soaring bird, while B. virginianus is not, and recent work has demonstrated that soaring flight plays a role in influencing lung morphology. Here we evaluate and compare the anatomy of the lower respiratory system of Buteo jamaicensis (n=4) and B. virginianus (n=3). With the exception of one hawk that was a live sedated clinical scan, the birds were intubated, inflated, microCT scanned, and checked for pulmonary decay. The respiratory tissues were then segmented into 3D digital anatomical models in the visualization program Avizo for analysis. The two taxa generally share a similar pulmonary bauplan; however, the owls have a relatively large caudal thoracic sac, whereas the hawks have a larger abdominal sac. Hawks have a large subpectoral diverticulum correlated with soaring, and a much larger subscapular diverticulum. In contrast, the owls have a much smaller axillary/subscapular diverticulum complex. The supracervical diverticulum is present in both species. A large pelvic diverticulum is present and pneumatizes the synsacra in both taxa, but is substantially larger in hawks. The femora are apneumatic in owls. These data demonstrate that there is considerable interspecific variation in the avian respiratory system which can inform functional hypotheses for the nonventilatory diverticula.

## The evaporation sensitivity of large-bodied North American mammalian herbivores

*Katherine Slenker, Jenny McGuire, Mark Clementz*

One of the most pressing threats to modern mammalian communities is increasing periods of aridity under climate change. Changes in water availability can affect community compositions based on species-specific responses to aridity. We track the influence of aridity on organisms via oxygen-18 isotope enrichment in body water and mineralized tissues. Different sources of ingested water generate different sensitivities to the effects of aridity on 18O-enrichment of tooth enamel. Mid- to high-latitude regions, such as North America, are also subject to seasonal variation in $\delta$18Oenamel values as a result of shifting precipitation regimes. Additionally, the magnitude of the isotopic signal incorporated into herbivore enamel can be confounded by species-specific physiologies that aid in body water conservation. We aim to scale modern North American large-bodied herbivores along the spectrum of evaporation sensitivity as a baseline for determining drought tolerance. We ground truth this analysis using a steady-state mass balance model of oxygen isotope fluxes in body water to differentiate the influence of physiological, dietary, and environmental factors on $\delta$18Oenamel values. Our preliminary results indicate that our model is effective at estimating mean $\delta$18Oenamel values in water-independent (pronghorn) and water-dependent (bison) taxa, as well accounting for seasonal fluctuations, given sufficient data on seasonal vegetation and water consumption and 18O-enrichment of environmental waters. Future analyses may utilize this model to determine the degree of influence exerted by individual factors.

## Capture and subsequent challenge disrupt the gut microbiome and health of a free-living songbird

*Morgan Slevin, Jennifer Houtz, Maren Vitousek, Rindy Anderson*

Wild animals experience many daily challenges to fitness. Because an animal's microbiome characteristics can be linked to its health, it is crucial we understand the effects of challenges on an animal's microbiota. We captured free-living Northern cardinals (Cardinalis cardinalis) to sample their gut microbiome, glucocorticoid response to stress, body condition index, and beak ornamentation, then recaptured and resampled individuals after ~11 days. Between captures, we administered one of two challenges to each cardinal: a temporary hold of an additional hour in a cage post-capture, repeated simulated territorial intrusions (STIs) via conspecific song playback, or no challenge (as a control). Challenge type had no effect on change in alpha diversity between sample timepoints, but it had a significant impact on microbiome dissimilarity. Temporary Hold birds' microbiomes showed the greatest differences between samples compared to those of Control birds, with STI birds showing an intermediate response. Overall, the birds that showed the largest beta diversity and greatest decrease in alpha diversity between samples experienced the greatest increase in CORT scope. We also detected relationships between beta diversity and change in both body condition and beak ornamentation, but these results were mixed among treatments. This is some of the first evidence of a proximate effect of a fitness challenge on the microbiome of an adult free-living songbird with concurrent data on shifts in glucocorticoids, body condition, and ornamentation.

## Patterns of raccoon cranial variation under domestication and urbanization

*Christina Sluka, Mark Clementz, Sarah Benson-Amram, Merav Ben-David*

With most urban growth in the United States occurring over the last 200 years, this novel habitat provides an opportunity to study how human influence affects evolutionary processes in wildlife. Raccoons (Procyon lotor) are well suited to assess these processes due to their abundance across multiple habitats. Here we investigate variation in raccoon cranial and mandibular morphology, across habitats, human densities, food availability, and time. We test multiple hypotheses related to domestication, cognition, and diet that were developed to explain cranial variations observed in other species across urbanization gradients. We sampled over 150 raccoon crania and pelts from museum collections representing urban, rural, and captive specimens from historical (1880-1920), mid-age (1920-1980), and modern (1980-2023) time periods. Linear measures and 3D models were used to assess variations in skull size and shape. Hair samples were used to assess the influence of diet via stable isotope diet analysis. Dental structures show evidence that raccoons consuming anthropogenic foods tend to have smaller carnassial blades and larger grinding surfaces, evidence of a decrease in carnivorous behaviors. The shape of the crania and mandible were variable across human density with urban animals presenting more gracile structures and smaller braincase volumes, suggestive of domestication-like pressures. These results demonstrate the flexibility of the raccoon cranium and the influence of direct and indirect anthropogenic pressures in a short period of evolutionary time.

## Influences of artificial selection and captivity on raccoon cranial morphology

*Christina Sluka, Mark Clementz, Sarah Benson-Amram, Merav Ben-David*

Artificial selection has long shaped the relationship between humans and animals through directed and accidental selection for visible traits. This “domestication syndrome” is a striking marker of the artificial selection for tameness across mammalian lineages. Similar trends have also appeared in wild species living in dense urban areas with high human activity, termed “self-domestication” (SD). This hypothesis describes how wildlife in urban spaces can exhibit domestication-like traits without direct human mediated selection. However, SD is not fully supported, and evidence is muddied by varied definitions of urbanization and diversity in behavioral ecology. To better understand the emergence of traits aligned with the domestication syndrome in a wild species, we investigated variations in cranial morphology across farm-bred, captive, and wild raccoons (Procyon lotor), a species with no close domesticated relative. We found notable differences including significantly wider braincases in wild raccoons, longer tooth rows relative to skull length in farm-bred raccoons, and a decrease in skull length relative to body size in the farm-bred raccoons. Additionally, wild caught raccoons demonstrated intermediary variations in morphometrics after a period of captivity suggesting a relationship between this confinement and morphology. While the driving mechanisms of these differences are complex, these results demonstrate that rapid morphological change occurs in raccoons in long-term selective breeding programs, under short-term captivity conditions, and is possible in wild raccoon populations over similar time periods.

## Resolving regulatory and coding sequence divergence in temperature-dependent sex determination

*Christopher Smaga, Samantha Bock, Josiah Johnson, John Wares, Thomas Rainwater, Randeep Singh, Vincent Deem, Andrew Letter, Arnold Brunell, Benjamin Parrott*

Developmental plasticity, the modification of phenotypes in response to the developmental environment, is known to vary across populations. Yet, our understanding of the evolutionary processes responsible for that variation remains limited. Temperature-dependent sex determination (TSD) is an example of plasticity where sex is determined by incubation temperature (Tinc), and recently the molecular mechanisms underlying TSD have become increasingly clear. Using TSD as a model, we compare coding sequence and hatchling gonadal gene expression variation within and across populations of the American alligator (Alligator mississippiensis) in response to Tinc to investigate the roles of neutral and non-neutral processes in shaping population-level molecular variation in plasticity. First, we assess if genes responding to incubation temperature evolve differently relative to background genes through either primarily neutral or non-neutral processes. We then compare variation within the hierarchy of gene expression dynamics arising from TSD to determine if environmental sensitivity genes (those responding solely to temperature cues) differ in patterns of variation relative to sexual differentiation genes (those sensitive to sex steroids). Finally, to determine potential targets for the adaptive evolution of TSD, we identify candidate genes showing signatures of selection. Our results not only add to limited empirical data on the evolutionary processes acting on the molecular mechanisms of developmental plasticity but provide critical information on the evolutionary potential of TSD.

## A Quest for Biological Accuracy and Design Utility in Biomimicry Frameworks: a quantitative study

*Dimitri Smirnoff, Anita Schuchardt, Mary Guzowski, William Weber, Jessica Rossi-Mastracci, Alan Love, Ruth Shaw, Mike Travisano, Mark Borrello, Gillian Roehrig, Emilie Snell-Rood*

The natural world is increasingly seen as a source of inspiration for solutions to socio-environmental challenges, a practice known as bioinspiration or biomimicry. Yet, practitioners without a background in biology can struggle to tap into the wealth of biological knowledge. To address the difficulty, frameworks distilling biology into accessible statements have been developed to educate and inspire professionals and students. However, these statements' biological accuracy and design utility have not been systematically assessed. Our study surveyed people of different professional backgrounds and career stages to assess their perception of the biological accuracy and problem-solving utility of two different frameworks used in bio-inspired design, Life's Principles and Nature's Unifying Patterns. Differences in perceptions emerged between biologists and non-biologists, and between biology professionals and biology undergraduates. Notably, non-biologists rated statements as more accurate than biology professionals, suggesting current frameworks may foster biological misconceptions. Simultaneously, specific statements were rated as more useful for inspiring designs by non-biologists. This study forms a foundation for exploring factors that enhance statement biological accuracy and relevance in bioinspired design. Ultimately, our work contributes to accessible biology education for practitioners of bioinspiration and as well as students from various grade levels.

## Fluid dynamics and feeding performance in infant mammals: evaluating the impact of nipple design

*Ani Smith, Maressa Kennedy, Thomas Stroud, Emily Volpe, Dylan Anderson, Harlow Smith, Skyler Wallace, Hannah Shideler, Shanique Yazzie, Holly Sabato, Elska Kaczmarek, Christopher Mayerl*

Milk flow during infant feeding is a primary factor in determining performance. Flow rate is affected by several factors, including milk properties, nipple design, and suction generation by the infant. However, experimentally measuring milk flow is challenging, as milk can only be visualized in two dimensions using videofluoroscopy, even though it is three-dimensional. A bottle nipple with branching ducts has previously been demonstrated to improve infant feeding outcomes, but is technically challenging to manufacture and maintain. We designed two ducted bottle nipples with similar properties and flow rates but with different branching patterns: a nipple with multi-level branching ducts and a nipple with a singular central channel. We experimentally calculated milk flow using a venturi valve while synchronously recording high-speed biplanar videofluoroscopy and intraoral pressure generation in infant pigs with and without feeding difficulties. We found no differences in pressure generation, tongue kinematics, or swallow bolus size between the two nipple types, and we found that milk volume per suck could be experimentally calculated using the venturi valve with increased pressures reflecting increased volume acquired per suck. Pigs without feeding difficulties achieved higher milk flow rates. Single and branched ducted nipples similarly improve feeding performance and the use of a venturi valve in bottle feeding can provide insight into the relationships between tongue kinematics, suction generation, and milk flow across various levels of feeding performance.

## Impact of Nipple Design on Feeding Biomechanics in Term and Preterm Piglets

*Harlow Smith, Elska Kaczmarek, Ani Smith, Maressa Kennedy, Skyler Wallace, Hannah Shideler, Emily Volpe, Dylan Anderson, Holly Sabato, Shanique Yazzie, Thomas Stroud, Christopher Mayerl*

Disruptions to development are known to impair critical physiological functions in vertebrates. In infant mammals, premature birth is known to compromise feeding performance, especially in establishing breastfeeding. Instead, these infants must often be fed with bottles, which use hollow nipples, unlike the ducted structure of breast tissue. Here we investigate the performance of term and preterm infants while feeding on a standard, hollow bottle nipple and on a biomimetic, ducted bottle nipple, as a proxy for breastfeeding. We raised one full-term litter and one preterm litter of pigs, and raised half of each litter on each nipple type. At 7 days of age, we evaluated feeding kinematics on both nipple types using high-speed biplanar videofluoroscopy. When feeding on a cisternic nipple, preterm infants compressed the nipple more to express milk and generated less suction than term infants. In contrast, term infants had greater posterior tongue movements than preterm infants which is likely a reflection of larger swallow volumes. These data suggest that gestational age at birth impacts tongue function during feeding. Most strikingly, the reliance on expression to acquire milk in premature infants points to a developmental disparity in oromotor functioning. Future research should examine mechanisms driving these differences in order to develop interventions to improve the suction-generating capacities of premature infants.

## DNA barcoding of Wood Ants (Hymenoptera, Formicidae) from a Tropical Area in Nigeria

*Kennedy Smith, Abubakar Adeoye, Segun Oladipo, Lotanna Nneji*

Molecular tools, particularly DNA barcoding, are increasingly used to identify species and overcome taxonomic impediments. However, few studies have used this approach to characterize Nigerian terrestrial insects, especially the eusocial ants. With the aim of expanding the knowledge base of ant species in Nigeria, we evaluated, for the first time, the use of mitochondrial Cytochrome C Oxidase Subunit I (COI) barcodes to identify ant samples collected from a tropical area in southwestern Nigeria. Different molecular analyses, including BLAST search in global databases (NCBI and BOLD), genetic distance-based evaluation and species delimitation tests, were used to accurately identify and delineate species. Our molecular analyses helped to delimit ant species based on COI sequences, and their results corresponded well with most of the morphospecies. This study provides information about the usefulness of DNA barcoding for ant studies in Nigeria. Our study forms the first step toward the compilation of a DNA barcode reference library for future ant barcoding work.

## The effects of competition on individual foraging patterns and within nest behavior across bumble be

*Matthew Smith, Julia Wiessing, August Easton-Calabria, Madalyn Laskowski, Brett Graham, James Crall*

Within bumblebee colonies, inter-colony competition for floral resources can be a significant ecological stressor leading to a negative impact on fitness. The link between an individual bee's competitive interaction while foraging and individual behavior in the nest remains unknown, largely due to the technical challenges of long term individual tracking across multiple settings. Using such a framework we can begin to answer what axes of behavior (across individual and collective scales) are modified in response to competition, and across what timescales. Here we present our work towards a better understanding of the effects of foraging competition on individual behavior, plant-pollinator interactions, and collective colony responses. In the following study we use hoop houses as contained foraging chambers in which we placed custom bee boxes outfitted with overhead cameras for continuous behavior tracking and tagged bees for maintaining individual identity across long time scales and settings. The 5 $\times$ 30m foraging chamber contains 90 cameras continuously monitoring flowers to track individual foraging behavior and flower interactions. The experiment begins with a single colony, after 3 days of baseline activity, a new colony will be introduced to the space for another 4 days. Through comparing individual foraging patterns and within nest behavior before and during competition we hope to better understand the behavior responses across different settings, timescales, and individuals and collectively.

## Trabecular bone confers different functional advantages across small mammals

*Stephanie Smith, Kenneth Angielczyk, Tristan Stayton*

The relative contributions of trabecular (spongy) and cortical (compact) bone to bone strength and stiffness are poorly understood across mammalian body size. In mammals, some small species have notably reduced their vertebral trabecular bone structure, resulting in mostly hollow medullary cavities. To assess the importance of trabecular structure to the mechanical properties of small mammalian vertebrae, we conducted finite element analysis on the lumbar vertebrae of 25 species of shrews (Soricidae) weighing 2-100g. We analyzed two sets of models: vertebrae with the trabecular structure intact (full), and vertebrae with all trabeculae excised from the centrum (hollow). All models were scaled to the same ratio of load to surface area. The cranial end of the centrum was immobilized, and a 5N craniocaudally-oriented load was applied to the caudal end of the centrum. We measured mean von Mises stress (MVMS) to capture strength, and total strain energy to capture stiffness. MVMS and total strain energy both decrease as body size increases, and hollow models experience higher stresses and strains than full models. With increasing body size, the difference in total strain energy between full and hollow models decreases, but the difference in MVMS slightly increases. This suggests a difference in the functional advantage conferred by trabeculae among small mammals, as well as a possible selective pressure for different functional emphasis in very small and larger mammalian bones.

## Optimizing the workspace: Internal nasal anatomy in roundleaf bats

*Tim Smith, Vaibhav Chhaya, Nicholas King, Abigail Curtis, Thomas Eiting, Sharlene Santana*

Among bats, nasal echolocation is a novel sensory mode hypothesized to have led to simplified olfactory anatomy, perhaps due to trade-offs among olfaction, respiration, and sound transmission. However, few studies have mapped the distribution of nasal mucosa types in nasophonating bats. To address this gap, we examined the nasal cavity in three species of roundleaf bats (Hipposideridae) using histology and iodine-enhanced microCT. In all specimens, olfactory mucosa (OM) is mainly observed on ethmoturbinals in the caudal half of the nasal fossa. The rostral half of the nasal fossa is mostly lined with highly vascular respiratory mucosa and is devoid of any turbinals. A previously undescribed structure,–a large venous sinus mass (VSM) separating olfactory and nonolfactory regions– would restrict airflow medially in a blood-filled state. The caudal three ethmoturbinals are maximally covered by OM within the olfactory recess; 92% of the recess is lined by OM in Hipposideros larvatus. Two specializations of turbinals are observed. First, the most rostral turbinals (ethmoturbinal I, semicircular lamina, and maxilloturbinal) anchor the VSM. Second, a supernumerary ethmoturbinal is found, which appears to be an enlarged version of a small turbinal that normally nests hidden between other turbinals. Our results demonstrate extreme compartmentalization of functional nasal regions, with turbinals restricted to olfactory function and sinus support, whereas the rostral region becomes a barren foyer that may amplify nasophonation.

## Graph theory tests the impact of metapopulation structure on population genetic diversity

*Anthony Snead, Andrey Tatarenkov, D Taylor, Kristine Marson, Ryan Earley*

Genetic drift and patterns of gene flow affect population genetic diversity. The strength of genetic drift increases as population size decreases leading management activities that have focused on increasing population size through preserving contiguous habitats. However, empirically evaluating the impact of drift and gene flow on genetic diversity is uncommon. Kryptolebias marmoratus, henceforth ‘rivulus’, is a small mangrove killifish with gene flow primarily associated with asymmetric ocean currents. Rivulus form distinct populations across mangrove patches, making them a well-suited system to test the extent to which habitat area, fragmentation and connectivity are associated with genetic diversity. Using genetic data from over 1000 individuals across the range, high-resolution landcover data and biophysical oceanographic simulations with graph theory, we demonstrate that connectivity to the metapopulation is more strongly associated with genetic diversity than habitat area or fragmentation. By comparing models with and without connectivity standardized by the source population’s genetic diversity, our results suggest that metapopulation centrality is critical to genetic diversity regardless of the diversity of adjacent populations. While we find evidence that habitat area and fragmentation are impacting genetic diversity, centrality is always a significant predictor with a larger effect than any measure of habitat configuration.

## The antimicrobial properties of essential oil phytoncides

*Tara Snyder, Alexander Rech, Caleb Hatton, Lily Caramagna, Brenden Garcia, Grace Baladi, Naya Batraki, Jose Romero*

This study aimed to investigate the effect of varying plant essential oils on the growth of Escherichia coli and Staphylococcus aureus bacteria. Our plant species of study were Citrus sinensis (sweet orange), Citrus lemon (lemon), Lavandula angustifolia (common lavender), Citrus paradisi (grapefruit),Cinnamomum verum (cinnamon), Chamaemelum nobile (chamomile), Cedrus atlantica (Atlas cedar), Rosmarinus officinalis (rosemary), Mentha piperita (peppermint), Melaleuca alternifolia (tea tree), Eucalyptus globulus (eucalyptus) and Juniperus virginiana (eastern red cedar). A Kirby-Bauer Assay was employed, and either Staphylococcus aureus or Escherichia coli were cultured on Trypticase Soy Agar (TSA). We positioned sterile discs coated with the essential oil into a quadrant of the TSA plate inoculated with either S. aureus or E. coli. After incubation at 37C for 24-26 hours, the size of the zone of inhibition surrounding the essential-oil coated disk was measured. We found essential oils are more effective against S. aureus than E. coli ($p<0.0001$), Eucalyptus globulus had the highest rate of effectiveness ($p<0.0001$) against E. coli and S. aureus, and similar sized zone of inhibitions formed on agar plates containing E. coli and S. aureus ($p = 0.1040$). Cinnamomum verum could have skewed these results since certain trials were unmeasurable due to no bacterial growth (and no assessable zone of inhibition). This information can be utilized for future applications promoting human health and the creation of antimicrobial preservatives on fruits and vegetables.

## Sink or Swim? Size-mediated buoyancy regulation in a fish without a swim bladder (Agonopsis vulsa)

*Jacob Sobol, Yohan Sequeira, Olivia Hawkins, Charbel El Khoury, Spencer Truman, Cassandra Donatelli, Meg Vandenberg*

Buoyancy regulation is essential to animals living in an aquatic environment. Many fishes use gaseous swim bladders to regulate buoyancy, sharks use their oily livers, and deep-sea fishes reduce skeletal density. The family Agonidae (poachers) lacks a swim bladder and are negatively buoyant, but juvenile Agonopsis vulsa can forage near the surface, likely using multiple methods to maintain position. One hypothesis is behavioral, where they create an S-shaped curve with their body, potentially increasing drag. Another hypothesis is morphological; compared to adults, juvenile poachers are more rugose, likely influencing passive hydrodynamics. We investigated both hypotheses. First, we quantified how rugosity affects drag by measuring the hydrodynamic forces on 3D-printed small, medium, and large A. vulsa scaled to the same total length. The “small”, more rugose model had the highest drag compared to the “medium” and “large” lower rugosity models. To see how creating an S-shape influences buoyancy control, we measured the sinking speeds of 12 individuals (1.6-20.5 cm TL) alive, after euthanization, and fixed in a S-shaped curve. Live juvenile A. vulsa sank slower than both dead juvenile treatments as well as adults due to increasing curvature and pectoral fin stabilization. Our results suggest that as A.vulsa age, changes in armor morphology and behavior interact to enhance buoyancy control, increasing our understanding of their life history transitions and ecological adaptations.

## Does water loss or hemolymph pumping explain mass loss during wing development in cicadas?

*Jake Socha, Alan Mach, Trevor Bryan II, Joshua Taylor*

For some insects, wing development occurs rapidly during the transformation to the adult stage, as small, folded wing pads expand to full size via circulation of hemolymph. In a previous study of cicadas, we found that, within approximately two hours, wing mass increased by a factor of 3 to full expansion, and then decreased afterward by a similar amount. This observation suggests that the hemolymph was pumped in to effectuate expansion, and then pumped out after expansion was complete. However, because developing wings are composed of thin, unsceloritized cuticle, it is unclear if transcuticular water loss played a major role in the observed mass loss after full expansion. To address this question, we conducted a mass-loss experiment on isolated wings (Magicicada septendecim), and in separate trials, observed wing viens in live cicadas using microscopy. Pairs of forewings were dissected from cicadas at three time points during wing expansion, and wings were weighed every five minutes for 1 hour. Mass data show that transcuticular water loss represented only a small fraction of the total mass loss exhibited by the wings post-expansion. Follow-up recordings of live cicada wings suggest that a tracheal tube within the vein expands during the process, allowing air to partially replace the volume of expelled hemolymph. Overall, these results support the hypothesis that wing expansion is a hydraulically-actuated process in cicadas.

## Assessing the relationship between cranial covariation and ecological specialization in Geomyoidea

*Francesca Socki, David Fox*

Geomyoidea (Order: Rodentia) is an ideal group for accessing the impact of cranial covariation on ecological specialization, given across its extant and extinct families there are cranial adaptations for fossorial, subfossorial, and ricochetal ecologies, many emerging early on in their diversification. Integration and modularity are hypotheses that can explain specializations of the cranium, where changes in covariation strength can cause the facilitation or constraint of morphological innovations. Our previous findings revealed that across its extant families, Geomorpha has a three-module pattern separating the rostrum, cranial vault, and occiput, and covariation strength within and between these regions differs across families. Here, we further explored the relationship between covariation and fossorial specialization by testing the degree to which integration across modules reflects morphology indicative of procumbency, an ecometric associated with chisel-tooth digging. Results reveal that morphology associated with greater procumbency (arching of rostrum, ventral extension of the maxillary region) aligns with shape changes related to covariation between the rostrum and cranial vault, while the covariation of either of these regions to the occiput does not appear to be associated with procumbency. Future work will compare covariation patterns to ecometrics associated with ricochetal locomotion. Lastly, we see our findings as a potential way to explore integration and modularity in the fossil record, where ecometrics of isolated parts of the cranium could act as proxies for patterns of covariations.

## The Euclidean process distance and its applications to the study of ecological communities

*Kenneth Soda*

Vector stochastic processes are mathematical models of how the states of a temporally dynamic system, such as population sizes, hormone levels, or nutrient concentrations in an ecosystem, change through time. Such processes are often represented using vector time series models, which predict the current or future value of two or more variables using the variables' previous values and/or the current or previous values of exogenous variables. Vector autoregressive (VAR) processes and models are among the simplest vector processes and time series models, as they only incorporate endogenous variables.

Here, I introduce a distance metric, the Euclidean process distance, to measure the difference between two stationary VAR processes. The Euclidean process distance represents the greatest expected Euclidean distance between two VAR processes' current states given that the Euclidean distance between the processes' previous states and their respective average states was one. I also discuss Monte Carlo techniques for establishing confidence intervals on these distances and provide simulation-based validation for these procedures.

Finally, I discuss how the Euclidean process distance may be extended to multivariate autoregressive models, which do incorporate exogenous variables. Over the past few decades, multivariate autoregressive models that use population sizes as endogenous variables and environmental variables as exogenous variables have grown increasingly popular to estimate community matrices in population ecology. The utility of the Euclidean process distance in an ecological context is discussed.

## Mechanosensors in the bluegill dorsal fin encode fin ray displacement

*Amanda Solano, Zulay Izazaga, Eric Tytell, Margot Schwalbe, Anabela Maia*

To navigate complex environments, fish rely on various sensory modalities to maintain stability. Although fish use the lateral line system to detect flow, even when this system is impaired, fish are still able to navigate complex flows. Fish have other mechanosensors, namely in the fins, but their functional role is poorly understood. It is possible that they provide additional navigation cues, but it remains unclear what stimuli these sensory structures detect. We have localized sensory structures to the soft and spiny dorsal fin rays and we hypothesize that these afferent neurons are responding to fin displacement caused by flow. By manipulating one fin ray on the dorsal fin at a time, we are able to characterize the sensitivity of these neurons. Afferent activity was recorded in dorsal fin preparations of bluegill, Lepomis macrochirus, using a suction electrode to measure activity in response to individual fin ray manipulations of varying direction (cranial and lateral) and magnitude. When we manipulated the spiny rays, low bending intensity caused a fast-adapting response, while high bending elicited slow-adapting response. The location of the spiny dorsal fin, which is mostly free from body deflections, makes it an ideal place to collect flow information through the presence of abundant mechanoreceptors. These sensory structures are likely working in tandem with the lateral line and vision systems to provide smooth mechanosensory integration.

## Comparing porefield density and distribution in male and female bonnethead sharks, *Sphyrna tiburo*

*Grace Solevilla-Moreno, Sonia Ali, Ingrid Reyes Patron, Kathy Liu, Lauren Simonitis, Callie Crawford*

Hammerhead shark species (family Sphyrnidae) are known to have a cephalofoil with specialized sensory organs called ampullae of Lorenzini. One of the smallest of this family is the bonnethead shark (Sphyrna tiburo) which presents a round, scoop-like cephalofoil unlike the exaggerated head shape we see in other members of the family. Bonnethead sharks are sexually dimorphic in their head shape where males display a distinct anterior point while females exhibit a more rounded cephalofoil. Previous research has established porefield-mapped head regions where ampullae are present. This research aims to determine if the porefields also differ significantly between male and female bonnetheads. Specimens were obtained in Tampa Bay, Biscayne Bay, and Long Key Bight (FL, USA). Along with body length measurements, ventral and dorsal photos were taken of each shark on a standardized grid board. We used ImageJ to obtain specific head morphology measurements as well as porefield morphometrics and counts for comparisons between male and female bonnetheads. We expect to observe differences in porefield density and distribution between males and females following previous findings of variation in head morphology. In our next steps, we aim to explore porefield sexual dimorphism in other shark species.

## Developing dominance: neural mechanisms across life history stages in a highly social cichlid fish

*Tessa Solomon-Lane, Isaac Miller-Crews, Jessica Maurice, Isabela Harmon, Margaret Mattson, Cristi Cruz, Findley Finseth*

Social status is an integrated phenotype that emerges as relationships establish. The mechanisms underlying status are studied almost exclusively in adults, in part, because a hallmark of dominance is reproductive advantage. Yet, juveniles of many species form stable status relationships. Using the highly social cichlid fish, Astatotilapia burtoni, a model system in social neuroscience, we directly compared mechanisms (whole brain transcriptome, hormones, behavior) of status in pairs of juveniles vs. adult males (with 2 females for reproductive context) during status establishment (1-day together) and while stable (7-days together). Juveniles and adults formed clear status relationships that strengthened over time, but behavior differed in nuanced ways across developmental stages. At the endocrine level, juvenile dominants showed elevated cortisol after a week, while testosterone was elevated in adult males, and higher in only adult dominants, but not juveniles. At the neural transcriptomic level, there was a striking degree of concordance between 1-day and 1-week across developmental stages. Development explained the most variation in gene expression. While status was reflected categorically for juveniles in neural transcriptome, status for adults was reflected in gene-by-behavior associations. These results suggest certain status-dependent mechanisms are already present in early life, while others shift over development. Given the important effects of status on fitness and health, the mechanisms regulating status across life history stages should be important targets for natural selection.

## The effects of accelerated growth on the vascular histology of hind limbs in Meleagris gallopavo

*Riley Sombathy, Patrick O'Connor, Kristin Stover*

Growth rate is often reported as a primary factor influencing vascular canal organization during bone deposition in tetrapod limbs. However, most tests of this relationship are limited to comparisons among multiple extant taxa with different, or even unknown, growth rates. We have developed a controlled system using the domesticated turkey (Meleagris gallopavo) to simulate how an evolutionary increase in growth rate influences bone histology. We sampled major hind limb bones in an ontogenetic series of turkey from an accelerated growth lineage to characterize age-specific histological organization in cortical bone. Our results indicate that this lineage exhibits dense reticular and radial canals in the cortex of both femur and tibiotarsus up to the tenth week. Differences in canal organization between femora and tibiotarsi appear by week fifteen, with the outer cortex of the femur becoming laminar with reticular canals in the deep cortex. By week nineteen, femoral cortex consists of solely laminar canals, with radial canals present only at the transition between the anterior and medial portions of the cortex. Tibiotarsal histology remains consistent throughout ontogeny. Our results indicate that growth rate is not the sole driver of vascular orientation, as both hind limb elements exhibit divergent vascular canal organization despite their shared growth rates. As such, other factors must be considered when drawing inferences from bone histology for inferring organismal life history traits.

## Energetics, Sexual Selection and Ecological Innovation

*Ummat Somjee*

Sexual selection drives the evolution of a broad diversity of traits from the enlarged claws of fiddler crabs that can account for 50% of body mass, the high-energy behavioral displays of hummingbirds, the wing 'snapping' displays of manakins to the calling of frogs. A majority of work in sexual selection has aimed to measure the magnitude of these signals. Yet, we know little about how different organisms use energy to fuel their sexually selected behaviors. The energetic properties of these sexual signals are ultimately fueled by metabolic machinery at multiple scales; from mitochondrial properties and enzymatic activity to the modification of muscular and neural tissues. However, different organisms have different underlying physiology and face different ecological selection pressures, and thus often have adaptations at multiple scales that shape sexually selected traits and behavior. These physiological adaptations that shape sexual traits likely feed back into life-history functions, and may lay a foundation for ecological innovation. We synthesize research areas across scales and across non-model organismal systems and to deepen our understanding of the links among sexual selection, metabolism and ecological innovation.

## Evolution of sexual dimorphism and morphological diversity in moth antennae

*Yash Sondhi, Ummat Somjee*

Moths commonly have large elaborate antennae, often more elaborate in males which can help them find females over long distances through pheromones, surprisingly however many species have plumose and feathery antennae in females as well, and specialist moths can detect host plant odors with their antennae. Moth antennae thus serve both a mate detection function (in males) and an ecological host detection function in both males and females, yet we don't know if sexual selection or ecological selection is the primary driver of antennae elaboration. We use digitized databases of specimens and examine a broad range of taxa to test the hypothesis that sexual selection on males drives the elaboration of antennae across different moth families. By mapping variation in antennae elaboration across males and females and using ancestral state reconstruction, we examine the potential linkage between sexual dimorphism, phylogenetic constraints and host-plant specificity. If sexual dimorphism in elaborate antennae precedes the evolution in elaboration in both sexes this would be consistent with sexual selection as a driver functional trait elaboration. Alternatively, both sexual and ecological selection may play active roles in driving antenna elaboration in moths.

## Immortal organisms: The evolution of natural history specimen collections

*Meaghan Sorce*

Natural history museum specimen collections have long served as a tangible snapshot of biodiversity, representing deep time to present-day. They exist as a repository of preserved organisms, to be categorized and studied. Accessibility was once limited to just a handful of scholars and their students, typically working in taxonomy, anatomy, and systematics. With advancements in technology and expanded potential uses for specimens, collections have evolved far beyond anything that could have been imagined upon their inception. Uses of these collections are virtually limitless. Specimens and data can be invaluable in tracking human ecological impacts such as climate change, habitat destruction, pollution, and the introduction of invasive species. Collections are frequented by a whole range of individuals working inside and outside the scope of academia, including researchers, students, bioroboticists, artists, historians, anthropologists, novelists, and documentary film makers, just to name a few. Digitization and data aggregators have made it so anyone with internet access can search holdings and all associated information pertaining to each specimen, from anywhere in the world. Digital archives and collection workers have made it easier than ever to do research without ever needing to step foot in a museum. Institutional database records can include links to media, such as radiographs, high resolution photos, 3D scans and models, as well as relevant citations, genetic information, and more. Preservation and constant care make it possible for deceased animals to live forever.

## Ecological functions and metabolic consequences of distributed vision in chitons

*Daniel Speiser, Adriana Halvonik-Sanchez, Madison Janakis, Alexandra Kingston, Daniel Chappell*

Animals with distributed visual systems have many separate eyes dispersed across their bodies. In some cases, these animals demonstrate spatial vision despite having eyes with overlapping fields of view and construct coherent neural representations of their visual environments despite having relatively decentralized nervous systems. Chitons (Mollusca; Polyplacophora), for example, have hundreds of small eyes in their dorsal shell plates and demonstrate spatial vision in behavioral trials. We have shown that chitons process visual information in complex ways: in Acanthopleura granulata, optic nerves innervate a body-circling ring of neuropil with overlapping arborizations to form a decentralized visuotopic map. These findings prompt questions about the ecological functions of vision in chitons. By recording light-evoked electrophysiological responses from the lateral neuropil, we found the distributed visual system of A. granulata is relatively fast-sampling, with a maximum temporal sampling rate $\sim$ 35 Hz, and colorblind, with a single spectral response peak at $\sim$480 nm. These findings are consistent with A. granulata using vision to spot predators approaching from overhead. A high temporal sampling rate indicates vision is metabolically expensive for A. granulata, but measurements of heart rate and oxygen consumption under changing light conditions suggest otherwise. We propose chitons minimize the cost of distributed vision by only encoding light-potentiated off-responses and by minimizing neural path lengths by extracting visual information locally to inform behaviors rather than processing visual information centrally.

## Implications of tetrapod trackways of the Albert Formation for the locomotion of early tetrapods

*Eleanor Spence, Matthew Stimson, Tetsuto Miyashita, Hillary Maddin, Emily Standen, Danielle Fraser*

'Romer's Gap', is an interval of geological time in the early Mississippian Period (Tournaisian stage; 350 ma) and has a sparse terrestrial fossil record. 'Romer's Gap' is thought to be when tetrapods transitioned from aquatic to terrestrial environments. Terrestrial fossils (footprints and skeletons) from this interval are only known from three localities world-wide, including the Albert Formation (lacustrine paleoenvironment) in New Brunswick, Canada. The Albert Formation has recently yielded the earliest known tetrapod trackways in 'Romer's Gap' including over 50 tetrapod trackways on a single surface.

Fossil footprints provide an alternative source of information to body fossils, allowing for the study of the behaviour and methods of locomotion of extinct animals. I will compare the anatomy and locomotion methods of early tetrapods to proposed extant tetrapods to determine the validity of these animals as analogs for Tournaisian-aged tetrapods. Extant tetrapod trackways will be registered in a saturated mud substrate and then analyzed according to standard ichnological methods of measurement and utilizing photogrammetry 3D modelling. The results will be compared to the same measurements taken of select fossil trackways from the Albert Formation to ascertain the diversity of locomotion methods present at the onset of the Carboniferous Period. By working at the intersection of biomechanics and paleontology I will be able to gain a more robust understanding of Tournaisian-aged tetrapod locomotion and diversity during 'Romer's Gap'.

## Environmental influences on protein turnover in black sea bass (*Centropristis striata*)

*Adele Spencer, Julie Neurohr, Kara Yopak, Stephen Kinsey*

Physical activity and a healthy diet enhance the protein clearance machinery in organs of aged mammals, and they are the only known interventions that stop or slow the progression of age-related brain diseases such as Alzheimer's disease. However, the effect of activity, diet, and other environmental factors on protein turnover in non-model organisms is less well understood. The present study investigated the role environment plays in expression of markers of protein turnover in a marine teleost, the black sea bass (Centropristis striata). We compared protein turnover markers in wild-caught black sea bass to those raised from eggs in an aquaculture setting. While wild-caught animals must forage, avoid predators, and navigate a complex environment, the aquaculture-raised fish face none of these challenges and live in a comparatively simple environment. We measured expression of proteins associated with the Ubiquitin Proteasome System (UPS) and the Autophagy Lysosomal System (ALS) in skeletal muscle, liver, heart, and brain. These measurements indicated that protein turnover was higher in wild-caught fish compared to aquaculture-raised fish. This work suggests that living in a more complex and challenging environment may carry additional costs associated with protein turnover, and maintenance of the proteome may therefore have important ecological ramifications.

## Sense and scent stability in agricultural crops: assessing honeybee responses to air pollutants

*Jordanna Sprayberry, James Blande, Ben Langford, James Ryalls, Robbie Girling*

Honeybees contribute more than an estimated US$ 10 billion annually through pollination services. These pollinators operate in polluted environments that could impact behavior via modulation of sensory stimuli and processing. Air pollutants interact with floral odorants, modifying their scent composition. Behavioral experiments with honeybees indicate that scent-modification can disrupt odor-recognition if changes are 'big enough'. Previous work with bumblebees, another important hymenopteran pollinator, introduced the "Compounds Without Borders" (CWB) odor geometry to quantify changes in scent structure. This study examines the applicability of CWB quantification to understanding the effects of air pollution on honeybee behavior. We found that modifying CWB odor comparisons to account for loss of molecular features from odor blends indicates a threshold of behavioral disruption at 12-15 degrees of pollution-induced degradation. We then modeled ozone and OH radical driven scent degradation of four agriculturally-important crops that produce oil (Brassica napus), seed (Sinapis alba), berry (strawberry, Fragaria x ananassa cultivar), and tree fruit (apple, Malus domestica). We found variable susceptibility to pollution degradation, with B. napus odor showing the most rapid shift to an odor-angle that is over the threshold of disruption for honeybees. S. alba and Fragaria follow closely, while M. domestica showed strong scent stability. This indicates that the impacts of air pollution on agricultural yields will not be uniform, with Brassica crops being more susceptible to disruption of honeybee-pollination.

## Non-consumptive effects of spiny lobsters on corallivores and implications for corals

*Cheyne Springbett*

Coral reefs in the Florida Keys are facing degradation resulting from climate change, anthropogenic pressure, and frequent disturbances from bleaching events and hurricanes. Coral resilience and restoration is essential for the long-term health of these reefs that support such a great diversity of marine life. However, coral restoration is costly, time?consuming, and labor-intensive. Unfortunately, these outplanted colonies can be sabotaged by predation from naturally occurring corallivores, such as snails and fireworms. Although spiny lobsters can eat these invertebrate corallivores, it is not known to what degree they control them through direct predation. This study investigated whether the presence alone of spiny lobsters on coral reefs may result in non-consumptive effects on these invertebrate corallivores. Using chemical choice assays, we examined the responses of corallivorous snails (Coralliophila galea) to seawater containing the chemical cues – urine – from the Caribbean spiny lobster (Panulirus argus) or the Spotted spiny lobster (Panulirus guttatus). Our results indicate that the presence of certain lobster species on reefs may be beneficial to corals as a chemical repellent of corallivores. This promotes a strategy for coral restoration to target sites with high densities of lobsters, as these nonconsumptive effects should benefit coral health by deterring corallivory

## A new dinosaur from Ghost Ranch expands end-Triassic dinosaur diversity in equatorial Pangea

*Simba Srivastava, Sterling Nesbitt*

Comparing and contrasting the dispersal of the first predatory and herbivorous dinosaurs in the Late Triassic has led to insights into their early ecology and evolution. How these patterns further distinguish different predatory clades remains to be documented because of uncertainty around the temporospatial ranges and phylogenetic relationships of early dinosaur lineages. We examine this potential pattern through the lens of dinosaurian assemblages of the southwestern United States. Recent studies recovered a clade composed of Tawa and Chindesaurus as early-diverging predatory dinosaurs, a clade best recorded from the low-paleolatitude Chinle Formation. The clade ranges from 230-212 mya, but seemed absent from younger rocks. We present a new species and youngest member of this clade known from a nearly complete skull (CM 31368) from the latest-Triassic aged Coelophysis Quarry (~205 mya) in New Mexico. CM 31368 exhibits clear synapomorphies with Tawa, most notably a dorsoventrally tall but laterally smooth jugal. CM 31368 is distinguishable from Tawa specimens and any other coeval ornithodirans by the combination of its ventrally deflected nasal and serrated, distally straight teeth. Unlike near-contemporaneous ecosystems of herbivorous dinosaurs alongside monotypic predatory dinosaurs, CM 31368 represents a third unique predatory lineage in a habitat void of herbivorous dinosaurs. The end-Triassic age of CM 31368, and lack of Jurassic relatives, also challenges the prevailing notion that dinosaurian diversity was unaffected by the Triassic-Jurassic Mass Extinction.

## Effects of parental diet on mormon cricket egg diapause, development rate, and periodic outbreaks

*Robert Srygley*

Transgenerational phenotypic modification can alter organismal fitness, population demographics and community interactions. Mormon cricket eggs diapause in soil for multiple years with duration largely dependent on temperature. Because Mormon crickets can be abundant in the landscape in one year and disappear suddenly the next, I asked: does parental nutrition affect the duration of egg diapause? To this end beginning in the ultimate nymphal instar, Mormon crickets were fed a diet high in protein, one equal in protein to carbohydrate, or a diet high in carbohydrates and the time for half the eggs to develop was measured. If parental nutrition affects egg diapause, then that change in temperature sensitivity might alter the relationship between embryonic development rate and temperature. I asked: does parental nutrition affect embryonic development rate as a function of temperature? I manipulated grasshopper and Mormon cricket densities in field cages, collected eggs, and measured optimal temperature, maximum rate, and thermal breadth for development. Mormon crickets fed high protein diet laid eggs with shorter diapause. Those housed with more grasshoppers to eat laid eggs with the fastest peak development rate, whereas those without grasshoppers had eggs with broader thermal breadth. Interestingly, doubling Mormon cricket density caused eggs to develop in nearly half the time. With thinner densities or less protein available, parents spread their bet-hedging and progeny spent longer as eggs in the soil.

## The impact of experimental heat on Tree Swallow investment trade-offs

*Nelly Stafford, Jennifer Houtz*

Wild organisms often face life history trade-offs between survival and reproduction. In response to unpredictable environmental conditions, organisms may devote more energy toward self-investment at the expense of reproduction. Given the increased frequency of extreme weather events, heat waves may be an essential factor mediating this trade-off. For our study, we experimentally increased nest temperature during days 7-9 of egg incubation of Tree Swallows (Tachycineta bicolor) in western Pennsylvania. We measured the innate immunity of adult females (bacterial killing assays) post-treatment on day 10 of incubation. We then measured adult female feeding rates over one hour on days 7-8 of nestling provisioning as a proxy of reproductive investment. We hypothesized that temperature mediates the trade-off between reproductive investment (nestling feeding rates) and self-investment (adult female innate immunity). We predicted that additional heat would allow adult females to decrease incubation time, facilitating them to prioritize self-investment (increased innate immunity). Due to reduced incubation pressure, adult females would have extra energy to invest in nestlings (increased feeding rates). We found no significant effect of heat treatment on adult female immune function or feeding rate. The results of prolactin measurements (a hormonal mediator of parental behavior) will also be discussed.

## Thermal biology of microplastics

*Zach Stahlschmidt, Kiersten Ngeow, Jiyoon Ryu, Rohan Aujla, Roxy Wang, Sahithi Mothukuri*

Microplastics (MPs) are small-sized (< 5 mm) bits of plastic that have been found in every type of ecosystem and in many types of human tissue. In addition to MPs, animals' regularly experience temperature shifts, and the biology of over 99% of animals is tightly linked to environmental temperatures that are rapidly warming due to climate change. Yet, the biological interplay between MPs and temperature is poorly understood. For example, warmer temperatures may increase the consumption of MP-contaminated food sources and, thus, increase the costs of MP exposure (e.g., reduced reproductive investment). Temperature may also directly influence the rate at which MPs get absorbed through the digestive tract and interact with (and potentially damage) internal body tissues. In turn, exposure to MPs may reduce animals' heat tolerance. Here, we addressed two fundamental questions related to the thermal biology of MPs. First, how does temperature influence (a.) the absorption of MPs through the digestive tract, and (b.) the effects of MPs on investment into reproductive and somatic tissues? Second, how does exposure to MPs affect heat and desiccation tolerance? To address our questions, we fed field crickets (Gryllus lineaticeps) different concentrations of nylon microfilaments (817 $\mu$m length; 17 $\mu$m diameter) while they were maintained at 23°C, 28°C, or 33°C. Our results will provide novel insight into animals' responses to two emerging features of environmental change.

## Comparing population structure of a mud crab host and its invasive parasitic barnacle

*Carter Stancil, April Blakeslee, Michael Brewer, Charlotte Bickley*

In this current era of human-induced global change, new selective forces brought on by global change are altering species interactions and ecosystem dynamics. An extreme example is when a novel species introduction imparts strong selection pressure on another species, like invasive parasites on their hosts. In North America, this is exemplified in a parasite-host system of an invasive castrating parasitic barnacle Loxothylacus panopaei and a native mud crab Eurypanopeus depressus. Indigenous to the Gulf of Mexico, L. panopaei was transplanted with oysters to the Chesapeake Bay ~60 years ago, where it has continued to spread southwards as far as Atlantic Florida. Since 2022, L. panopaei has become established on the northern banks of Long Island Sound. Population genetics studies can reveal key information on species distributions and spread, especially in cases of invasion or accidental introduction. I collected E. depressus, both uninfected and infected with L. panopaei, from 7 sites in the non-native range from Georgia to Connecticut, and compared them to native Gulf of Mexico sequences on Genbank. From each population, I compared DNA sequences of the parasites and their hosts at the COI mitochondrial marker and created haplotype networks. My work can help further understanding of whether parasite population structure is driven by the distribution of the host or as a result of currents-driven dispersal during the parasite's larval form.

## Exploring urban biodiversity via DNA barcoding with cost-effective tools in a vertical STEM pipeline

*Janet Standeven, Jacob Harrison, Angelina Tong, Juan Mendoza, Justina Jackson, Saad Bhamla*

The Frugal Science Academy, funded by an NIH Science and Education Partnership Award, develops low-cost replacements for lab equipment to enable hands-on research in limited resource settings. This program focuses on training teachers and their students in inventiveness, the engineering cycle, and molecular biology techniques, enabling broader and more diverse participation in authentic research experiences. Frugal devices lower the barrier for K-12 students and their teachers to actively experiment despite minimal budgets. Here we discuss the application of several frugal devices: 3D printed centrifuge, pocket pcr, along with low-cost technique: Chelex DNA extraction, to the exploration of DNA Barcoding in an urban setting. We leverage the integration of various skill and ability levels by utilizing a vertical pipeline composed of a high school intern, undergraduate researcher, and postdoctoral mentor. This creates an inclusive experience, allowing each participant to tackle research questions at their level of preparedness while contributing to the DNA Barcode database and increasing STEM opportunities for underrepresented minorities. Discussions and lessons learned help scientists who face common challenges of professional communication skills, wet-lab experience, and scientific preparedness when implementing outreach efforts to broaden impacts across academic targets.

## The development of a reliable detection assay to detect active citrus blight infection

*Daniel Stanton, Jason Hurlbert, Bill Schneider, Ron Brlansky*

## Ecomorphological but not allometric trends in mechanical performance in eulipotyphlan vertebrae

*Tristan Stayton, Stephanie Smith, Kenneth Angielczyk, Myleen Amendano, Maddie Cannistra, Catherine Suitor*

Eulipotyphla includes the smallest extant terrestrial mammals, presenting an opportunity to examine phenotypic evolution near the lower extreme of mammalian size. Recent work on the eulipotyphlan lumbar spine has revealed ecomorphological patterns in vertebral shape, but a lack of allometric trends. This study builds on these results with an examination of performance evolution within eulipotyphlan lumbar vertebrae. Performance is assessed using finite element (FE) modeling of vertebral responses to various loads, supplemented with validation of a subset of those responses. Analyses are conducted on performance at real sizes, with vertebrae scaled to equal surface area. Although a lack of allometric trends in vertebral shape would seem to preclude allometric trends in performance, many-to-one mapping of performance onto shape means that multiple shapes could produce the same response to loads in, e.g.„ larger species. Performance results mirror morphological results – moderate ecomorphological trends in expected directions (e.g., greater compression resistance in fossorial species), but a lack of allometric trends in size-corrected performance. Given the immense potential impacts of size on organismal performance, and the large mass range of the organisms considered (three orders of magnitude), this lack of allometric trends is surprising. Future research will examine three potential explanations– size-related variation in bone material properties, potential constraints on shape in extremely small species, and variation in selection pressure for strength versus stiffness across sizes.

## Contextualizing Imposter Phenomenon within Biology Doctoral Education

*Ariel Steele, Kelly Lane*

Imposter phenomenon is a persistent barrier for graduate students to balance their mental health and productivity. Many studies have explored graduate students' experiences with imposter phenomenon, however, few studies have mapped imposter phenomenon to specific structures within biology graduate education. In this study, we interviewed 20 biology doctoral students from two R1 institutions in the United States about their experiences with imposter phenomenon. We qualitatively analyzed the interview data to identify academic structures relevant to students' experiences with imposter phenomenon. Our results identified eight structures that activated imposter feelings for participants: the application and admissions process, the waitlist, course work, lab meetings, lab rotations, qualifying exams, and completing the dissertation. Imposter phenomenon is prevalent in contexts where students make comparisons to their peers, and each of these structures provide opportunities for comparison. Many of these structures also act as gate-keeping mechanisms and require knowledge of the hidden curriculum to be successful, which can impact graduate students' sense of belonging. Finally, these structures are often high-stakes, as the consequences of failing are high. These results identify both the structures and the characteristics of these structures that we could innovate to improve graduate student mental health and belonging.

## Ontogeny of stimulus perception and response in embryonic fathead minnows (*Pimephales promelas*)

*Karly Steinberg, Jessica Ward*

Aquatic organisms rely on multiple types of environmental sensory stimuli to detect and respond to threats. Although most research on the sensory ecology and development of behavior in fish has focused on responses to stimuli at juvenile and adult stages, research suggests that embryos not only perceive but also respond to these cues in ways that increase fitness. However, an embryo's ability to respond to environmental information is dependent on development of the sensory and neural systems required to detect and process these cues, which may differ across sensory modalities. This study aims to determine the stages of embryogenesis at which embryos of a common stream fish, fathead minnow (Pimephales promelas) first show behavioral evidence of response to ecologically relevant chemical, visual, and mechanosensory stimuli, and whether embryos differentiate between threat cues within a sensory modality indicative of stage-specific predation (i.e., predation on eggs vs adults). Embryonic minnows begin to respond to environmental cues as early as 3 days post-fertilization, and preliminary data indicate that they may be able to distinguish between cues that signal an attack on eggs vs adult conspecifics. The ability to differentiate and respond to stimuli would suggest that embryos are more cognitively sophisticated than previously thought.

## Patterns in Carapace Shape and Autotomy in Pacific Northwest Intertidal Crabs

*Melissa Steinert, Sophia Swain, Kenneth Taylor, Alex Melendez, Glenna Clifton, Tara Prestholdt*

Carcinization has evolved at least five times in crustaceans, yet crabs retain a diverse array of body shapes. All crabs may autotomize their limbs; however, it remains unknown how autotomy relates to carapace shape and mobility. Intertidal crabs navigate rocky terrain leading to many factors that could cause leg loss such as injury, predation, intraspecific conflict, or molting complications. To understand how carapace shape impacts autotomy patterns and locomotion, we collected intertidal crabs across 10 species (n=1200) on San Juan Island, WA. In addition to determining sex, carapace width, and the limbs that were autotomized or regenerated, we also tested preferred walking directionality. To quantify carapace shape, we photographed crabs and outlined the carapace using ImageJ for 10 individuals from each species. The carapace outlines were quantified using Elliptical Fourier Analysis and then analyzed using a Principal Components Analysis. The PCA revealed a gradient in carapace shape from trapezoidal to triangular. Carapace shape does not influence the number or identity of lost limbs, with only two species showing elevated rates of limb loss (T. cheiragonus and P. producta). Similarly, walking direction does not correlate with carapace shape. Only P. gracilis walked almost equally sideways and forwards. These findings will help inform patterns in crab morphological evolution and will aid in the design of multi-legged or crab-inspired robots needing omnidirectional movement.

## Developing functional genomic techniques in the scyphozoan jellyfish Cassiopea

*Bailey Steinworth, Mark Q. Martindale*

The upside-down jellyfish Cassiopea is emerging as a useful laboratory system for studying cnidarian-dinoflagellate symbiosis and the life cycles of medusozoan cnidarians. Here, we investigate gene function by microinjecting small hairpin RNAs (shRNAs) at the one-cell stage and characterizing the effects of these gene knockdowns during embryonic development. We focus on the orally expressed gene Brachyury to investigate its role in gastrulation and on Hox genes to investigate their role in oral-aboral axis patterning. Cassiopea undergoes primary body axis patterning at multiple points in its life history: first during embryonic development and again during asexual budding at the polyp stage. During this form of asexual reproduction, the polyp produces a swimming bud that behaves similarly to the planula, settling in response to the same chemical cues and developing into a polyp. Hox genes are expressed in spatially restricted regions along the oral-aboral axis during both of these patterning events. Successful gene manipulation in Cassiopea provides the opportunity for future functional work on this emerging cnidarian system.

## Effects of temperature on physiology may explain latitudinal patterns of growth in a marine snail

*Kara Stella, Darren Johnson*

Rates of growth may increase with temperature, yet organisms generally grow to larger sizes in colder environments. The understanding of such patterns can be aided by physiological models. We measured the energetics underlying growth in an intertidal snail, Tegula funebralis. The physiological scope for growth was estimated using measurements of energy acquisition and expenditure across a range of body sizes and temperatures. This was paired with field measurements of growth across a range of cool and warm water locations to evaluate whether the effects of temperature on bioenergetic processes can explain geographic variation in growth. We described energy acquisition and expenditure as the best of seven models for each using AIC scores. The data suggests the scope for growth is highly temperature dependent and largely driven by temperature effects on respiration. These models were then used to obtain the relative surplus energy at a given temperature and size. Taken together these results suggest reduced physiological scope for growth at high temperatures. Higher temperatures shifted the surplus energy curve such that growth reached an asymptote at smaller sizes. Our model accurately predicted the observed gradient of smaller maximal sizes from north to south in the study region. These results thus suggest that a clearer understanding of the physiology underlying growth can help explain a major gradient in life history differences.

## Changes in stress-induced corticosterone between pre- and post-captivity in two anole species

*Emily Stelling, Marquise Henry, Caroline Henry, Keegan Stansberry, Tosha Kelly, Annelise Blanchette, Alex Gunderson, Christine Lattin*

Invasive species introductions are one factor that can lead to the decline of native species. For example, the brown anole (Anolis sagrei) is an invasive lizard whose introduction and range expansion may be responsible for the decline and displacement of populations of native green anoles (Anolis carolinensis) in the southeastern United States. Although we still do not fully understand what physiological traits contribute to the success of invasive species, some studies suggest that higher levels of circulating corticosterone may contribute to an invasive species' ability to survive and establish in a novel environment. The goal of this study was to assess stress-induced corticosterone levels in male native green ($n=18$) and male invasive brown anoles ($n=16$) both pre- and post-captivity. At capture and after at least 8 weeks in captivity, we collected blood samples from lizards $\sim$30 min after restraint and handling. Corticosterone was then extracted from blood plasma and assessed using enzyme-linked immunoassays. We found that invasive brown anoles had higher levels of stress-induced corticosterone at capture compared to native green anoles, but that corticosterone levels declined to green anole levels post-captivity. Green anoles showed no change in stress-induced corticosterone pre- vs. post-captivity. Overall, our results suggest that higher stress-induced corticosterone and increased plasticity of the hypothalamic-pituitary-adrenal response may help invasive brown anoles adaptively respond to a novel environment.

## Silk genetics of orb weaving spiders and kin

*Sarah Stellwagen*

Spiders make up to seven different silk types, each used for a different purpose. Orb weaving spiders make typical 2-dimensional ‘wheel’ webs with a sticky spiral, while related species have developed other unique web structures but still employ glues for prey capture. Parasteatoda tepidariorum, the common house spider, uses gumfoot lines to capture prey while Mastophora phrynosoma, the bolas spider, uses a single silk line with a globule of glue to ensnare moths. The proteins that make up spider silks, called spidroins, are encoded by extremely long and repetitious genes, making them difficult to sequence and study. Using long-read technology was used to discover and compare silk genes from several species of spider, including capture thread and gluey silk. Spidroin genes of prey capture glues are incredibly large, and the diversity of silk genes across a single spider species is more extensive than previously reported.

## Muscle spindle and Golgi tendon organ afferent firing during in-vivo muscle work loops

*Jacob Stephens, Paul Nardelli, Lena Ting, Gregory Sawicki, Timothy Cope*

Muscle proprioceptors, namely the muscle spindle (MS) and Golgi tendon organ (GTO), offer critical sensory feedback for movement control. MS are classified as length and velocity sensors, but recent evidence suggests they may encode forces exerted on the spindle itself. GTOs lie at the muscle-tendon junction, and respond to force in the skeletal muscle. With the GTO signaling muscle force, and the MS signaling internal forces when stretched, we hypothesize that combined MS and GTO feedback signals the balance of active force (generated by the muscle) and external force (imposed by the environment).

To test this, we applied sinusoidal length changes to the medial gastrocnemius (MG) muscle-tendon unit in deeply anesthetized rats while activating the MG at different phases of the sinusoid. During passive stretches, MS and GTO afferents fired approximately sinusoidally in phase with muscle stretch. When activating during muscle lengthening, MS and GTO signals shifted out of phase, with GTO firing rates increasing with active force during stimulation and MS firing rates rapidly increasing when activation ceased. This supports our hypothesis that taken together, these sensors have the capacity to provide information on the exchange of force between the muscle and environment.

## Biophysical model explains firing properties of primary and secondary muscle spindle afferents

*Jacob Stephens, Surabhi Simha, Paul Nardelli, Lena Ting, Timothy Cope*

Muscle spindles offer vital sensory information for movement and posture control. Muscle spindles are capsules of intrafusal muscle fibers and sensory endings – both primary and secondary endings that innervate different sets of intrafusal fibers and respond differently to stretch. Previously, we developed a biophysical model of primary afferents that reproduces the key features of stretch responses: the initial burst of firing at stretch onset, the dynamic response during lengthening, and history dependence (when the burst is absent and dynamic response diminished with subsequent muscle stretches). Muscle spindles also have a secondary ending, which lacks an initial burst and has a smaller dynamic response. As the secondary ending doesn’t innervate the bag1 type fibers that the primary does, we aimed to test whether the removal of the bag1 fiber in our model would reproduce secondary ending stretch responses.

We analyzed firing rates of primary and secondary afferents in response to stretches of the triceps surae in deeply anesthetized rats. In ramp-hold stretches, we found the response during the ramp phase of secondary endings scaled with velocity, and this behavior was qualitatively captured by our model. In sawtooth stretches (constant-velocity ramp-release), we noted history dependence in the firing rates of secondary afferents that is also qualitatively captured in our model. This indicates the bag1 fiber may explain differences in stretch responses between primary and secondary endings.

## Mitochondrial resilience: Unveiling the secrets of longevity

*Jess Sterling, Justin Havird, Kendra Zwonitzer*

Why do some species live for mere months, while others persist for centuries? The Mitochondrial Theory of Aging suggests that the answer may lie in the mitochondria, the cellular powerhouses. Mitochondrial efficiency diminishes with age due to the systematic accumulation of mutations within mtDNA. This study explored the relationship between mitochondrial mutation rates and species’ lifespans across four diverse clades: Birds, Fish, Rockfish, and Bivalves. We first examined the rates of nonsynonymous (dN) and synonymous (dS) mutations across the entire mitochondrial genome, assessing whether long-lived species experience lower mtDNA mutation rates. Our findings reveal that vertebrate species with extended lifespans show a significant reduction in mutation rates, suggesting a potential protective mechanism against mtDNA deterioration over time. This trend aligns with the idea that decreased mutation rates may help preserve mitochondrial integrity in long-lived vertebrate species. To further refine our understanding, we analyzed specific types of mtDNA substitutions, focusing primarily on C→T, G→A, and C→A substitutions. These mutation spectra reveal that long-lived species, though they have lower mutation rates, have the same composition of mutations as their short-lived counterparts. This suggests long-lived species' decreased rates of mtDNA mutations are not due to protection against one primary type of mutation, but rather a broad protection against all mutation. Together, these findings underscore the critical link between mitochondrial stability and lifespan, suggesting that the evolution of reduced mtDNA mutation rates and specific mutation patterns may contribute to the prolonged vitality.

## Testing social buffering and repeated stressor exposure on early-life cortisol in juvenile cichlids

*Eliyah Stern, Alyssa (Aly) Alvey, Erika Moore, Tessa Solomon-Lane*

Although stress responses are crucial to organismal function and survival through impacts on physiology and behavior, early-life stress can lead to altered and potentially adverse long-term effects. Glucocorticoids are an important component of the stress response. Here, we measured the glucocorticoid cortisol in juveniles of the highly social cichlid fish Burton's Mouthbrooder (Astatotilapia burtoni). We investigated 1) whether very young juveniles habituate to potential stressors and 2) if social buffering mediates cortisol response. Testing for habituation, on three consecutive days, we subjected juveniles (age 0 days) to various elements of the water-borne hormone collection process (e.g. 30 minutes in an isolated beaker). On day 4, hormones were collected from all fish. Repeated beaker exposure did not decrease cortisol compared to unhandled or handled controls. In a separate cohort, juvenile (age ∼2 months) social groups were placed in netted beakers (4 minutes) on three sequential days, either together or in separate beakers. Controls remained undisturbed. On day 4, prior to hormone collection, exposure conditions (alone vs. groups) were switched for some social groups. We did not find evidence of social buffering-mediated effects on cortisol. Future research will investigate when habituation mechanisms develop in A. burtoni, and whether social buffering and/or individual cortisol variation are influential. This work contributes to our understanding of the early-life stress axis and the potential roles of social effects.

## Eye size evolution in sharks

*Phillip Sternes, Kenshu Shimada, Lars Schmitz*

Vision is a key sensory system for many animals, including predators such as sharks (Elasmobranchii: Selachii). Sharks are chondrichthyan fishes found across many different photic environments of the marine ecosystem, from the near shore intertidal zone to the deepwater depths of the abyssal zone. Previous work with limited sample size suggests that both active pelagic and deepwater sharks have larger relative eye size compared to other species. We examined the eye diameter of 96 species of extant sharks found in a wide range of photic environments. Using a phylogenetic generalized least squares analysis, we found that shallow water sharks (up to 200 m water depth) have smaller eyes for given precaudal length compared to sharks found in the intermediate (200–1,000 m) and deepwater (>1,000 m) depth zones. Analyses of relaxed Ornstein-Uhlenbeck models suggest selection of smaller relative eye size in two clades that are predominantly active in shallow water, the requiem sharks (Carcharhiniformes) and carpet sharks (Orectolobiformes). These results indicate that the evolution of selachian eye size was impacted by changing light conditions. Our findings can inform analyses of the possible depth range of sharks with unknown ecology, including extinct species. Using relative eye size as predictor, the large predatory Cretaceous shark Cretoxyrhina mantelli (Lamniformes: Cretoxyrhinidae) and its large eyes indicates it was able to exploit deep waters.

## Metabolic strategies for glass frog transparency

*Jake Stevens, Jesse Delia, Carlos Taboada*

Glass frogs possess a unique ability to control their blood flow, significantly enhancing their transparency. It is known that the reduction of transparency during exercise is largely due to the increased light absorption of oxygenated and deoxygenated hemoglobin; however, during sleep, glass frogs can pool up to 90% of their red blood cells into the sinusoids of their livers. Hiding red blood cells in this fashion reduces the availability of oxygen carriers, subjecting the frogs to daily cycles of oxygen deprivation. To cope with this, glass frogs must rely on non-oxidative metabolic pathways and/or adaptations to increase oxygen gradients to transport oxygen across their tissues. In this study, we hypothesize that glass frogs have evolved strategies to facilitate transcutaneous oxygen diffusion to sustain their metabolic needs. To test this, we combined physiological measurements of oxygen consumption with transcriptomic and proteomic analyses to identify molecular targets involved in oxygen exchange. Our findings reveal that glass frog skin expresses proteins that modify water surface tension, similar to those in vertebrate lungs. These results suggest that glass frogs can potentially enhance oxygen uptake at rest, indicating a possible metabolic adaptation to maintain transparency. The implications of these findings will be discussed in the context of the evolution of oxidative metabolism in amphibians.

## Plasticity in meiotic recombination rate across different genetic backgrounds

*Laurie Stevison*

For over a century, scientists have known that meiotic recombination rates are plastic, thus varying among individuals depending on environmental and/or physiological stress. Our lab has investigated how genetic background influences recombination rate plasticity due to various perturbations. In addition to recombination, we measured individual stress response including physiology and reproductive output, which vary by stock, sex and among individuals. Specifically, using the Drosophila Genome Resource Panel (DGRP) and a visible marker stock of D. melanogaster, we used a simple genetic crossing scheme to measure meiotic recombination rate in response to perturbations in caloric density, temperature and oxygen concentration across various inbred strains of fruit flies. Our results show recombination rate to be significantly altered due to changes in caloric density, with significant genotype by environment interactions. Similarly, we show that temperature leads to meiotic recombination rate plasticity that also varies due to genetic background. However, we found no changes in recombination due to hypoxia. Interestingly, we found that differences among stocks in recombination rate in the standard lab conditions significantly impacted plasticity across treatments. Together, our work reveals recombination rate to be variable due to both differential exposure and susceptibility to environmental stress with interesting GxE interactions. This outcome has important implications for how changes in the environment can interplay with genetic background to alter the landscape of genetic variation in natural populations.

## Hypothalamic Dio3 is a neuroendocrine substrate controlling the timing of the seasonal response in S

*Calum Stewart, Tyler Stevenson, Timothy Liddle, Francis Ebling, Jo Lewis, Peter Morgan, Christopher Marshall, Elisabetta Tolla, Neil Evans*

Changes in external photoperiod (day-length) drive large physiological changes in mammals that inhabit temperate zone environments. However, the neuroendocrine mechanisms controlling the timing of these changes is not clearly understood. Here, we generated a temporal map of the transcriptomic changes occurring in discrete hypothalamic nuclei in Siberian hamsters (Phodopus sungorus) and tested the hypothesis that changes in hypothalamic Dio3 drive energetic seasonal changes. Adult male ($n = 54$) animals were exposed to either long-photoperiods (LP, 16h light;8h dark) ($n = 9$) or short-photoperiods (SP, 8h light;16h dark) ($n = 45$) for up to 32-weeks and RNA sequencing was performed at 4-week ($n = 9$) intervals. We identified several novel seasonal transcripts which followed an induction phase, a maintenance phase and a refractory phase ($FDR < 0.1$). Dio3 expression peaked in the initial induction wave of transcripts. Next, to investigate the role of Dio3 in controlling the timing of these phases, we generated Dio3 knockdown hamsters using CRISPR-cas9 and recorded the period for interval timing of body mass and pelage. Dio3 knockdown hamsters had significantly shorter period of body mass recovery ($n = 4$, period $= 29.012$) than wild type ($n = 6$, period $= 32$) animals, implying an attenuated seasonal response. This work demonstrated Dio3, expressed in hypothalamic tanycytes, may be a key neuroendocrine substrate for interval timing in seasonal life history transitions.

## Larger fledglings may get the worm; the relationship between nestling size and fledging order

*Kathryn Stewart, Addi Lusk, Jasmine Morris, Olivia Saari, Troy Murphy*

Within altricial birds, there are often asymmetries in the competitive ability of siblings that dictate differences in their size and overall health. The most competitive siblings are often larger and in better condition, which may allow them to fledge the nest box earlier than less competitive siblings. We hypothesize that larger nestlings, or nestlings in better condition, will fledge the nest before smaller nestlings. This asymmetry in the time of fledging is predicted to be most pronounced amongst nestlings with the large differences in nestling size. The black crested titmouse (Baeolophus atricristatus) is a cavity nester, and nestling size is highly variable within a brood, as is fledging date. Research was carried out north of San Antonio, Texas. Fledging order was established by placing passive integrated transponders on nestlings and recording fledging order with an radio frequency identification (RFID) antenna affixed to nest boxes. Mass and condition of nestlings were not related fledging time; however, nestlings of larger structural body size fledged earlier than their smaller siblings. Larger nestlings may benefit from early fledging by avoiding predation within an easily detectable (i.e., loud and acrid) nest, or larger nestlings may benefit by placing themselves in a position outside the nest that allows them to intercept food delivered from the parents.

## How small is too small? Measuring zebra finch kinematics in the Mecadev biplanar fluoroscopy system

*Kelsey Stilson, Pauline Provini*

X-ray imaging and computational facilities are just now becoming precise enough to measure the internal anatomical movements of bones smaller than an average nail clipping. The recent assembly of a biplanar cineradiographic system at the Muséum national d'Histoire naturelle in Paris prompted us to quantify the maximum resolution of the system. As a case study, we focused on movement in anatomical structures of the avian head and neck (oropharynx and orolarynx). This is a key system for many behaviors necessary for survival including breathing, feeding, and vocalizing. However, it is unknown how similar the kinematics (i.e. anatomical movements) are between these three behaviors.We imaged industry-standard calibration objects as well as zebra finch (Taeniopygia guttata) individuals using biplanar fluoroscopy and digitized the data using the X-Ray of Moving Morphology (X-ROMM) pipeline. We tested machine-learning methods to cut down digitization time. We found that impanated metal markers as small as 0.3 mm are trackable at 400 fps. We recommend adding a small calibration device to all data collection events. We found that small animal data is especially prone to error amplification. Automatically tracked data must be checked by a researcher to avoid correlation of movement artifacts, especially for small animals.

## Melanism, temperature and density in the cowpea beetle *Callosobruchus maculatus*

*Andrew Stoehr, Liam Donahue*

Variation in dark coloration due to melanin, i.e. melanism, in insects is often phenotypically plastic and adaptive. However, the pigment melanin and/or components of the melanin synthesis pathway, have many functions in insects beyond just coloration, such as roles in immune defense and cuticular hardening. For these reasons, melanism responses may sometimes be complicated particularly if melanin-based coloration trades off with other melanin-based functions; such trade-offs may be related to resource availability. We manipulated the temperature and density of cowpea beetles, Callosobruchus maculatus (Coleoptera: Chrysomelidae) during the larval and pupal period and found both variables affected the coloration (melanism) and size of the emerging adults. Lower temperatures produced darker and larger beetles in both sexes, with females also being darker than males. The effects of density were more complicated and depended upon how we analyzed our data; increased numbers of beetles per bean tended to decrease melanism in both sexes when density was analyzed as a numerical variable, whereas the categorical treatment of density affected female but not melanism. The effects of temperature on melanism are consistent with the adaptive thermal melanism hypothesis. The less consistent effects of density on melanism may reflect resource-based trade-offs, maternal effects, or both but require further investigation.

## Comparing jellyfish eyes from a common origin but differing life history

*Marina Stoilova, Lucian Sours, Matthew Travert, Cory Berger, Todd Oakley, Paulyn Cartwright*

Within the Cnidarian subphylum Medusozoa (including box jellyfish, true jellyfish, and hydromedusae) there is an immense diversity of light sensing systems, ranging from the light-sensitive but eyeless Hydra vulgaris to the 24-eyed box jellyfish Tripedalia cystophora. The class Hydrozoa displays considerable diversity of life history strategies, which may mirror their diversity of light sensing systems. When comparing sister genera in the family Cladonematidae, some lineages transition from benthic colonies to a free-swimming medusa (e.g. Cladonema sp.) while others transition to a benthic "crawling" medusa (e.g. Staurocladia sp.). Previous studies have proposed at least nine convergent origins of eyes in Cnidaria, with Staurocladia and Cladonema sharing a single origin. This provides an excellent comparative system through which the relationship between life history and light sensing system diversity can be disentangled, given that benthic and pelagic environments may require distinct visual cues. We are characterizing differential gene expression in the eye tissue of Cladonema and Staurocladia to determine both the core conserved genetic mechanisms and toolkits employed between close relatives from a shared instance of cnidarian eye evolution as well as differences present due to differing life histories and ecologies. In future studies, these patterns can be tested with molecular and functional experiments in genetically tractable species to validate the results of our bioinformatic analyses.

## Shelter choices of the Rusty Crayfish are influenced by the relative size of a predator

*Gaige Stopjik, Arthur Martin, Paul Moore*

An important aspect of the landscape of fear is the organism's understanding of the spatio-temporal nature of risk and refuges in their environment. The presence of risk modulates habitat use such that as risk increases organisms are more likely to use refuges and vice versa.

The theory of Landscape of Fear is predicated on the idea that an organism's use of an environment is based on the perception of predatory cues (fear), but what is missing from this theory is the inclusion of safety (or refuge) cues. In this study we investigated how increasing predatory risk in a gape limited predator (largemouth bass) alters shelter choice in crayfish. In experimental mesocosms, we provided shelters of differing quality under differing risk. Video analysis of crayfish behavior allowed us to analyze safety choices under different risk scenarios. Results indicate that crayfish alter shelter use and in particular the type of shelter used as a function of increasing risk.

## Boldness and congener presence impact on the behavior of *Faxonius rusticus* and *Faxonius virilis*

*Nicoleena Storer, Paul Moore*

Within conservation, the impact of personality on the success or failure of a species has become an increasing area of interest. Understanding how personality plays into competition can also give insight into invasive success. This study looks at two crayfish species, one invasive in the study region Faxonius rusticus and one native F. virilis. Artificial streams were used to investigate the impact of boldness, size and crayfish giving the donor cues for the experiment. Paired sets of male F. rusticus and F. virilis were used to determine that foraging and sheltering behaviors were determined based on different criteria based on the focal species or the cue donor crayfish. Understanding the indirect competition and behavioral decisions between invasive and native species can help understand how an invasive species can outcompete a native and insight into future methods of helping native species.

## Do cold nest temperatures during incubation have effects on glucose levels of nestling bluebirds?

*Sunny Stout, Sarah Knutie, Jennifer Houtz*

Climate change has increased the frequency of unpredictable extreme weather events, such as cold snaps. Warmer temperatures are now occurring earlier in the spring, which signals to birds to initiate egg laying earlier. Earlier incubation dates put individuals at an increased risk of stochastic weather events. Wild birds can deal with variable temperatures by changing physiological processes that underlie metabolism and growth such as blood glucose levels. Glucose is the primary simple sugar that is used to power metabolic processes and fuel tissue growth. Colder nest temperatures during egg development may slow glucose mobilization, which could lead to decreased body mass in hatchlings. For our study, we experimentally reduced nest temperature to simulate a cold snap during egg development of Eastern Bluebirds (Sialia sialis). We then measured the lasting effect of temperature on nestling blood glucose levels and body mass when they were 13 days old. We predicted that lower nest temperatures during incubation would have lasting effects through the nestling stage, including lower blood glucose levels and subsequently smaller body mass of nestlings. However, we found that cold treatment did not significantly affect blood glucose or body mass of nestlings. Our results indicate that nestling body mass may be more susceptible to changes in temperature during the nestling stage rather than the egg stage.

## Genetic and physiological mechanisms driving the northern range expansion of a tropical jellyfish

*Marie Strader, Myles Wagner, Ziyu Wang, Mikayla Clark, Stephanie Hendricks*

As environments rapidly shift in response to global change, many species are suffering dramatic declines in population size and facing extinction, while others are expanding their ranges into previously uninhabited regions. We have documented the northward expansion of the tropical coastal marine jellyfish, Cassiopea xamachana, along parallel coasts in Florida using community science data and profiled morphological phenotypic shifts along this gradient. We observe shifts in appendage shape across latitudes, which may indicate adaptive responses involved in this range expansion into more temperate environments. To understand the underlying mechanisms of this expansion, we investigate both physiological and genetic factors that may be contributing to this range expansion. We assess maximum and minimum thermal tolerance (LT50) limits in multiple life-history stages in both core and expanding populations and conduct shallow whole genome sequencing to explore potential genetic adaptations. Ultimately, this study reveals insights into the novel mechanisms enabling the northern range expansion of a tropical symbiotic cnidarian.

## A legacy of competitive exclusion: Temperature-dependent effects on host stage structure and disease

*Alexander Strauss, Daniel Suh, Katie Schroeder, Jenavier Tejada, Emily Landolt*

Dilution effects arise when increases in diversity reduce disease risk, and amplification effects arise when the opposite occurs. Despite ample evidence for both phenomena, the mechanisms driving dilution and amplification effects and how they are mediated by environmental factors remain poorly understood. We conducted a mesocosm experiment to assess how temperature mediated the effects of an alternative host on disease dynamics in a focal host population. In the field, Metschnikowia parasites cause seasonal epidemics in Daphnia focal hosts, but outbreaks are smaller in lakes that contain more Ceriodaphnia alternative hosts. We hypothesized that warmer temperature would strengthen dilution effects driven by these alternative hosts by elevating their abundance and their per-capita consumption of parasites.

Results of the mesocosm experiment refuted this hypothesis in several surprising ways. First, focal hosts rapidly outcompeted alternative hosts regardless of thermal conditions. Second, initial presence of the alternative hosts altered focal host population dynamics and disease dynamics for several generations, even after being competitively excluded. Third, this legacy effect of alternative hosts actually increased disease, rather than reducing it, due to enduring changes in host stage structure that favored parasite transmission. Finally, this amplification effect was strongest at intermediate temperature (20C). These surprising results highlight the need for a broader understanding of processes that can create relationships between diversity and disease, and how those processes are shaped by environmental conditions.

## Antennal motion drives haltere movement in Drosophila

*Amy Streets, Marie Suver, Jessica Fox*

Insect flight requires rapid sensory processing of multiple stimuli. In flies, sensory information for flight control comes primarily from eyes, antennae, and mechanosensory halteres, but how these systems function in concert is unresolved. Recent work showed that visual input to haltere steering muscles changes their activity and thus the haltere's motion, which in turn changes haltere sensory input to wing and neck motoneurons. We ask whether haltere muscles can also be driven by input from other sensory modalities, like antennae.

Here, we stimulate the antennae with wind at different speeds and angles, and use high-speed cameras to closely observe haltere and antennal motions. We have found that during the wind stimulus, the haltere's frequency and trajectory change, especially in the lower part of the haltere stroke. Additionally, in quiescent flies, a frontal pulse of wind to the antenna elicits a downward haltere motion. This motion is not seen if the fly is dead or the antennae are immobilized, and thus is not a result of passive mechanics. These results suggest a specific and modifiable link between antennae and halteres that allows them to act as interconnected sensors. They also provide evidence that halteres are not isolated sensors, but are under active control from multiple other senses.

## Motion and morphology's influence on TMJ stress field location across common model species

*Alyssa Stringer, Nicholas Gidmark*

The mammalian jaw joint — the temporomandibular joint (TMJ) — is uniquely complex in its anatomy and motion. This motion enables critical activities such as speech and mastication and is facilitated by the fibrocartilagenous articular disk. Disk integrity and function abnormalities can result in joint pathologies (Temporomandibular Disorders, TMD). Previous human studies have examined the TMJ stress field — the contact area between bone and articular soft tissues — to compare TMJ loading between healthy and pathological populations. However, the stress field metric has yet to be applied comparatively across the clinical model species used in TMD research. Here, we use XROMM data of normal mastication in three common clinical model species (rats, pigs, and monkeys) to examine three aspects of stress field: the closest distance between condyle and fossa, its translation along the articular surfaces, and its location within joint space. Stress field distance and translation during the chew stroke did not differ between species and were comparable to the magnitudes observed in healthy human joints. Stress field location in joint space differed between species — tending centrally in rats, anteriorly in pigs, and posteriorly in monkeys — correlating with each species' individual skeletal anatomy. We hope this study will help inform future choices of clinical model species and introduce the stress field metric as a rigorous tool for quantifying articular soft tissue loading across disparate motions and morphologies.

## Marine and terrestrial sediment on algal turf limits herbivory pressure and species richness

*Amarie Strong, Zuri Murph, TaVon Palmer, Alondra Gallegos, Paul Barber, Peggy Fong*

Herbivory on coral reefs provides strong top-down control that maintains turf algae in a short healthy state after disturbance kills coral. While it is well known that marine sediment deters herbivory, what remains unknown is the effect of terrestrial sediment that is increasing on coral reefs due to climate change and coastal development mobilizing soils in developed watersheds. We evaluated the effect of marine and terrestrial sediment on herbivory rate on algal turf in three sites in Mo'orea, French Polynesia. We confirmed that turf height (LME, $p<0.001$) and sediment depth ($p<0.0001$) varied across sites ($n=10$ plots per site). Total herbivory rates quantified from video recordings of bite rates on replicate experimental plots did not vary between sites (Kruskal-Wallis, $p>0.05$). Rather, bite rates for individual species and the species richness of the fish taking bites differed across sites. Richness and herbivory rates were highest where sediment and turf were lowest. Both herbivory and fish diversity declined at the site with marine sediment and long turf and were lowest by far at the site with terrestrial sediment and long turf. Overall, we found that terrestrial sediment deterred herbivory more than marine sediment. Thus, increases in sedimentation, particularly of terrestrial sediments, associated with climate change could further degrade coral reefs by decreasing total herbivory and the species richness of the herbivore community, ultimately inhibiting coral recovery.

## Understanding fluid-structure interactions in devil ray filter-feeding

*James Strother, EW Misty Paig-Tran, Leandra Hamann*

Manta and devil rays feed by swimming with open mouths, drawing large volumes of seawater into the buccal cavity, and then filtering out and ingesting small zooplankton. Prior studies have indicated that the unique morphology of the filtering structure allows these animals to employ an unusual solid-fluid separation mechanism, which has been referred to as ricochet separation. However, this filtration process involves highly complex fluid-structure interactions, and we are only beginning to understand the relationships between fluid flow, solid particles, and solid filter surfaces. In this study, we employ a combination of computational fluid dynamics and experimental studies to dissect the forces on solid particles interacting with the filter structure of a devil ray. Our results indicate that contact forces have a crucial role in determine particle trajectories, while other fluid forces induce smaller particle movements.

## Neuromuscular control of feeding in the red-footed tortoise (Chelonoidis carbonarius)

*Thomas Stroud, Kendall Steer, Chloe Edmonds, Johnson Gao, Khaled Adjerid, Kree Kerkvliet, Rebecca German, Christopher Mayerl*

Feeding is a complex behavior requiring integration of several neural and musculoskeletal components to be successful. Material properties of food, such as size and texture, add to this complexity, and the feeding apparatus must be able to modulate mechanics and neural control to meet these functional demands. Studies of neuromuscular control of feeding modulation in vertebrates have historically been restricted to mammalian systems, whereas non-mammalian taxa have received less attention. Tortoises feed on a wide variety of food sizes and textures, making them an excellent model for exploring these topics. We used X-ray Reconstruction of Moving Morphology (XROMM) synchronized with electromyography (EMG) of select feeding muscles while red-footed tortoises fed on strawberries of various sizes (whole vs. chopped) and textures (fresh vs. cooked). We observed minimal variation in muscle activity due to texture or size. However, we did observe variation in activity and function across the hyoid musculature, as well as functional differences during oral processing than during swallowing in these muscles. All muscles were active for greater duration during swallows than during oral processing, and intermandibularis was active later and at proportionally higher amplitudes than others during swallows. Future work would benefit from further systematic study of testudine feeding plasticity and how environment or phylogeny may influence feeding function.

## Locomotor strategies in terrestrial and aquatic life stages of Notophthalmus viridescens

*Mikayla Struble, Kaelyn Gamel PhD, Christopher Mayerl, Alice Gibb*

Vertebrates inhabit a range of environments, each with distinct physical principles, particularly when comparing aquatic and terrestrial habitats. Locomotion in these environments presents unique mechanical challenges due to differences in body weight support and substrate or media interaction. Although biomechanical adaptations across aquatic and terrestrial habitats have been studied, such studies often compare species with different anatomies, evolutionary histories, and ecologies. To better understand locomotor biomechanics across environments, we measured triaxial ground reaction forces (GRFs) in Notophthalmus viridescens, a newt with both terrestrial juvenile and aquatic adult life phases. Aquatic adults often dragged their tails and collapsed on their chests during midstance phases, sliding forward along their bellies and reducing vertical limb GRFs compared to terrestrial juveniles, which supported their entire body weight on their limbs. Aquatic adults showed higher variability in kinematic and GRF patterns compared to terrestrial juveniles. GRF characteristics in fore- and hindlimbs were similar in adults, suggesting uniform mechanics across limb girdles. In contrast, terrestrial N. viridescens exhibited greater mechanical differences between limbs, including evidence of rear-wheel driven propulsion, indicating more pronounced biomechanical roles during terrestrial walking. Aquatic adults also exhibited a more sprawling posture, particularly in the forelimbs, resulting in more medially directed GRFs. These results illuminate the biomechanical adaptations used by N. viridescens and other salamanders with multiple life stages to survive in and navigate aquatic and terrestrial habitats.

## Flow characteristics around crocodilian scutes

*Patience Strutton, Noel Rajive, Arvind Santhanakrishnan*

Crocodilians possess highly vascularized osteoderms on their backs and tails, known as scutes, which provide protection and aid in thermoregulation. The projections on crocodilian scutes often extend beyond the boundary layer region where viscous forces are significant, unlike micron-scale surface features in other aquatic animals that are within the boundary layer (e.g. shark skin denticles). However, it remains unknown as to how the projections on the scutes impact swimming performance. This study aims to characterize the flow around alligator scutes using particle image velocimetry (PIV). 3D printed physical models of alligator scutes were fitted onto a blunt-edged flat plate and tested in a water tunnel facility under continuous background flows ranging from 0.5-0.9 m/s. Two-dimensional, time-resolved PIV measurements were used to visualize the flow at several transects. Multiple arrangements of scutes representative of different regions along the crococilian body were examined. Flow characteristics will be compared with a baseline flat plate without scutes, and the impact of scutes on drag force production will be presented.

## An effect of dominance on filial cannibalism in an African cichlid *Astatotilapia burtoni*

*Josh Stueckle, Andrew Anderson, Susan Renn*

Parental care is critical for offspring survival in many species, yet parenting is energetically costly and balanced against future reproductive potential. Mouthbrooding, an involved parenting method where an individual incubates and protects fry in their mouth, sometimes resulting in filial cannibalism, provides an interesting system to address this decision. We use an African cichlid, Astatotilapia burtoni, which both has a strong social hierarchy and maternally mouthbroods for around two weeks, protecting the fry for another two weeks post-release. We hypothesize that if dominance is positively correlated with ability to raise and defend fry, then less dominant fish are predicted to engage in filial cannibalism more often in order to recover energy. We used two assays to quantify dominance until the female consumed or consistently ignored their fry. For baseline measures, each pair of females was housed in a divided tank, allowing visual but not physical interaction with another female of matched brooding stage and dominance behaviors were tallied. For a more acute measure, after both females released fry, they were periodically moved to an arena for staged interactions. We found that when two brooding females are paired together less dominant fish are more likely to consume their fry than more dominant fish, providing evidence that social dominance positively correlates with parental success in A. burtoni.

## Hydrodynamic effects of oral arms on jellyfish locomotion

*Yunxing Su, Nicole Xu*

Jellyfish possess locomotive abilities that contribute to their low cost of transport, which allows them to be the most energy-efficient organism in the ocean. Despite extensive research on jellyfish locomotion, the specific contributions of their oral arms on swimming performance remains largely unexplored. To address this gap, we conducted a series of experiments comparing intact jellyfish to those with oral arms excised. Using particle image velocimetry (PIV) with biodegradable particles as tracers, we visualized their swim vortices and examined interactions with the oral arms – specifically, how the vortices and their induced flow impinging upon the oral arms. Because the vortex-induced jet propagated in the opposite direction of the jellyfish's trajectory, this interaction could introduce an additional drag force, potentially impeding locomotion and decreasing their swimming speed. To test this hypothesis, we conducted experiments on straight-swimming jellyfish to quantify their swimming speed both with and without oral arms. Preliminary results indicated that jellyfish achieve up to 30% enhancement of speed without their oral arms. We then expanded upon previous hydrodynamic models to predict these swimming speeds by incorporating the effects of oral arms on locomotion, and validated the model with experimental data. These results shed new light on the role of oral arms in jellyfish movement and their influence on marine fluid dynamics, enhancing our understanding of these ancient, efficient ocean-dwelling animals.

## Trends in the evolution of limb elements in the Eulipotyphla

*Catherine Suitor, Myleen Amendano, Maddie Cannistra, Tristan Stayton*

The mammalian order Eulipotyphla spans a wide range of body sizes (including the smallest extant terrestrial mammals) and ecological niches, with many semiaquatic and fossorial species and some scansorial or semiarboreal taxa. We examined morphological evolutionof four limb elements – scapula, humerus, innominate, and femur – in response to changes in body size and ecology. Approximately 75 specimens were examined per element. We photographed elements in consistent orientations, and digitized 2D landmarks on the images. We analyzed relationships between size and shape, between ecology and shape, and their interactions. Besides considering overall shape, we also examined muscle lever arms and other functionally-relevant aspects of shape. Surprisingly, but consistent with other results, we found no evidence for allometric trends in overall limb shape. There is evidence for ecological signal in overall shape, with the humerus and scapula showing strong differentiation in fossorial taxa (consistent with previous results). Additionally, certain functionally-relevant aspects of morphology showed allometric signal. Overall, changes in size of eulipotyphlan limb elements are associated with a range of changes in morphology. Ecology is a better predictor of overall shape, but size can also be used to predict the lengths of muscle attachments or lever arms. These results add to a growing consensus that Eulipotyphla may be subject to different selective pressures at different sizes, even in the face of consistent ecological pressures.

## Fossil synapsids reveal insights into the evolutionary origins and history of mammal-like dentitions

*Pranati Sukh, Megan Whitney*

The evolutionary transition from reptiles to mammals has been an area of interest due to the rich fossil record present. Characterized by transitional morphology, fossil non-mammalian synapsids offer a connection in understanding the origins of different mammalian traits. Mammalian teeth have long been considered particularly derived and specialized, specifically concerning tooth attachment, tooth replacement, and enamel structure. Here, we present data collected from over thirty clades of fossil non-mammalian synapsids that span the phylogenetic and temporal range of the lineage. These data include metrics related to the tooth replacement rate, enamel structure, and enamel thickness. We found that low tooth replacement levels correlate with a soft-tissue tooth attachment and enamel structure with prisms and columns. Further, replacement rates slowed over the course of synapsid evolutionary history, and while in Permian taxa, there was a wide range of tooth attachment and tooth replacement phenotypic combinations, Triassic taxa trend towards the more stereotyped mammalian condition in both of these dental features. These results suggest that the evolution of complex mammalian dental features may have been more complicated than a simple stepwise transition during the lineage's evolutionary history. Further, these results reveal that a shift towards a more mammalian dentition began across the Permian-Triassic boundary (∼252 mya) rather than at the origin of mammals (∼170 mya).

## Enhancing microclimate models with AI: from bias correction to spatial Interactions

*Idan Sulami, Alon Itzkovitch, Shimon Shahar, Michael Kearney, Ofir Levy*

Accurately predicting microclimates is essential for understanding species' responses to environmental changes, yet traditional models often lack the fine-scale resolution needed for precise ecological predictions. In this study, we developed a novel approach that combines drone-based data collection with artificial intelligence (AI) to improve microclimate modeling. By using high-resolution RGB and infrared imagery captured by drones, we generated detailed maps of terrain, vegetation cover, and thermal conditions. These maps were used as inputs for traditional physical models and advanced AI techniques, including Random Forests and Convolutional Neural Networks (CNNs), to enhance prediction accuracy.

Our findings reveal that AI can significantly reduce prediction errors, improving microclimate model accuracy by over 50%. Additionally, incorporating data from nearby pixels—rather than relying solely on single-pixel data—further enhanced model performance, indicating that heat exchange between adjacent areas plays a critical role in shaping local microclimates. These advancements not only provide more accurate tools for ecological research but also have significant conservation implications. Improved microclimate models can better inform strategies to mitigate the impacts of climate change and habitat loss, aiding in the preservation of biodiversity. Our next steps involve developing a system for broader use, allowing researchers and conservationists to generate microclimate predictions using their own data.

## Orientation of blacktip sharks (*Carcharhinus limbatus*) to underwater sound

*Caroline Sullivan, Edmund Gerstein, Stephen Kajiura*

Sharks respond to low frequency pulsed sounds but are thought to lack the capacity to detect these sounds beyond the acoustic near field. This study quantified the distance that blacktip sharks (Carcharhinus limbatus) oriented to sound stimuli and determined that responses could be consistently initiated from the acoustic far field. Populations of wild sharks were exposed to sound stimuli (100–200Hz; 200–400Hz; and 400–800Hz; 10kHz control) presented by an underwater speaker. The sound pressure levels (SPL) for all stimuli were measured in situ and used to model the propagation away from the source. This permitted direct calculation of the SPL at the point each shark initiated its response. Stimulus intensity was a minimum of 50dB above ambient to ensure that the sharks would respond. An aerial drone was used to film the shark's response and quantify the distance at which sharks reacted. When a sound was presented, blacktips elicited a sudden 20–160° turn away from the speaker, and rapidly swam away. Sharks responded to all frequencies from at least 62m, and 71.6% of all responses (n=209) occurred in the far field. Sharks never responded to the control stimulus of comparable volume. The ability of blacktips to detect and orient away from a sound stimulus at distances extending beyond the near field, suggests that they are detecting these sounds using a non-otolithic pathway.

## Rapid propulsion and maneuver by aquatic whirligig beetles (Gyrinidae)

*Yukun Sun, Emily Palmer, Aspen Shih, Christopher Dougherty, Chris Roh*

Water surface-dwelling whirligig beetles (Gyrinidae) are the fastest swimmers among insects. They are one-centimeter-long and can achieve a peak acceleration of 10g and top velocity of 100 body lengths per second. Their morphology has evolved to adapt to the hydrodynamic features of their surrounding environment. The propulsion mechanism of whirligigs has been previously studied by tethering them to a fixture, suggesting that their oar-like legs generate thrust through hydrodynamic drag. However, drag becomes insufficient in propelling the beetle forward in free swimming. Here we present whirligigs' (Dineutus discolor) locomotion mechanism in high-speed free swimming from our in vivo experiments. Firstly, we show that their thrust generation relies on lift rather than drag. The legs acting as hydrofoils had nearly no motion relative to the surrounding fluid along the axis of swimming. Instead, the legs were subjected to drastic transverse motions producing large lift.

Additionally, we present the mechanism behind whirligigs' maneuvering behavior for avoiding aerial predators. When threatened, they dive under water. However, it is not clear how vertical momentum is generated to enable rapid diving. Our experimental result shows that their rapid transition from free surface to full submergence is initiated by bending their abdomen. The new body conformation generates hydrodynamic torque, which orients the body suitable for diving.

## Correlating jaw muscle architecture with bite force in turtles using new digital methods

*Rohan Sundaran, Julia Molnar*

Turtles have various diets and feeding strategies related to their diverse habitats, including large or tough prey that require high bite forces. Ontogenetic increases in bite force are thought to be driven by changes in volume and pennation of jaw adductor muscles in turtles, but how these parameters vary across species is not known. To address this question, we studied three turtles with a range of bite forces and diets: the omnivorous black breasted leaf turtle, the durophagous loggerhead musk turtle, and the carnivorous alligator snapping turtle. Using contrast-enhanced micro-CT and algorithmic fiber tracing, we measured muscle volume and fiber length of the superficial jaw adductor muscles relative to head size. Surprisingly, we found very little difference in fiber length among the turtles. However, there was a strong positive relationship between the adductor cross-sectional area and bite force, driven by the volume of adductor mandibulae externus profundus. Our results indicate that interspecific differences in bite force are driven mainly by muscle volume rather than internal architecture. If this pattern proves broadly applicable, then osteological features such as the size of temporal emarginations and supraoccipital crests (which provide attachments for the external adductor muscles) could be considered predictors of bite force in turtles. This non-destructive approach can greatly increase taxonomic sampling and elucidate the relationships between skull morphology, muscle architecture and feeding performance across turtle evolution.

## Molecular regulation of seasonal adiposity in Japanese quails (Coturnix japonica)

*Sayantan Sur, Calum Stewart, Timothy Liddle, Irem Denizli, Tyler Stevenson*

Seasonal timing depends on an endogenous circannual clock entrained by environmental cues. Photoperiod is a robust predictive cue that influences lipid accumulation in metabolic organs. Growth hormone (GH) release from the pituitary gland can induce photoperiodic signaling to drive adipogenesis and body mass change. In many seasonally breeding species, circulatory GH levels increase during the breeding season. To understand the molecular regulation of adiposity we housed Japanese quails in laboratory conditions and exposed birds to a semi-natural autumnal decrease in daylength followed by a vernal increase in daylength to mimic seasonal changes. High throughput Nanopore GridION sequencing was performed in adipose and liver tissues. Transcript expression was conducted to measure hepatic GH receptor (GHR) expression. We observed increased adipose weight, adiposomatic index, and adipocyte area in vernal long days. RNAseq analyses of adipose tissue showed enrichment of lipid localization, lipid transport, and aerobic respiration pathways. The transcriptomic analyses identified several genes in both the liver (eg., CD36, PDK4, FASN, FADS2) and adipose tissue (eg., VLDLR, IGFBP2, APOD) involved in lipid metabolism which shows robust seasonal changes. We propose that vernal GH secretion and not the change in GHR abundance signal the metabolic organs. Furthermore, long-day-induced upregulation of both positive and negative adiporegulators drives nonpathological adipogenesis. Overall, our data can be used to identify conserved pathways that regulate seasonal adipogenesis.

## Marine Microbes as Sources of HDAC Inhibitors: Ecological and Bioactive Insights

*Julia Sutton, Alexander Bogdanov, Paul Jensen, Douglas Sweeney*

This research investigates marine microbial communities to identify potential histone deacetylase (HDAC) inhibitors. Cryopreserved bacterial strains from diverse marine environments were cultured in one-liter liquid media to produce crude extracts for analysis. These extracts were fractionated and tested using high-performance liquid chromatography (HPLC) to examine their bioactive properties. Notably, one crude extract exhibited bioactivity even before fractionation, indicating a potent ecological interaction driving its production. Following purification, HPLC revealed a single peak with continued bioactivity, suggesting the presence of a strong HDAC inhibitory compound.

Marine microbial compounds are increasingly recognized for their role in regulating epigenetic mechanisms, which are crucial in ecological interactions such as microbial competition, symbiosis, and defense. This research highlights the relationship between microbial morphology, ecological pressures, and the production of bioactive compounds that contribute to survival and adaptation in complex marine ecosystems. By studying these microbial communities, we gain insights into how environmental factors shape chemical diversity and bioactive potential, emphasizing the importance of ecological development and ecoimmunology in understanding how marine organisms utilize bioactive compounds.

These findings contribute to the growing field of marine natural product discovery, revealing the adaptive strategies and chemical diversity present in marine microbial communities, and underscoring the untapped potential of marine-derived compounds for ecological and biotechnological applications.

## Exploring neural mechanisms of cold acclimation in dark-eyed juncos

*Serina Suzuki, Cory Elowe, Maria Stager*

Peak oxygen consumption under cold exposure (Msum) is often used as a proxy for thermogenic capacity, with many bird species showing an increase of 10–50% in Msum during winter. This remarkable cold acclimation often involves several functional changes, such as enlarged thermogenic organs like pectoral muscles, enhanced cellular aerobic capacity, upregulated genes related to muscle growth, angiogenesis, and metabolism, as well as increased enzyme activity. Although research is gradually assembling pieces of the mechanistic puzzle, significant variation across species and experimental conditions remains unresolved. Surprisingly, there is a notable lack of research on neural-level changes underpinning these adaptations. To address this gap, we investigated changes in gene and protein expression in the brains of wild Dark-eyed Juncos (Junco hyemalis) during cold acclimation. Dark-eyed Juncos, also known as the ‘snowbirds,’ increase Msum in as little as one week with cold exposure. Specifically, we hypothesized that neurogenesis occurs during cold acclimation and contributes to enhanced thermogenesis. We exposed juncos to cold (-5 C) or control (25 C) temperatures for one week while quantifying body temperature, oxygen consumption, and food consumption continuously. We then conducted brain immunohistochemistry for PCNA, a marker of neurogenesis. Additionally, we performed region-specific RNA sequencing to identify genes with altered expression in the brain during cold acclimation. By integrating across these different measures, we aim to uncover the neural mechanisms underlying avian cold acclimation.

## Microbes Matter in Adaptation: Phenotypic Effects of Microbiota in Wild House Mice

*Taichi Suzuki*

Natural selection targets phenotypic variation, influenced by genetic and environmental factors, including the microbiome. While selection on soil microbiomes can alter plant phenotypes, it remains unclear whether selection on gut microbiomes alters animal phenotypes. We addressed this question in a mammal. First, we demonstrate a list of host traits that are likely involved in local adaptation and may be mediated by the microbiome in natural populations of house mice across latitudinal and altitudinal transects in the Americas. We then characterized host traits phenocopied upon the transfer of the gut microbiome from two wild-derived mouse lines to germ-free recipients. Population differences in activity behavior were most strongly controlled by the microbiome. In a selection experiment, microbiomes of mice with low activity were serially transferred to five cohorts of separately bred germ-free mice. Microbiome selection significantly reduced host activity, concurrent with changes in microbiome diversity and metabolism. Our results show that selection on microbiome function alone can drive adaptive host trait shifts independently of changes to the mammalian genome.

## The tale of degenerate ascidian tails

*Billie Swalla, Sydney Popsuj, Lenny Negrón-Piñeiro, Anna Di Gregorio, Alberto Stolfi*

Ascidians are invertebrate chordates and develop into chordate tadpole larvae, with a head containing sensory organs and a tail with a notochord, dorsal neural tube, and muscle cells. However, in the Molgulidae, both the larval tail and pigmented otolith have been lost multiple times independently during evolution. The transcriptome of taillesss Molgula occulta embryos at different stages was sequenced and analyzed, compared to a closely related tailed species, Molgula oculata and to hybrid embryos obtained from tailless eggs fertilized with tailless species sperm. Larval tails are formed through convergent extension and then swelling of 40 notochord cells. This process fails to occur in tailless molgulid species, leaving a "notoball", a 20-cell aggregate, expressing many of the notochord genes. We are studying the breakdown of the larval gene regulatory networks that lead to the lack of functional tissues in tailless ascidians. We have discovered that a maternal SHARK tyrosine kinase, the larval muscle actins and the larval tyrosinase genes have become pseudogenes and produce nonfunctional RNAs and proteins in the tailless embryos. Therefore, the intact tailed paternal genes can rescue the function of the pseudogenes in the hybrid embryos. We have found both the neural and notochord larval gene regulatory networks are intact in the tailless species, M. occulta, but we have found some broken links and are examining how they are restored in the hybrids.

## Combat consequences: quantifying weapon damage in the leaf-footed bug *Acanthocephala femorata*

*Juliana Swanson, Zachary Emberts*

Many animals that directly compete with one another over access to mates and resources have sexually selected weapons. These weapons are used to physically attack their rivals. Thus, weapons can wear out and break. Possessing a damaged weapon can decrease an individual's fighting ability. Despite this consequence, both the frequency of damaged weaponry observed in the wild and our ability to predict which individuals are more likely to have broken weapons remains understudied. To address this gap in knowledge, first we quantified the frequency of weapon damage observed in a wild population of Acanthocephala femorata. Males of this species use their enlarged, spine-ridden hind legs to squeeze and pierce rival males. As a result, the hind leg spines can wear out and break. After quantifying spine damage, we conducted a few correlations (e.g., with body size and weapon shape) to investigate why only some individuals have broken weapons.

## Temperature Independent Prodigiosin Reduction by Bd Metabolites

*Morgan Swanson, Jacob Kerby*

The pathogenic fungus Batrachochytrium dendrobatidis (Bd), has been responsible for worldwide amphibian mortality events. A key defense element of the amphibian against Bd is the microbiota living in symbiosis with the amphibian. Bacterial symbionts are capable of the production of antifungal metabolites which can act in concordance with the innate immune response to stave off Bd. However, Bd also produces a full metabolite profile with which it can influence changes in the host immune response. The direct effects of these Bd metabolites on the bacterial symbionts with which it competes is presently understudied. We tested two different isolated strains of Serratia marcescens, a noted anti-Bd symbiont producing an antimicrobial pigment called prodigiosin, by growing the strains in serial dilutions of Bd metabolites grown across the temperature gradient that Bd is capable of surviving. UV-vis spectrophotometry was used to observe the relative production of prodigiosin over the course of 7 days. We discovered the reduction of prodigiosin increased in both strains as the concentration of Bd metabolites increased and that this occurred regardless of the temperature in which the S. marcescens and Bd were cultured. S.

marcescens was then tested via stress assays against specific Bd metabolites that have previously demonstrated modulatory effects. The quorum sensing molecule tryptophol ultimately produced results most similar to what was seen previously in the study.

## Information networks underlie divergent schooling behaviors of Neotropical tetras

*Nathan Swanson, Ashley Peterson, Christopher Martinez, Matt McHenry*

The study of social behaviors, like fish schooling, is crucial for understanding the ecological processes and evolutionary pressures that promote group cohesion and cooperation of individuals. Despite the importance of schooling in fishes, we know little about its variation across related species. A comparative assessment of schooling in multiple species is necessary to begin understanding the diversity that exists for this behavior. We quantified schooling kinematics and associated information network properties across five closely related species of South American tetra (Characidae) in the subfamily Stethaprioninae. With our analysis, we aimed to identify divergence in the kinematics of schools across closely related species and highlight specific network properties which may contribute to such variation. Examination of kinematic traits revealed that faster swimming species with less intermittent movements tend to form schools with greater polarization, (i.e., coordination of individual headings), but vary in the amount of spacing between fish and the collective tendency to swim in a circular motion. In addition, analysis of network properties indicated that stronger, more polarized schools are achieved by more cohesive, homogenous and efficient networks. These results suggest that communication and network organization play a pivotal role in the modulation of schooling kinematics and the expression of a fundamental collective behavior in fishes.

## Territorial contests and snapping claw morphology in kelp forest snapping shrimp

*Megan Sward, Amelia Fuentes, Patrick Green*

Understanding how animals interact with conspecifics provides insight into how animal behavior impacts ecosystems. Contests can occur over access to limited essential resources such as food and territory, with contest winners gaining access to these resources. Contests drive aspects of resource ecology: how individuals in populations utilize resources. Alpheus clamator, the "twistclaw" snapping shrimp, is abundant off the Santa Barbara, California coast. Over 50 individuals can live in a single kelp holdfast or in complex networks created by tubeworms. Both sexes have enlarged claws with rotated dactyls that "snap" with bullet-like speeds, stunning prey and potentially crippling competitors. To understand A. clamator contest behaviors and what factors determine contest success, we staged contests between 40 sex-matched pairs who competed over burrow territories. Preliminary findings indicated that animals with larger body sizes are more likely to win, matching common findings in animal contest research. Analysis of snapping claw morphology from 219 individuals indicates that claw length scales with positive allometry, as expected in animal weapons. Claw length did not predict fighting success, suggesting that the snapping claw might not function in contest resolution. Future analysis will analyze contest behaviors using a newly-developed ethogram and ask what physical factors influence contest behaviors. This study provides insights into conflict resolution strategies in animals with potentially deadly weapons, and the implications of contests for resource use and the ecology of kelp forests.

## Exploring biological diversity at multiple trophic levels to better respond to vector-borne diseases

*Andrea Swei, Heather Broughton, Shannon Summers, Grace Shaw, Arielle Crews, Marie Lilly*

The emergence of infectious diseases is largely driven by spillover events from animal communities into human populations, with zoonotic pathogens accounting for 75% of novel infectious agents. In recent years, incidence and prevalence of these pathogens is on the rise and efforts to understand the underlying ecological principles responsible for the reported increase have highlighted the role of biodiversity loss as a major contributing factor. Despite its role in pathogen emergence, how biodiversity is measured can differ drastically and may underly variability in study results, making the impacts of biodiversity on pathogen behavior difficult to untangle. Here, we discuss the ways that different aspects of biodiversity, such as functional, phylogenetic, and trophic diversity, can provide novel insight into the relationship between host communities and disease emergence and transmission. Specifically, we focus on the tick-borne pathogen that causes Lyme disease in this review and highlight the role of predators in host community structure and disease transmission to discuss the ways that intact trophic interactions can lead to pathogen regulation. In addition, the growing public health burden of tick-borne diseases necessitates both holistic thinking as well as ecologically-informed actions to decrease the risk of disease to humans and protect natural communities, making this topic highly applicable to interdisciplinary scientists.

## How different body configurations affect perturbation resistance in arboreal lizards

*Savannah Swisher, Amanda Kellerhals, Trevor Brewington, Victor Munteanu, Richard Blob*

Animals often must contend with unexpected changes in their habitat and environment. In an arboreal habitat, failure to implement corrective behaviors in response to such changes (e.g., perch perturbations) can result in high risk of injury or death upon falling. However, many arboreal animals exhibit morphological features that might alter the mechanics and types of corrective behaviors that are used to resist falls. To better understand how arboreal animals accommodate perturbations in their habitat, we subjected three species of arboreal lizard, representing three distinct body configurations, to a series of simulated perch perturbations that were recorded using high-speed cameras: Chamaeleo calyptratus (tall-bodied), Gastropholis prasina (low-bodied, long tail), and Anolis equestris (low-bodied, shorter tail). Videos were then analyzed to calculate three-dimensional kinematic variables, including forelimb and hindlimb angles, and center of mass tortuosity. Chameleons maintain more acute and consistent limb angles throughout perturbation events than the other species, and the path of the center of mass through space is less tortuous and chaotic for chameleons than it is for the other species. These results suggest that arboreal specializations in some species may compensate for body configurations in which the center of mass is held far from the substrate, which are more prone to instability.

## Functional Morphology of Red Sea Urchin (Mesocentrotus fransiscanus) Spines

*Sarah Synan, Stephanie Crofts*

For red sea urchins (Mesocentrotus fransiscanus), spines can be used for defense, stabilization, and movement, though the importance of each function may change as the urchin grows. Here we examine the changes in urchin spine size, shape, and function over a range of test sizes (22.2 mm to 154.7 mm) to detect potential functional trade-offs across ontogeny. To determine changes in spine size and shape, we measured length and width for each spine. We focused on two measurements of spine function: resistance to bending and puncture ability. To quantify changes in resistance to bending, we estimated the 2nd moment of area at the midpoint of each spine. We measured the applied force required for spines to fracture a medium in order to quantify puncture ability. Spine length grows in proportion to test size, though spine width grows slower. 2nd moment of area also increases more slowly than test diameter grows. Puncture ability declined more slowly than would be predicted by test diameter growth. Differences in spine dimensions and performance across ontogeny suggest that it is more useful for red sea urchins to invest energy into growing spines longer than it is for them to grow spines stronger. This may be to prioritize functions of length, like movement and outgrowing gape-limited predators.

## The Link Between Male Aggression and immunity: A Critical but Negelcted Life-History Trade-Off

*Sydney Szwed, Benjamin Sadd, Scott Sakaluk*

Life-history theory posits that organisms distribute limited resources among growth, maintenance, and reproduction. Across systems, male aggression determines access to females and hence reproductive success, whereas immunity contributes to maintenance, ensuring survival and future mating. We hypothesize that there is a trade-off between investment in aggression and immunity. This trade-off could be realized through one of two non-mutually exclusive routes, with immune investment determined by either an intrinsic difference in male investment in aggression and immunity, independent of their deployment, or through direct costs of competitive interactions. This study investigates the nuances of the aggression-immunity trade-off in male field crickets, Gryllus assimilis, to determine, (i) whether the outcome of aggressive interactions is associated with baseline immune investment, and (ii) how engaging in aggression affects future immunity. Male aggression is being quantified and combined with assays of cellular and humoral immunity. We predict lower baseline immunity in subsequently dominant males compared with subordinate males, demonstrating an intrinsic cost of investing in aggression. Additionally, we predict that engaging in aggression will decrease immunity relative to control males, with the reduction more pronounced in higher investing, dominant males. This work will provide important insights into a frequently assumed, but little studied, trade-off between aggression and immunity. An integrative assessment of this trade-off will contribute to our understanding of factors maintaining variation in immunity and other life history traits.

## You can hide but you can't run: glass frogs hide their red blood cells for transparency

*Carlos Taboada, Jesse Delia, Sonke Johnsen*

Whole-body transparency is a ubiquitous form of camouflage in pelagic species, and is also found to a lesser extent in benthic and terrestrial habitats. It requires multiple adaptations to reduce light absorption and scattering, but a particular challenge in many species is light attenuation by the blood cells in the vasculature. Earlier work on the glass shrimp (Palaemonetes pugio) showed that it maintained its transparency at rest by restricting blood flow to its abdominal musculature and thus reducing light scattering within this tissue. Given the strong light absorption by the hemoglobin found in vertebrate red blood cells (RBCs), we hypothesized that a similar process may occur in neotropical glassfrogs (Centrolenidae), which are highly transparent when at rest, but far less so when active. Using spectroscopy, optical modeling, and in vivo photoacoustic imaging, we show that resting glassfrogs increase their transparency two- to threefold by removing ~90% of their RBCs from circulation and temporarily storing them in their mirrored liver. This mechanism seems to be an exaggerated form of the ability of certain frogs to store RBCs in this fashion, suggesting it may have been co-opted for camouflage. Furthermore, glassfrogs' ability to regulate the location, density, and packing of RBCs without clotting offers potential insight into metabolic, hemodynamic, and blood-clotting research.

## Metachronal mechatronics: Exploring metachronal swimming performance with bioinspired robotics

*Nils Tack, Diego Delgado, Monica Wilhelmus*

Many of the most abundant aquatic invertebrates swim metachronally by sequentially beating closely spaced flexible appendages. This commonality across taxa and scales promotes high efficiency and hydrodynamic performance compared with single-propulsor systems, likely optimizing the tradeoff between thrust, drag, and maneuverability during swimming. Biological and robotics studies have been invaluable in evaluating the fluid-structure mechanisms enhancing thrust. Yet, despite the emergence of innovative methods to study metachronal propulsion, we still need a comprehensive overview of the morphological, functional, and physical mechanisms promoting drag reduction and enabling maneuverability in a three-dimensional environment. Using in-vivo and $\mu$CT measurements marsh grass shrimp (Palaemon vulgaris), our model organism, we designed a morphologically accurate, modular metachronal robot in which morphological and swimming parameters can be manipulated independently. Simultaneous flow and force measurements showed that integrating passive appendage asymmetrical bending reduces the appendage (pleopod) drag coefficient by up to 75.8% relative to stiff legs. Combining these effects with pleopod coalescence during the recovery stroke enhances net thrust production by 30.2%. By untethering the robot and independently manipulating kinematics parameters such as inter-pleopod phase lag and beat frequency and amplitude, we can generate pitching and yawing moments to evaluate how metachronal organisms maneuver. Our methods and results shed light on fundamental biological and physical principles of metachronal propulsion that may aid in developing a unifying theory and inspire novel bio-inspired underwater vehicles.

## Endocrine flexibility can facilitate or constrain the ability to cope with global change

*Conor Taff, Maren Vitousek*

As a consequence of global climate change, animals are exposed to both more extreme and more variable temperature regimes. Some populations or species are able to cope effectively with these changes, while others are negatively impacted. In some cases, altered phenology, morphology, or behavior appears to keep pace with climate change, while in other cases these shifts are inadequate. Endocrine flexibility is one proximate mechanism that might play an underlying role in these shifts. While understanding flexibility in endocrine regulation has been a focus over the last decade, relatively little is known about whether it plays an important role in facilitating or constraining the ability of individuals, populations, and species to cope with a changing climate. Here, we first review approaches to studying endocrine flexibility. Next, in describing our work on tree swallows (Tachycineta bicolor), we illustrate the challenges that have limited our ability to connect conceptual frameworks with empirical studies at the individual level. Finally, we describe the results of our recent simulations and comparative studies investigating variation in the scope and speed of flexibility. We argue that a combination of empirical, simulation, and theoretical work along with studies taking both a between-individual and comparative approach are needed in order to understand when endocrine flexibility acts as a motor or a brake on climate adaptation.

## Kisses, cuddles, and near misses: mating behaviors in a nudibranch sea slug

*Cheyenne Tait, Kristina Nedeljkovic, Meagan Olson, Paul Katz*

Many gastropods are hermaphroditic, known for their outrageous mating behaviors, including the use of "love darts" and traumatic insemination. Nudibranch sea slugs, in particular, are known for whole or partial cannibalism between partners. Here, we studied the mating dynamics of the nudibranch Berghia stephanieae. Pairs of individuals were often observed to “cuddle” together for many hours, beginning by holding onto each other’s mouths, or “kissing”. This contrasted with many of the flashy, risky mating seen in other nudibranchs. We systematically characterized the behaviors leading up to and out of the clasping behavior seen between pairs of Berghia, finding that copulation lasts for mere seconds in the middle of the sequence. We speculate that pre- and post-copulatory time periods are dynamic arenas for mate choice, mate competition, and mate guarding. Synchronization of behaviors between individuals is vital for copulation to occur successfully; for example, we captured instances of one individual striking an expectant pose only to be rejected by the other. Our next steps include looking for central and peripheral neural and hormonal factors coordinating these interactive behavioral sequences.

## Exposure to polyethylene microplastics effects dragonfly (*Tramea sp.*) nymph respiration

*Kai Takenaga, Anna Gregg, Steven Lane*

Through litter and stormwater runoff, plastic is polluting our waterways. Once there, these plastics break down into microplastics, which can accumulate within aquatic organisms over time. Although microplastic accumulation has been shown to affect growth, behavior, and survivorship, few studies have tested their effects on respiration. Here, we tested how polyethylene microplastics (MP) affect the oxygen consumption in dragonfly nymphs (Tramea sp.). Dragonfly nymphs can accumulate microplastics through tidal ventilation, whereby they draw in water through their anal pyramid and microplastics can accumulate on their gills. Dragonfly nymphs were exposed to three concentrations of microplastics: 0 MP L-1 (control), 197000 MP L-1 (low), and 1970000 MP L-1 (high) for 48 or 168 hours. Following exposure, we measured oxygen consumption and density of external and internal microplastics. After 48 hours, a higher density of internal and external microplastics were found on nymphs exposed to the high concentration. However, oxygen consumption did not vary between the groups. After 168 hours, individuals exposed to high concentrations consumed oxygen faster than those in the control and low concentrations, which were not significantly different. Trials to compare internal and external microplastics after 168 hours are still ongoing. Dragonflies can spend up to five years as aquatic nymphs, therefore the impact of short-term exposure observed here can have significant long-lasting impacts on their development.

## Does tolerance of infection in a songbird host predict responses to subsequent pathogen exposure?

*Katherine Talbott, Anna Perez-Umphrey, Amberleigh Henschen, Francis Tillman, Julia Weil, Jesse Garrett-Larsen, Dana Hawley, Arietta Fleming-Davies, James Adelman*

Tolerance of infection is quantified as the relative fitness declines that hosts experience per unit pathogen load, with more tolerant individuals showing relatively low pathology at a specific pathogen load. Selection is expected to favor some level of tolerance, yet wide variation in host pathology exists. Thus, it’s possible that the costs and benefits of tolerance vary based on the number of exposures to a particular pathogen. We investigated how tolerance influences reinfection likelihood using house finches (Haemorhous mexicanus) infected with Mycoplasma gallisepticum (‘MG’), a bacterial pathogen characterized by partial immunity and high rates of reinfection in the wild. Using finches from two populations with documented differences in tolerance, we experimentally inoculated finches sequentially with MG, allowing recovery between exposures. From these data, we explore whether the degree of tolerance following primary inoculation predicts susceptibility to reinfection or tolerance during reinfection. Preliminary results suggest that higher tolerance to primary infection is associated with a reduced likelihood of reinfection; however, tolerance to primary infection does not predict the degree of tolerance to secondary infection. Furthermore, while finches show population differences in tolerance of primary MG infection, there is no such relationship for secondary infection. Understanding temporal variation in costs and benefits of tolerance will help inform predictions about phenological trade-offs in host immune function, as well as the evolution of infection response strategies in vertebrate hosts.

## Microbial communities experienced during early development shape the host immune system and epigenom

*Amy Tan, Katherine Buckley, Marie Strader*

Ocean warming can alter microbial communities, leading to increased bacterial loads and pathogen spread, making it imperative to understand how this impacts physiological and molecular traits in marine organisms, as well as their immune function. We examined how early developmental exposure to high temperature and host-associated microbes impacted larval morphology, immune cell development, and the epigenome of the purple sea urchin (Strongylocentrotus purpuratus). Embryos were reared in four conditions: ambient or elevated temperatures (14°C or 18°C) and two levels of microbial content (sterilized artificial sea water (SASW) or microbiome exposed (MBE)). Larvae cultured in SASW or at 18°C were larger and had more pigment cells (one type of immune cell) at 5 days post fertilization than MBE larvae. MBE larvae had increased open chromatin regions whereas temperature altered very few chromatin regions but was associated with more differentially expressed genes (DEGs). GO enrichment based on DEGs showed that temperature and microbial content regulate processes such as translation, chromatin organization, and stimulus response in opposing directions. Overall, we show that early developmental environments strongly influence whole organism and molecular phenotypes, with early exposure to microbes altering host immune cells and epigenome. With the potential for marine environments to dramatically shift, these results reveal mechanisms behind how a keystone invertebrate species could acclimate to changing environments.

## Short Photoperiod and Endogenous Regulation of Brown Adipose Tissue in Siberian Hamsters

*Avalene Tan, Sayantan Sur, Calum Stewart, Tyler Stevenson*

Brown adipose tissue (BAT) plays a critical role in non-shivering thermogenesis and metabolism. BAT is composed of multilocular lipid droplets and mitochondria containing uncoupling protein 1 (UCP1). Exposure to winter's short photoperiod (SP) increases BAT function, but limited studies have investigated how prolonged exposure to SP influences BAT in seasonal animals. The current study aimed to explore changes in BAT morphology following exposure to SP to better understand endogenous seasonal timing regulators. In this study, thirty male Siberian hamsters (Phodopus sungorus) housed in long photoperiod (LP; 16L:8D) were moved to SP (8L:16D) and harvested at 8, 16, 24, and 32 week intervals (N=6). The analysis revealed a larger ratio of lipid to mitochondrial BAT components in LP animals, with significant decreases between LP and SP-16 ($p=0.031$) and LP and SP-24 ($p=0.046$). Examination of lipid droplets revealed no significant difference in perimeter or feret diameter, but significant decreases in area and increases in droplet count between LP and SP-16 and LP and SP-24 were observed. These physiological trends began reversing by SP-32 despite maintenance of SP. Such results suggest BAT morphology in seasonal animals becomes more thermogenically advantageous by developing a larger quantity of smaller sized lipid droplets during SP. Furthermore, endogenous seasonal regulators may be contributing to the reversion pattern after SP-24.

## Adhesive performance of four species of sea urchins inhabiting contrasting habitats

*Shakina Tanjong, Austin Garner, Alyssa Stark, Carla Narvaez Diaz*

Sea urchins possess hundreds of mobile appendages called tube feet which are connected to the animal by a proximal stem and a distal disc. The disc secretes an adhesive for attachment and a de-adhesive for detachment allowing for temporary adhesion. Tube feet coordination allows urchins to evade predators, forage, and withstand hydrodynamic forces. We assessed the adhesive performance of four urchin species: Strongylocentrotus purpuratus (purple), Mesocentrotus franciscanus (red), Strongylocentrotus droebachiensis (green), and Strongylocentrotus pallidus (white); to determine if their contrasting habitats influence their adhesion performance. Purple and red urchins are typically found in more exposed habitats, while green and white urchins inhabit deeper, more sheltered habitats. Adhesive performance was assessed by measuring: 1) whole animal adhesive force (force needed to remove an urchin from a substrate), 2) disc adhesive force (force required to detach a disc), 3) stem breaking force (force needed to cause material failure), 4) disc tenacity (disc adhesive force per unit area), 5) righting behavior (time required for an urchin to flip itself), and 6) the number of tube feet used for whole animal adhesion. Purple urchin exhibited superior performance across most variables followed by the red urchins. Green urchins showed intermediate performance, while white sea urchins demonstrated the lowest performance. These results suggest that urchins from more exposed habitats may have evolved more effective adhesive mechanisms compared to those from sheltered habitats.

## Regulation of Diapause Gene Expression by the Vitamin D Receptor (VDR) in Annual Killifish, Austrofundulus limnaeus

*Rosalia Tanori, Amie Romney, Jason Podrabsky*

Austrofundulus limnaeus, a species of annual killifish found in unpredictable temporary habitats in South America, has a profound ability to survive long periods without water and oxygen. This tolerance is associated with the ability to enter metabolic dormancy associated with diapause. An interplay of genetic and environmental factors governs entrance into diapause and tolerance of environmental stress. The vitamin D receptor (VDR) is among these factors and plays a crucial role in determining if an embryo will enter diapause or actively develop. My work aims to use a CUT&RUN assay to identify the genomic locations where VDR proteins bind to DNA and alter gene expression, under conditions that induce diapause and those that do not. A custom anti-VDR A. limnaeus antibody was validated for CUT&RUN through western blotting, and in situ hybridization, confirming its ability to specifically interact with the VDR protein in vivo. This study will provide insight into molecular processes that support metabolic dormancy and survival of extreme environmental stresses.

## Sexual dimorphism in the vestibular system of the North American river otter

*Erika Tanquilut, Hansan Jones, Heather Smith, Celeste Delap, Dominik Valdez, Leigha Lynch*

Previous research has demonstrated that variation in mammalian behavior and environment among species correlates with variation in the vestibular system. Yet, very little is known about how behavioral variation influences this system intraspecifically. Sexual dimorphism provides an ideal model to test this question, as many species exhibit variation in behavior and environment between sexes. Using the North American river otter, Lontra canadensis, as a model taxon, our research addresses this gap by analyzing shape variations in the vestibular system among a single wild population collected in Arkansas in 1982-1983. We obtained micro-CT skull data for 32 specimens (16 females, 16 males). Using Avizo software, we segmented the vestibular system by isolating the negative space within the bone. We then quantified shape variation using 3D geometric morphometric landmark data (11 primary landmarks and 109 semilandmarks). A Procrustes ANOVA of the landmark data revealed no significant shape differences in the vestibular system between males and females. We found this observation intriguing, given the notable differences in shape between sexes in the skull and brain previously quantified in this region. This suggests that the morphology of the surrounding bone preserves the inner ear orientation and shape. Further investigation incorporating linear measurements and volume data may allow us to determine how males and females have preserved similar vestibular morphologies despite differences in the temporal bone.

## Using whole genome sequencing by-catch to find blood microbes across populations of gopher snake

*Stephen Tansie, Tonia Schwartz*

Studies have shown that the types and load of microbes that host species carry are dependent on their ecology, including diet and environmental conditions. Blood is argued to give an accurate representation of microbial load of host species. The goal of this study is to characterize the diversity and distribution of blood-borne microorganisms in the gopher snake, Pituophis catenifer, using whole genome sequencing data from the host blood DNA. We aim to understand how ecology, environment, and population divergence influence the composition and distribution of blood-borne microbes between island and mainland gopher snakes. Twelve gopher snakes from the Channel Islands, Santa Rosa and Santa Cruz, and two California continental sites were sequenced at 60X coverage on the Illumina platform. “By-catch” sequences (those that did not map to the gopher snake reference genome assembly) were extracted and analyzed using kraken2 custom database built from NCBI database to assign taxonomic labels, and bracken to calculate relative abundances of the microbial sequence reads. Preliminary mapping returned results for viruses, and bacteria of varied taxonomic phyla from the blood of both island and mainland gopher snakes. A notable viral sequence discovered was Taterapox, which has been associated with North African gerbils. We are working to validate this result. We will present our approach and additional results from ongoing analysis including alpha and beta diversities and a metagenome-assembled genome (MAG).

## Force awakens: exploring reinnervated guinea fowl force-frequency dynamics

*Rubi Tapia Rayo, Caitlin Bemis, Marie Schwaner, Dean Mayfield, Manny Azizi, Monica Daley*

Surgical self-reinnervation can be a useful manipulation for investigating neuromechanical control mechanisms in locomotion. Self- reinnervation results in short-term muscle paralysis followed by motor recovery, with long-term loss of proprioception in the reinnervated muscle. We have found several changes in gait kinematics, motor control and in vivo muscle function following self-reinnervation of the lateral gastrocnemius (LG) in guinea fowl. We previously hypothesized that these changes might relate to shifts in connective tissue compliance, muscle fiber types or intrinsic properties. To investigate the mechanisms underlying the observed differences in muscle function and gait between intact and reinnervated guinea fowl, we measured the force kinetics in fixed-length contractions over stimulation frequencies from 5-150Hz. We analyzed the characteristics of the sigmoid force-frequency curve and measured the half activation and deactivation times. Initial analysis indicates that intact guinea fowl LG fuse tetani responses at lower frequencies than reinnervated guinea fowl. This result would be consistent with observations that reinnervated birds have higher LG muscle-tendon force and ankle stiffness at the swing-stance transition in locomotion, when activation generally occurs. Preliminary analysis suggests no significant differences in activation kinetics of reinnervated LG and suggest that plasticity in the connective tissues contributes to the observed changes in in vivo muscle function. Funded by NSF-IOS 2016049, DBI-2319710

## Male polymorphism in harvestmen (Arachnida, Opiliones): an integrative approach

*Pietro Tardelli Canedo, Shahan Derkarabetian, Tom Nguyen, Hannah Wood, Gonzalo Giribet, Gustavo Hormiga*

Neopilionidae is a circum-Antarctic family of harvestmen notable for its common occurrence of male polymorphism. In Forsteropsalis and Pantopsalis, two genera endemic to New Zealand, male polymorphism is expressed through variations in the length and width of chelicerae (grasping appendages used for feeding and mating). However, our understanding of the evolutionary history and mechanisms underlying these traits is sparse. Using phylogenomics, micro-CT scans and cheliceral measurements, we employ an integrative approach to unravel the evolutionary patterns in the form and function of cheliceral polymorphism in Neopilionidae. We describe the inter- and intraspecific variation in muscle architecture and the respective physiological cross-sectional area (a proxy for force), elucidate the evolutionary history of male polymorphism across Neopilionidae, and investigate genus-wide correlation patterns between juvenile leg loss and male morph determination. Ancestral state reconstructions using our UCE-based phylogeny show multiple independent gains but few losses of male polymorphism within and across neopilionid genera. Multidimensional muscle modeling highlights the different force potentials for each male morph, suggesting that differential fitness and alternative reproductive tactics govern aspects of its mating system. This finding is further supported by a strong correlation between reduced morphs and juvenile leg loss in Forsteropsalis and Pantopsalis. Our work highlights the outstanding degree of morphological diversity observed in Opiliones and describes one of the more unique examples of male polymorphism in this order of arachnids.

## Cnidarian circadian clocks model how animals find predictability in a complex world

*Ann Tarrant, Cory Berger*

Behavioral and physiological plasticity enable organisms to modulate biological processes in response to environmental conditions and improve their fitness. Circadian clocks are a fundamental mechanism through which organisms anticipate and respond to dominant daily cycles in light, temperature and other environmental features. Clocks regulate daily cycles in behavior and metabolism, and in some animals, this includes strong causal relationships between daily activity cycles and metabolic demands. Several components of animal circadian clocks are uniquely shared between cnidarians and bilaterian animals, and the complexity of sensory systems and circadian regulation have increased in parallel within these groups. However, the specific drivers of this innovation, and potential evolutionary correlations between sensory and circadian systems, are poorly known. This review examines the diversity of circadian regulation in cnidarians in a comparative context with a specific emphasis on environmental entrainment. We discuss current knowledge of circadian entrainment in cnidarians and how this compares to clocks in other animals and non-metazoans; and how this relates to organismal properties of clocks such as robustness and redundancy of the circadian system. We also look forward to how emerging methods and creative approaches can be applied to improve our understanding of how environmental signals are perceived by cnidarians and integrated into the circadian regulatory machinery.

## Genome analysis of Aeromonas hydrophila strain S14-452

*Zarin Tasnim Raya*

The Aeromonas hydrophila are gram-negative, opportunistic bacteria that can infect many groups of organisms, mainly fish and amphibians. In channel catfish, A. hydrophila causes fatal bacterial septicemia, leading to massive economic losses for catfish farmers. Therefore, an understanding of its genome will aid in identifying its virulence factors, metabolic pathways and survival mechanisms within the host. This study details the draft genome sequence of A. hydrophila strain S14-452, isolated from channel catfish exhibiting bacterial septicemia during a disease outbreak at a catfish farm.

A. hydrophila strain S14-452 was sequenced using the Illumina iSeq 100 System. Assembly was performed with SPAdes, producing 218 contigs which were annotated using the Rapid Annotations Subsystem Technology (RAST) server and the SEED viewer. The draft genome comprises 5,047,785 bp and has a G+C content of 60.8%. It has 5,013 predicted genes, of which 4,903 are coding sequences (CDS), 110 tRNA, and 5 rRNA.

## Axial twist: A flying snake's secret weapon for jumping?

*Joshua Taylor, Jeffery Anderson, Joshua Pulliam, Jake Socha*

Arboreal environments are discontinuous, requiring that animals cross gaps to survive. While most arboreal snakes use a cantilever crawl, extending their bodies outward and maintaining support from the original branch, flying snakes of the genus Chrysopelea exhibit an extraordinary ability to dynamically cross larger gaps. A key element of Chrysopelea's mechanism is the "J-loop", whereby the snake extends its head forward, feeding the anterior portion of its body into the gap and creating a "J" shape. It then launches into a dynamic movement from this posture. Previous studies show that the depth of this loop increases with gap distance and that a consistent feature of the J-loop is an axial twist at the bottom of the "J". However, the role and extent of this twist in loop formation remain unknown. We hypothesize that the axial twist aligns the body so that the snake's lateral musculature produces upward acceleratory movement. This study aims to test this hypothesis by addressing two questions: Does the degree of axial twist increase with gap distance? And, does the proportion of the body involved in the twist increase with gap distance? To address these questions, we recorded dynamic gap crossings at varied distances using 3D motion capture (Qualisys) and high-speed video (Edgertronic). These results may also lend insight into how flying snakes create unique postures during aerial undulation while gliding.

## Scheduling problems and the energetics of biparental care in an imperiled seabird

*Liam Taylor, Patricia Jones, Mark Haussmann, Robert Mauck*

For organisms with biparental care, reproductive success is a function of not only the energetic investments from individual parents but also the way those investments are scheduled between parents. We integrate rules from physiology, life history theory, and social behavior to develop an agent-based simulation of biparental incubation in birds. The model investigates how parental care schedules influence hatching success and parent body condition. We parameterize the model using a long-term dataset for Leach's Storm-Petrels (Procellariiformes: Hydrobatidae: Hydrobates leucorhous), a seabird with obligate biparental care, extraordinarily long incubation periods, and globally declining populations. Projecting energetic parameters into the future, we explore whether deteriorating marine ecosystems affect incubation schedules during seabird reproduction. Our flexible model highlights two principles, which may at first seem opposed: (1) biparental care can help organisms buffer against energetic variability in uncertain environments; and (2) biparental care can expose organisms to new reproductive risks in uncertain environments, such as schedule breakdown.

## Using eDNA to assess phytoplankton communities and the presence of harmful algal species

*Max Taylor, Nicolaus Adams, Stephanie Moore*

The Olympic Coast National Marine Sanctuary on the U.S. West Coast is home to a number of economically and culturally important species that are sometimes affected by harmful blooms of diatoms in the genus Pseudo-nitzschia. Some species of Pseudo-nitzschia produce the neurotoxin domoic acid which can accumulate in filter-feeding fish and shellfish, shutting down fisheries and causing illness or even death in humans, marine birds and mammals. This study uses environmental DNA (eDNA) collected by an autonomous sampler called the Environmental Sample Processor to assess phytoplankton community composition, including the presence of Pseudo-nitzschia. DNA metabarcoding analysis using the 18S rRNA V9 region was performed on 37 samples collected by the ESP during two deployments in summer/fall 2021 and spring 2022. The phytoplankton community composition differed significantly between the two deployments, with higher relative abundances of Pseudo-nitzschia in the summer/fall, consistent with higher levels of domoic acid. Five Pseudo-nitzschia species were observed: australis (71% confidence), seriata (90%), delicatissima (78%), heimii (96%), and fraudulenta (72%). The ciliate genus Mesodinium, the silicoflagellate genus Dictyocha, the amoeboflagellate family Mataza, and the diatom genera Skeletonema and Actinocyclus were the most closely correlated with Pseudo-nitzschia, occupying a similar ecological niche. Further monitoring of Pseudo-nitzschia, domoic acid and phytoplankton communities will help us determine what allows Pseudo-nitzschia to outcompete these genera and form harmful algal blooms.

## The effects of stretching on the viscoelastic properties of the muscle-tendon unit

*Skylar Taylor, Madison Gaines, Gregory Sawicki, Young-Hui Chang*

Stretching is an activity common to nearly all animals. There is little agreement on the effects of stretching on the viscoelastic properties of muscle tendon units. Previous work surveyed subjects from a variety of sports, activity levels, and muscular builds. This study used humans as a tractable model to understand the effects of controlled stretching on the viscoelastic properties of the muscle tendon unit with the aim of identifying factors that may contribute to differences across subjects. Subjects (n=3) had their calf muscles stretched on a dynamometer while an ultrasound was used to measure dynamics of the Medial Gastrocnemius-Achillies tendon junction during activation. Metrics used in this study include hysteresis, force development and muscular work. Preliminary results show that some subjects have a greater increase in muscle tendon unit hysteresis than other subjects. This is paired with a decline in maximum rate of force development during isometric maximum voluntary contractions. These results show that subjects have varying responses to stretch, which may be explained by different subject activity levels, stretching history, muscular structure. Although this work is focused on single joint mechanics, it will provide the basis for understanding how strain in muscle can influence balance and perturbation control paradigms.

## Asymmetric morphology in bird knees suggest a passive stabilizing mechanism unique to birds

*Skylar Taylor, Ryan Johnson, Karen Graham, Young-Hui Chang*

Energy conservation is an important selection pressure that can drive functional and morphological change in species. Passive stay mechanisms exemplify how some animals reduce energy cost of activities like standing, perching, or hanging. Previous work suggested flamingos have a passive stay mechanism that stabilizes the knee joint during unipedal stance. We aimed to identify anatomical structures within the knee capable of enabling passive stance in a convenience sampling of extant and extinct bird species (Phoenicopteridae, Accipitridae, Strigidae, and Dinornithiforme). We found all birds studied to have high mediolateral asymmetry indices in the distal femur distinct from the more symmetric morphologies of distantly related Crocodilians and Mammals. Interestingly, the asymmetry index of the extinct crocodylomorph, Macelognathus vagans, fell between that measured for birds and mammals. The mediolateral asymmetry of the tibial and tibio-fibular condyle protrusions in the distal femoral condyles suggests that bird femoral condyles may be acting to passively stabilize frontal plane loads during unipedal stance. We have also identified a separate bistability mechanism associated with the lateral and medial collateral ligaments of the knee, which promote passive stability in the sagittal plane at the extreme ranges of knee flexion and extension. It is hypothesized that these passive stance mechanisms in bird knee joints function to reduce energy consumption during quiet stance and may be a unique morphological character distinguishing Aves from other taxa.

## Two roads taken: superelongation in the obliquely striated muscles of soft-bodied animals

*Kari Taylor-Burt, Joseph Thompson*

Hydrostatic skeletons do not impose the same limitations on muscle operating length ranges as their rigid counterparts. For example, the extensive changes in body length typical of many worm-like animals may require longitudinally oriented muscle fibers to have broad length-force relationships (LFRs) to permit high force production along the entire operating range. Previous work suggested that the obliquely striated muscle of many soft-bodied animals may have evolved broader LFRs by modifying the arrangement of contractile proteins. Here we present a second possible strategy for achieving a broad LFR: muscle fiber folding. Bloodworms, Glycera dibranchiata, have a highly elongating, eversible proboscis, with mesentery muscles that connect the body wall to the digestive system putatively functioning as proboscis retractors. We measured LFRs in anterior mesentery muscles (n=18) and found that they have broad LFRs, similar in breadth to superelongating obliquely striated muscle fibers in other taxa. Histological examination of the mesentery muscles revealed that although all of the fibers appear to run longitudinally and for the entire length of these muscles, many, though not all, fibers are highly folded. Muscle fiber folding may allow the fiber to unfold as they are lengthened and thus permit a broad LFR. Additional work is needed to determine if superelongating obliquely striated muscles achieve their broad LFRs through fiber folding, adjusting protein arrangement, or a combination of both.

## Reconstructing self-righting behaviors in centipedes via robophysics

*Erik Teder, Baxi Zhong, Daniel Soto, Massimiliano Iaschi, Juntao He, Daniel Goldman*

Centipedes locomote by propagating body undulation and limb-stepping waves, but little is known about how they self-right after tipping from obstacle interaction. Here, we used a comparative biological and robophysical approach to understand centipede self-righting schemes. We released S. polymorpha ($N = 3$; length $= 11.3 \pm 0.9$ cm) upside down from a 10 cm height and captured their self-righting using top and side view high-speed cameras. Kinematic analysis revealed two primary strategies: the "one shot" (all body segments roll at once) and the "sequential" (the roll propagates from end to end). We hypothesize that these behaviors can be prescribed by two traveling waves superimposed in the body's horizontal and vertical planes, respectively, where wave spatial frequency characterizes the transition from one-shot to sequential strategies and wave amplitude characterizes body curvature. To test our hypothesis, we built a robophysical model with an elongated series of alternating vertical and horizontal servomotors and detachable 11 cm static limbs. The one-shot strategy (spatial frequency 0) was successful (the robot consistently flipped) at a body amplitude of 15 degrees without limbs and 30 degrees with limbs, and the sequential strategy (spatial frequency 0.5) was successful at a body amplitude of 22.5 degrees without limbs and 37.5 degrees with limbs. Our results suggest that body motion is critical to effective elongate self-righting and that legs increase the necessary body amplitude.

## Lessons from armadillos: Tapered osteoderm tiles increase armor flexibility

*Julia Teeple, Karly Cohen, Cassandra Donatelli, Theodore Stankowich, EW Misty Paig-Tran*

Biological segmented armors integrate mineralized tiles with soft tissues, forming a structure that is both puncture resistant and flexible. Examining these natural armors reveals a diversity of armor shapes, arrangements, and materials, that interact to influence flexural response or redistribute puncture stresses. Our study investigates the relationship between armor geometry and flexibility in armadillo (Dasypus novemcinctus) osteoderms. We used micro-CT scans to measure osteoderm tile height, width, spacing, and taper angle. Pectoral and pelvic region osteoderm tiles are hexagonal and have a larger superficial face than base, causing a gradual taper. If taper geometry decreases tile-tile contact forces, we would expect a decrease in armor stiffness. To test the contribution of taper and underlying connective support to flexural stiffness we designed three 3D-printed simplified physical models with varied taper angles and embedded our tiles into three different fabrics of varying compliance. Resistance to bending was tested using a 3-point bend test. Regardless of taper, embedded models in stiff fabric had higher flexural modulus than elastic fabric. Armor with no taper had the highest flex modulus compared to tapered models when attached to the same fabric types. The tapered geometry of armadillo armor decreases the stiffness of the system, possibly indicating a selectivity for flexible armor. This study shows that a complex multifunctional biological system can be simplified and investigated through 3D-printing.

## Stepping up softly: transferring animal gaits to soft-robotic walkers

*Joscha Teichmann, Lang Gauthier, David Zimmermann, Falk Tauber, Thomas Speck, Sebastian Kruppert*

The inherent benefits of soft materials in robotic designs have rendered Soft Robotics a growing field in research and engineering. Due to their compliance, soft robots are safe in working environments shared with humans, offer great potential in health care and medical applications, and may be operational in environments inaccessible or unfit for their hard-shelled counterparts. In our attempt to increase the load bearing capacities of our 3D-printed soft robotic walker, we seek inspiration from nature: the erect gait of mammals has been shaped by evolution to fit the requirements of the respective animal's ecology. For our model organism the elephant (Elephantidae), we assume that leg morphology and gaits are optimized for energy efficiency and/or load bearing, given the body weight of the animal as well as its weight bearing capabilities. However, as soft actuators are remarkably different from the mammal joint-and-muscle-system, a direct transfer from joint angles and muscle movement is not possible. We therefor adapted the known kinematics of elephant gaits to our soft actuators by means of fitting the actuators' bending angle to elephants' joint angles. We here present our current version of a soft robotic walker with erect gait.

## A hairy situation: the diversity of bat wing pelage and its functional implications

*Alexandria Tennant, Andrea Rummel*

Bats are the only mammals capable of true flight. Their wings are primarily hairless, although many bats have varying amounts of pelage distal to the trunk. Little research has investigated how wing pelage varies across bat species or the potential tradeoffs between increasing insulation of a surface likely to lose heat and the potential cost of increased drag due to fur on the wing. We hypothesize that wing pelage variation among bat species is correlated with body mass and thermoregulatory pressures related to aspects of bat ecology. Using images of wings from 106 species representing 12 families, we qualitatively analyzed pelage density along the dorsal and ventral surfaces of the wing membrane and forelimb. We used phylogenetic regressions and principal component analysis to evaluate the relationship between body mass, roost type, sociality, and diet on pelage in each region, finding significant effects of these factors on the extent of pelage along the patagium and limb. We suggest that wing pelage may be important for insulation despite potential aerodynamic costs. This study provides insight into the distribution of pelage in a diverse sample of bats, establishing a foundation for future research to explore morphological tradeoffs that may be advantageous for thermoregulation but incur other costs.

## Microfossil spiraling teeth reveal paleocene origin of cyclothone (bristlemouths)

*Karinne Tennenbaum, Karly Cohen, Immanuel Bissell, Elizabeth Sibert*

Cyclothone is the most numerically abundant genus of fish in the world's oceans. Commonly known as "bristlemouths," these fish bioluminesce and inhabit the mesopelagic ocean zone. The oldest known fossils of Cyclothone date to the middle Miocene epoch, approximately 11-16 million years ago, suggesting that the group evolved relatively recently, likely in concert with the expansion of oxygenated mesopelagic habitat. However, as deep-sea fish are rarely preserved in the fossil record, their evolutionary history is inferred from molecular, rather than fossil data. Microfossil fish teeth preserved in oceanic sediments provide a detailed fossil record of deep-sea fish, allowing for precise dating of fossil occurrences. Identifying these isolated teeth to specific taxonomic groups is challenging. We show that 55.6-million-year-old microfossil fish teeth (ichthyoliths) with distinctive spiral striations are unique to the extant genus Cyclothone. Spiral striations are found on the teeth of all extant Cyclothone species but absent on other taxa in the Order Stomiiformes and taxa sampled from across the fish tree of life, reasonably identifying these striated ichthyoliths to Cyclothone and pushing their fossil record back over 40 million years. Non-Cyclothone Stomiiformes species exhibit teeth with other tooth surface textures, providing further support for the use of ichthyolith microstructures to investigate phylogenetic relationships in deep-sea fish lineages and raising questions about the diversity of fish teeth and the factors driving their evolution.

## Multi-level investigation of an antagonistic heat-by-salinity interaction in *Tigriopus californicus*

*Caroline Terry, Josie Liebzeit, Ella Purvis, Maxime Leprêtre, Dietmar Kueltz, Wes Dowd*

Natural environments present multivariate abiotic stress, and organismal responses to multiple stressors are often unpredictable and non-additive relative to single-stressor scenarios. In the splashpool copepod Tigriopus californicus, salinity antagonistically interacts with heat tolerance, such that copepods survive higher temperatures under high-salinity conditions. To better understand the mechanisms driving this interaction, we investigated responses at multiple physiological and biochemical levels. Whole-organism rates of oxygen consumption in T. californicus were unaffected by temperature, regardless of salinity. We posit that the effect of temperature likely exists but is obscured by simultaneous temperature and salinity effects on activity levels. Acute transfer to lower salinities, however, did transiently increase metabolic rates – a pattern not reflected upon acute transfer to higher salinities. Accumulation of free amino acids (FAAs) was hypothesized to drive increased heat tolerance under high salinities, but enrichment of copepods with FAAs had no effect on heat tolerance. To generate alternative, mechanistic hypotheses to explain this antagonistic interaction, we quantified global protein expression patterns of copepods exposed to high salinity, heat, or a multi-stressor condition. Despite salinity's notable effect on thermal tolerance, it led to a relatively small number of differentially expressed proteins compared to high-temperature and multi-stressor conditions. We will discuss the implications of these multi-level findings and the need to understand the mechanisms underlying non-additive stressor interactions.

## Competition modulates the expression of cryptic genetic variation in spadefoot tadpoles

*Christopher Hal Terry, Cris Ledón-Rettig, Dante Nesta, Sydney Jacobsen*

Stressful or novel environments can reveal otherwise unseen heritable variation —"cryptic genetic variation" — providing raw materials for the evolution of novel traits. While previous studies have shown that a single novel or stressful environmental can reveal cryptic genetic variation, how multiple environments interact to shape the expression of cryptic genetic variation is largely unknown. To understand how concurrent environments effect the expression of cryptic genetic variation and its consequences for novel trait evolution, we used spadefoot toad. Tadpoles of the spadefoot genus Spea have evolved novel trophic features that are induced by and specialized for consuming a novel shrimp diet. Consistent with a scenario where cryptic genetic variation facilitated the evolution of these novel trophic traits, tadpoles of the outgroup spadefoot genus Scaphiopus exhibit higher genetic variance in their trophic traits when fed the shrimp diet. Here, we tested whether shrimp-induced cryptic genetic variation in Scaphiopus tadpoles is modulated by a second environmental factor: conspecific competition. Using both individual traits and geometric morphometrics, we found that while shrimp revealed cryptic genetic variation in body condition across both levels of competitive, individual traits only expressed this variation under low competition. These results demonstrate that stressful and novel environmental conditions can interact to influence the expression of cryptic genetic variation, offering a more nuanced understanding of how such variation contributes to novel trait evolution.

## Assessing secondary immune responses to three antigens in a freshwater turtle

*Jen Terry, Isabella Davis, Virginie Rolland, Lori Neuman-Lee*

Emerging diseases threaten wildlife health and overall population viability, but previous exposure may prepare individuals to overcome subsequent re-infections in the wild. However, patterns of secondary exposures and responses are poorly studied in reptiles and may provide a key to understanding the broader immunological strategies employed by all vertebrates. In this study, we aimed to investigate if wild turtles exhibit changes in their immune responses after a second exposure to antigens. We held adult male red-eared sliders (Trachemys scripta) in flow-through cages following simulated infections using four injection treatments: lipopolysaccharide (bacterial), zymosan (fungal), Poly(I:C) (viral), and saline (control). We collected blood samples before injection (0h) and 12h, 24h, 48h, 72h following initial injections. Males were held for two weeks following the conclusion of the initial experiment and injected with the same treatment. Blood samples were collected again 0, 12, 24, 48, 72h. We assessed differential immune responses by conducting microbial killing assays against Gram-negative Escherichia coli, Gram-positive Staphylococcus aureus, and the fungus Candida albicans using fresh, frozen, and frozen+heat-treated blood serum and comparing initial and secondary responses to antigens. Our results suggest that individuals may modulate their immune response following secondary exposure to a pathogen. Insights into immune responses of wild populations will inform both conservation issues and mitigation strategies as wildlife diseases continue to emerge.

## Characterizing immune responses in a reptile

*Jen Terry, Isabella Davis, Virginie Rolland, Lori Neuman-Lee*

Immunity is essential for survival in wildlife and an important metric for assessing conservation needs and approaches. However, many ecoimmunological studies in wildlife lack the ability to put measured responses into context because the basic immune response and components of the organism are not yet fully understood. In particular, studies in reptiles have remained scarce, resulting in an inability to compare potentially at-risk populations with a "healthy" population. To address these gaps, we experimentally assessed the initial immunological response to a bacterial, fungal, and viral antigen. We held adult male and female red-eared slider turtles (Trachemys scripta) in flow-through cages and simulated infections using four injection treatments: lipopolysaccharide, zymosan, Poly(I:C), and saline. We collected blood samples before injection (0h) and 12h, 24h, 48h, 72h following injections. We assessed differential immune responses by conducting microbial killing assays against Gram-negative Escherichia coli, Gram-positive Staphylococcus aureus, and the fungus Candida albicans, using fresh, frozen, and frozen+heat-treated blood serum. Immune responses varied among treatments when challenged with the different microbes. Additionally, different immune components (e.g., leukocytes, complement, antimicrobial peptides) responded differently across time and treatment. This work is especially critical as emerging bacterial, viral, and fungal pathogens continue to be described in reptiles. To move the burgeoning intersection of ecoimmunology and conservation forward, established immune responses must be characterized to better interpret and apply results gathered from wild populations.

## Characterizing the early genetic and epigenetic control of cichlid craniofacial plasticity

*Emily Tetrault, Niah Holtz, Craig Albertson*

Phenotypic plasticity is the ability of a single genotype to vary its phenotype in response to the environment, and has important implications for individual-level fitness and population-level evolvability. Plasticity of the skeletal system in response to mechanical input is widely studied, but its timing and genetic/epigenetic control are not well understood. We have recently shown that plasticity of the cichlid feeding apparatus is underlain by a robust transcriptional response at 1 week following the onset of foraging trials. Here we seek greater resolution in the timing of this response, as well as insights into its epigenetic regulation. We subjected a cichlid species known to be plastic to alternate pelagic/benthic foraging challenges, dissected a functional complex of bone and soft-tissue at 0, 4, 8 and 12 days, and performed a combination of RNA-seq and methyl-seq on these tissues. As expected we document an early and robust transcriptional response to alternated feeding modes, and show that some of this is due to differential DNA methylation. Since tissue-level plasticity is often measured in weeks, months or even years, its early transcriptional regulation has gone largely unappreciated. Moving forward, a challenge for the field will be to better understand these early molecular responses, and to connect them to tissue-level changes that follow weeks or months later.

## Habitat structure affects cover use of two montane lizards

*David Tevs, Winsor Lowe*

In ectotherms, time spent under cover versus in the open affects fundamental ecological activities, including mating, foraging, and thermoregulation. While temperature has been considered a key driver of cover use, factors such as water availability and predation risk may also be important. Quantifying the conditions associated with cover use will contribute to a more holistic understanding of how the environment shapes ectotherm biology. Here, we provide preliminary data on cover use of two montane lizards, northern alligator lizards (Elgaria coerulea) and western skinks (Plestiodon skiltonianus), across habitats that differ in temperature, moisture, and vegetation structure. Northern alligator lizards were detected only in the open and almost exclusively in cool, moist, densely vegetated forest patches. Western skinks were observed across a wider range of temperature, moisture, and vegetation conditions, but were predominately detected under cover in hot, dry, sparsely vegetated forest patches and in the open in cool, moist, densely vegetated forest patches. These data contradict previous reports of both species being detected most frequently under cover. In sparsely vegetated habitats, western skinks also showed no association between cover use and temperature or humidity, suggesting that lack of cover use in densely vegetated habitats may be driven by factors other than temperature and moisture, such as predation risk due to increased cover.

## Characterisation of wing morphing in manoeuvring avian flight

*Davina Thandi, Lydia France, Henry Cerbone, Graham Taylor*

For avians, morphing wings are key in enabling agile flight behaviour to ensure success in manoeuvring pursuit flight, particularly when chasing their prey. However, the morphing wing phenomenon in birds is not well understood and hence a complete model that accurately captures its flight dynamics, governing control laws, and subsequent constraints does not yet exist. We seek to begin addressing this issue experimentally by tracking the motion of Harris' hawks, Parabuteo unicinctus, in manoeuvring flight in a motion capture arena. Compared to previous work, higher resolution measurements of morphing wings are achieved in turning flight around a stationary obstacle by placing markers on alternating wing feathers, as well as along the wing base and the leading edge. The labelling of a high-density marker point cloud is non-trivial, and hence machine learning approaches are used to track each marker uniquely and accurately throughout each flight trial. This allows the measurement of finer changes in wing angles and morphology using three-dimensional positional data, which can be used to determine logical coordinate systems and input parameters to build the foundation for more detailed morphing wing models and help identify flight control mechanisms. The applications of this work pertain to improved predator-prey chase models, understanding of the evolution of manoeuvrability, and enhancing bioinspired aircraft design.

## Squid mutualisms running hot – symbiotic bacteria as a proxy of host fitness under climate stress

*Malcolm Thieme, Brent Zeyus Valdez, Michele Nishiguchi, Diya Vakil*

Stable microbial associations contribute to host fitness, but recent anthropogenic warming is inducing stress on individuals and their host communities. Examining how symbiotic bacteria respond to such changes can provide insight into how their hosts accommodate climate stress. The beneficial association between bobtail squids (Cephalopoda: Sepiolidae) and their Vibrio symbionts is an ideal model to understand how microbial associations can be used as a yardstick to measure adaptation to climate change. Here, we examine how temperature impacts symbiotic response and competency. Squid isolates from Hawaii (ES114), Australia (ETBB1-C), the Philippines (EAS005), and Japan (EM17) were evolved under three temperature conditions: high (32°C), mid (25°C), and low (18°C). All strains were experimentally evolved for 2000 generations. Symbiotic characteristics such as growth rate, bioluminescence, motility, and biofilm formation were measured throughout the study. We observed that bioluminescence under heat and cold stress decreases in tropical isolates; whereas, temperate isolates luminesce equally across all temperature ranges. Faster growth rates were also characteristic for all strains at 32°C. These results indicate that temperate strains can adapt to high temperature stress better than tropical strains, due to their ability to accommodate broader ranges of temperature given their physiological versatility. Thus, disentangling trade-offs due to long term exposure to temperature will give a broader perspective on the ability of microbial partners to offset changing climate conditions.

## Epistasis and GXE Interactions Drive Microbial Adaptation and Antimicrobial Resistance

*Misty Thomas, Brittany Sanders, Joseph Graves*

Understanding the genetic and environmental factors that shape microbial adaptation is crucial for addressing important health issues including antimicrobial resistance. This research investigates the role of epistasis and genotype-by-environment (GxE) interactions in the evolution of silver resistance in Escherichia coli. Focusing on mutations in the cusS gene, part of the two-component response system (TCRS), we demonstrate how single mutations can confer resistance while interacting epistatically with other regulatory genes, such as ompR, rho, and fur. These interactions significantly alter global stress response pathways, leading to diverse resistance phenotypes that are tailored to specific environmental conditions.

In addition, we explore how GxE interactions influence the fitness of resistant strains. Adaptive mutations in cusS trigger a three-step response: upregulation of TCRS, crosstalk with other regulatory systems, and fine-tuned gene expression based on environmental context. Through fitness assays and RNA sequencing, we reveal the complexity of these adaptive processes, highlighting the importance of both genetic background and environmental factors in shaping microbial evolution.

These findings provide key insights into the mechanisms of bacterial resistance, with broader implications for predicting evolutionary outcomes in microbial populations. This work underscores the need for a deeper understanding of epistatic interactions and environmental influences in the fight against antimicrobial resistance, offering potential avenues for novel therapeutic interventions.

## Arctic seal aerobic dive limits inform physiological flexibility in the face of environmental change

*Nicole Thometz, Colleen Reichmuth, Madeline Meranda, David Rosen*

Arctic seals are especially vulnerable to environmental warming, yet it is difficult to determine their ability to respond to rapidly changing conditions. The aerobic dive limit (ADL) approximates the amount of time an animal can spend underwater on a single dive before incurring an increase in blood lactate, and is commonly used to assess physiological limits in marine mammals. ADL is calculated by dividing total body oxygen stores by oxygen demand. Here we measured blood, muscle, and lung oxygen stores, as well as activity-specific metabolic rates in adult ringed (Pusa hispida), bearded (Erignathus barbatus), and spotted (Phoca largha) seals to determine species-specific ADLs. Hematological parameters including hemoglobin, hematocrit, and total blood volume were obtained from free-ranging and captive seals. Muscle myoglobin was quantified in tissues from deceased seals. Total lung volume was measured in live seals using CT imaging technology or estimated based on published values. Using these species-specific source data, blood, muscle, and lung oxygen stores were calculated and summed to determine total body oxygen stores. In addition, stationary diving and submerged swimming metabolic rates were measured via respirometry with trained seals. Calculated ADLs were remarkably consistent (16-17 min) for all three species when performing stationary dives. However, when swimming at preferred speeds calculated ADLs diverged greatly (ringed: 6.2, bearded: 10.8, spotted: 4.0 min) suggesting a link between routine behavior and physiological flexibility.

## Bush crickets shift to increasingly stable gaits when moving on challenging substrates

*Rebecca Thompson, Calvin Riiska, Jacob Harrison, Jennifer Rieser, Saad Bhamla*

Organisms in natural habitats contend with substrates varying widely in roughness and incline. When traversing increasingly challenging substrates, organisms alter their gait and speed, especially at larger body sizes when they must support a larger mass. Here we investigate the scaling of movement patterns in bush crickets (Tettigonidae) collected in the Peruvian Amazon rainforest as they move across a track with different inclines and surface roughnesses. We used bush crickets because they were often seen walking across various surfaces in the field and could be found across a wide range of body sizes. Individual bush crickets (n=24; 0.06 - 2.4g) were prompted to walk along a track positioned at either 30, 45, 60, 75, or 90° and one of six different sandpaper grit roughnesses, for a total of 599 trials. In experiments, individuals walked faster at lower inclines and on rougher substrates, regardless of body mass. Bush crickets preferred the alternating tripod gait at lower inclines ($< 6\,0^{\circ}$). However, as the incline grew, individuals adopted a quadrangular or pentagonal gait pattern - where more limbs contact the substrate during each step. These alternative gait styles increase the duty factor and increase stability during walking. These experiments provide behavioral evidence of gait transitions in hexapods when traversing increasingly challenging substrates, which has important ecological and mechanical implications for walking and climbing in biological and robotic hexapods.

## Acute effects of estradiol on behavioral responses associated with group living in male and female zebrafish

*Richmond Thompson*

The role that estrogens play in the dynamic modulation of social behaviors related to reproduction has been well established, yet whether they can rapidly modulate social responses outside of reproductive contexts, in males and/or females, remains less clear. Further, while estrogens typically promote aggressive responses in competitive contexts, especially in territorial species, it is possible they enhance non-sexual, prosocial interactions in other contexts, especially in species that live in groups. We therefore tested the acute effects of two doses of estradiol (E2) and of an aromatase inhibitor, Fadrozole, on social approach/preference responses for same-sex shoals in male and female zebrafish. Estradiol significantly increased approach / preference responses in both sexes in less than 1 hour, whereas Fadrozole inhibited social approach responses 1 hr and 17 hr after exposure in females, but not in males. Thus, E2 can enhance similar behavioral responses in both sexes, but endogenous E2 may play a more prominent role in females, or the contexts in which endogenous E2 produces similar effects in males were not present in our tests. Neither the effects of E2 nor FAD were paralleled by influences on measures of stress/anxiety, indicating E2 rapidly increases tendencies to approach and maintain proximity to groups in this highly social species through direct actions on social brain circuits.

## Avoiding perils and pitfalls when modeling species richness

*Anna Thonis, Resit Akcakaya*

Reliable predictions of species richness are increasingly important as the number of threatened species rises. While various methods exist for modeling species richness, macroecological models (MEMs) and stacked species distribution models (SSDMs) are particularly popular given their relatively simplistic modeling frameworks and the availability of seemingly appropriate data. For MEMs – which require richness per location for some pre-defined spatial scale – richness is often extracted from superimposed species range maps. However, as range maps do not imply the continuous presence of a species and are commonly developed with species conservation in mind, their underlying assumptions unsurprisingly lead to richness overpredictions. Compared to MEMs, SSDMs offer a reasonable alternative, utilizing species occurrence records to predict species richness and composition. In this study, we assess the reliability and accuracy of MEMs built with range map richness and SSDMs by comparing modeled richness predictions to surveyed Anolis lizard richness at 70 sites across Puerto Rico. Our results indicate that MEMs based on range map richness frequently overpredict richness and produce potentially unreliable variable importance and correlation metrics. Although SSDMs demonstrate improved accuracy at coarser spatial scales and align well with survey data, they underpredict richness at finer scales. Together, these findings highlight the need for careful consideration at every stage of the modeling process and emphasize the crucial role of field surveys in validating model predictions.

## Introducing the new IUCN Anolidae lizard specialist group

*Anna Thonis, Jhan C. Salazar Salazar*

Anolis lizards ("anoles") represent the most species-rich vertebrate terrestrial genera on Earth with 381 species described to date. Unfortunately, the conservation of this important and well-studied group of lizards is often neglected. According to the Global Reptile Assessment published in 2022, over 25% of Anolis species are threatened with extinction and over 10% are considered Data Deficient and therefore unable to be evaluated. Additionally, the population trends for 13% of anole species are decreasing and 47% of anole species have population trends that are currently unknown. Given the broad distribution of Anolis and the number of anole species, it is particularly important to have an organized network of experts dedicated to anole conservation. To this end, the International Union for the Conservation of Nature (IUCN) Species Survival Commission's (SSC) Anolidae Lizard Specialist Group (ALSG) has recently been reestablished. As many anole biologists are known to attend the annual meeting of the Society for Integrative and Comparative Biology – as well as other researchers who may have general interest in Anolis – we would like to take this opportunity to officially introduce the new IUCN ALSG. Additionally, we will share the group's short- and long-term goals, describe what it means to be an IUCN Specialist Group, and encourage interested individuals to consider getting involved.

## The influence of ecology, evolutionary history, and physical constraints on teleost eye evolution

*Mason Thurman, Mary Freeman, Grace Seyle, Jessica Stepp, Samantha Price*

For many fishes, vision is crucial for feeding, predator avoidance, mate selection, and navigation; thus eye traits are likely to be under strong selection. Estimating allometric relationships between eye traits and size can reveal the relative investment in the visual system, which is likely influenced by a species' ecology, evolutionary history, and physical constraints. Although these relationships are well established in tetrapods, less is known about the evolution of fish eyes as studies have been generally limited to single morphological and ecological characters. In this study we estimate the allometric relationships between fish size and eye size, shape, and position on the head for over 1,000 teleost species. Using evolutionary models of trait evolution in a robust phylogenetic framework we then assess the influence of ecology, evolutionary history, and physical constraints on relative eye investment. We quantified fish eye morphology using eight linear measurements taken from both lateral photos and with calipers on museum specimens. For comparison, seven visually relevant ecological characters (e.g., water depth and feeding niche) were assembled from public databases and published literature. Preliminary findings show overall negative allometry, high phylogenetic signal in some clades, and nuanced effects of ecology. This comprehensive view is needed to fully understand the integrated evolution of teleost eye morphology and to help explain the greater variation in allometric slopes when compared to tetrapods.

## Gait transitions from land to shallow water in aquatic hexapods

*Snigdha Shiuly Tikader, George Kuney, Alex Handwork, Margaret Byron*

Amphibious locomotion is a sought-after goal for many applications in robotics (e.g. defense, exploration, and remote sensing). However, this objective can be difficult to achieve effectively. Biological contexts provide inspiration and insight into the design and development of vehicles, devices, and engineered technology that must traverse boundaries between terrestrial and aquatic environments—but effective terrestrial vs. aquatic locomotion strategies often use different motion patterns and even different appendages. Here we compare the walking gait of aquatic hexapods (backswimmers and diving beetles) on a dry substrate vs. in shallow water. We use high speed videography and kinematic tracking to measure gait patterns, finding that dry-land gaits differ significantly from shallow-water gaits. As water depth increases, the insects transition to a "hybrid" gait in which hind legs dominate propulsion, but anterior legs are still used for stability between hindlimb strokes. As water depth increases, the insects transition to typical free-swimming patterns, using primarily hind legs for propulsion without any contact with the substrate. Our results carry implications for both engineering and biology. For engineering, further investigation of the efficacy of such gait transitions may carry the key for efficient amphibious robotics. For biology, aquatic macroinvertebrates typically serve as important indicator species for ecosystem health, and a better understanding of the differences in gait between swimming and walking could inform dispersal patterns writ large.

## Infection alters foraging decisions in a common songbird

*Francis Tillman, James Adelman*

Behavioral changes during infection often reduce overall food consumption. However, we know much less about how such behavioral changes alter specific foraging choices, which will have important consequences for contact rates and pathogen spread if infected and healthy foragers make different decisions. Here we ask how infection with the bacterial pathogen Mycoplasma gallisepticum (MG), commonly spread via bird feeders, alters foraging decisions and abilities in house finches (Haeomorhous mexicanus). Using wild-caught finches, we conducted food choice experiments pre- and post-inoculation with MG, presenting birds with two food sources of varying quality. We also quantified food handling time of sham- and MG-inoculated birds. Healthy birds always preferred the higher-quality food, while MG-inoculated birds only showed a preference in trials with the greatest differences between choices. MG-inoculated birds also took longer to process food items and were equally likely to pick up items that were easier or harder to manipulate. Our results suggest that MG infection mutes foraging preferences, which should reduce contact rates at food resources of varying quality.

## Social resurrection: Social interactions and restoration of disturbed bumble bee microbiota

*Ravi Timsina, Benjamin Sadd*

Eusociality represents a major evolutionary transition. Eusociality, and social living more generally, have several associated benefits but also counter costs, affecting their evolution. The ecological dominance of eusocial insects suggests advantages of group living, including reduced predation risk, better resource utilization, and increased tolerance of adverse conditions. Conversely, costs include greater likelihood of pathogen transmission due to individual proximity and high relatedness. However, little attention has been given to the transfer of beneficial microbes among group individuals as an additional benefit of sociality. Both intrinsic, including host immunity, and extrinsic factors, including infection and antibiotic exposure, can disrupt the structure and functioning of a beneficial microbiota, leading to dysbiosis. We hypothesize that sociality can maintain a healthy gut microbiota, with social interactions facilitating the spread of beneficial microbes or resurrecting beneficial microbial communities following dysbiosis. Using the bumble bee Bombus impatiens, we test this hypothesis by disturbing a focal individual's gut microbiota through a stimulation of host immunity or antibiotic treatment. Subsequently we expose these focal individuals to solitary or social settings, before assessing gut microbiota structure and health effects. We predict that dysbiotic gut microbial communities will be resurrected by social interactions, accompanied by associated health benefits. This work will further our understanding of host-microbiota relationships, including how social transmission of beneficial microbes may favor the evolution of social living.

## A conceptual framework can aid the jump from organismal biology to bioinspired design

*Jessica Tingle*

Conceptual frameworks can help researchers identify important open questions and determine the most effective approaches to answering those questions. One such framework, Arnold's morphology-performance-fitness paradigm, has become a SICB staple due to its huge and enduring impact on how we think about organismal biology. In this talk, I will explore the utility of a similar conceptual framework for aiding the jump between organismal biology and bioinspired design. Along the way, I will highlight several key topics common to organismal biology and bioinspired design, as well as some aspects of organismal biology that aren't applicable to design, but that designers should understand to avoid potential pitfalls. I will illustrate concepts with snakes, a fascinating group with major potential for bioinspiration.

## The mechanics and behavior of knotting in California blackworms: Part 1

*Ishant Tiwari, Vishal Patil, Ghufran Bhatti, Saad Bhamla*

Limbless organisms, including worms, eels, and snakes, employ various strategies to perform functions typically associated with limbs, such as gripping and grooming. One such strategy involves the formation of knots using their flexible bodies. However, the mechanisms behind how these organisms form and untie these knots without becoming entangled have not been systematically studied. In this study, we focus on the California Blackworm (Lumbriculus variegatus) to explore this knotting behavior. We observed that blackworms spontaneously form knots under laboratory conditions, with configurations ranging from simple three-crossing overhand knots to more complex knots with up to six crossings. Using high-speed videography, we first investigate the mechanics of their sub-second timescale unknotting behavior when undergoing acute stress. We then attempt to isolate potential triggers for these knots by performing a behavioral assay, involving the worms cleaning debris from their bodies or sustaining high turbulence in their aquatic habitat. Our study helps in considering the broader implications of knotting behavior across various limbless organisms, from microscopic bacteria to large pythons, suggesting a potential universality of this strategy across six orders of magnitude in length.

## Eye spy the raptor os opticus: Anatomy, morphometry, and variation influenced by ecology & phylogeny

*Khanh To, Donald Cerio*

The optic nerve (CNII) is a crucial component of the visual system; if disrupted, the retina malfunctions. Soft tissues like dura mater protect CNII, but so do hard tissues, including— potentially—the os (or "ossa") opticus. This bone, which cradles CNII, is unique to Aves, a group characterized by aerobatic locomotion and remarkable vision. The os opticus phylogenetic distribution is homoplastic, seen in raptorial birds of prey ("raptors"; i.e. owls, hawks, falcons): owls lack it, hawks sometimes have it, and falcons consistently have it. Owls (mainly nocturnal) with scotopic vision differ from hawks/falcons (mainly diurnal) with acute vision. However, reasons for the discrepancy between hawks and falcons are not immediately apparent.

We documented os opticus anatomy qualitatively and quantitatively among raptors, using CT data from Morphosource. The bone varies considerably in form (e.g., horseshoe shape in Harpagus bidentatus vs. complex J-shape in Haliaeetus vocifer). Hawks and falcons have relatively similar eye size regardless of os opticus presence($F=0.001$). Those with the bone had similar os opticus size relative to head width($F=0.029$). The lack of difference in this initial sample suggests comparable pressures on optic nerve of falcons and hawks, which share convergent traits including active eye movements and fast flight. Owls, in contrast, have static eyes and slower flight. We plan to expand sampling across Inopinaves to investigate the presence/absence pattern in a broader phylogenetic context.

## Work loops of the primary flight muscles of birds

*Bret Tobalske*

Flapping flight requires more power than any other form of animal locomotion and to produce this power, birds use their proportionally massive pectoralis and supracoracoideus muscles that effect downstroke and upstroke, respectively. Andy Biewener and colleagues produced major advances in understanding of the contractile behavior of these muscles by applying in vivo techniques including electromyography, sonomicrometry and strain gauge measurements. These data are effectively summarized using work loops for which the shape and area provide measures of positive (concentric) and negative (eccentric) work in each muscle during the wingbeat cycle. Characteristics of such work loops vary among species, flight styles and experimental techniques including recent work using aerodynamic force platforms and computational fluid dynamics. As a result, we are only beginning to have insight into the functional significance of antagonistic force development and negative work in the pectoralis and supracoracoideus. An evolutionary hypothesis that merits future comparative study is that the relative magnitude of negative work and thus elastic energy storage and recovery increases as a function of decreasing body size among species. The large size, anatomical complexity and short tendon of insertion of the pectoralis highlight that is a worthy model for testing emerging hypotheses about the contractile properties of titin.

## Hangry corals: Can coral venom expression predict propagule health?

*Coral Tolman, Sofiia Kuklina, Bradford Gemmell, Jason Macrander*

Coral reefs are in severe decline due to a variety of factors. Global restoration efforts have focused on coral propagation, rearing, and outplanting, yet recovery success remains relatively low. Given the substantial investment in these efforts, strategies to enhance coral growth and outplanting success are critical. Feeding corals with Artemia has been shown to boost propagule growth rates prior to outplanting, but the role of venom expression in response to feeding, and its potential impact on outplanting success, remains poorly understood. Our study investigates venom expression as a proxy for coral propagule growth under two feeding regimes: nocturnal feeding and starvation. We conducted an 8-week experiment using five coral species across both treatments. We measured growth biweekly and performed comparative RNA sequencing at the start, 4 weeks, and 8 weeks into the experiment. Although growth rates did not show significant differences between feeding and starved treatments, this is likely due to small sample sizes as the experiment progressed. Comparative transcriptomic analysis identified several differentially expressed genes, including some venom candidates upregulated among the fed conditions when compared to the starved treatment. Overall, these results offer preliminary insights into molecular responses of coral propagules under different feeding conditions, providing a foundation for optimizing coral propagation and outplanting strategies.

## Decoding social communication in a eusocial ant species, Harpegnathos saltator

*Roeskva Torhalsdottir, Amu Tawawalla, Lulu Wright, Aiden Masters, Benjamin Morris, Lydia Naughton, Gregory Pask*

Insects use olfaction to drive a variety of fundamental behaviors such as finding mates, foraging for food, finding egg-laying sites, and communicating with conspecifics. Harpegnathos saltator ants are a primitively eusocial species and success in colony life relies on highly-sensitive olfactory systems. This species has highly expansive odorant receptor (OR) families that have been attributed to pheromone communication using cuticular hydrocarbons (CHCs) which serve to signal fertility, caste, and colony identity. Here we use in vivo heterologous expression to functionally characterize individual ant ORs (HsOrs) in Drosophila melanogaster. We performed single sensillum recordings (SSR) against a panel of relevant hydrocarbons in order to assess CHC sensitivity of individual HsOrs. A receptor-to-ligand map was made based on neuronal responses to specific hydrocarbons and the strongest ligands were further examined with subsequent dose response assays. With the addition of these characterized HsOrs, we extend the analysis to existing HsOr functional data to observe trends in coding capacity relative to HsOr subfamily and hydrocarbon chain length. This represents the most ORs decoded in any insect species, and enables further investigation on the molecular evolutionary signatures including the combinatorial coding necessary for successful eusocial communication.

## Comparing genome-wide genetic variation in declining and stable bumble bee species

*Emma Torija-Olson, Jeffrey Lozier*

Bumble bees (Bombus) play a crucial role in pollinating native and agricultural flowering plants. In the United States, bumble bees are experiencing unique population dynamics. While some species are maintaining stable population sizes over time, other species with similar geographic ranges are experiencing decline in abundance alongside severe range contractions. This suggests that closely related species have different sensitivities to factors contributing to decline such as global climate change. Differences in genetic variation, on which evolution acts, could explain why some species are more susceptible to decline in the face of threats. Previous work using molecular markers (microsatellites and RADseq) provided somewhat conflicting results about the diversity estimates of various Bombus species. The recent assembly of Bombus genomes in conjunction with decreased sequencing costs allow us to avoid marker biases by using whole genome sequencing to get a true comparison of genomic variability. In this study, we employ whole genome resequencing of range-wide samples to compare genome wide heterozygosity of an abundant and stable species, Bombus impatiens, and a geographically overlapping species that was once widespread but has recently declined, Bombus pensylvanicus. We compare estimates of variation using methods that account for genotype uncertainty and take advantage of whole genome data (e.g., runs of homozygosity). Finding differences in genome wide variability will establish this potential explanation for species level differences in response to environmental threats.

## Genetic polymorphism and the early amniote fossil record

*Fernando Torres, EJ Huang, Gabriel Bever*

Comparative genomics is a powerful heuristic tool that is rapidly expanding our understanding of evolutionary mechanisms and the time scales on which they operate. A prominent example is the concept of incomplete lineage sorting (ILS), which promotes the conservation of genetic polymorphism across successive speciation events as a potentially prominent source of gene tree-species tree conflicts. The definition and detection of ILS in molecular data has its challenges but bears the potential for informing variational dynamics that are beyond the reach of classical population genetics, thus bringing long disputed evolutionary problems into a new analytical context. We place the problem of turtle origins into this context by examining patterns of genetic polymorphism across the base of the major amniote lineages. Our data indicate that the crown divergence of turtles and archosaurs, and their shared stem lineage, were marked by especially high levels of polymorphism. The phenotypic implications of these ILS patterns are still being elucidated but may offer critical insights into the historic lack of consilience in molecular and morphological/paleontological solutions to the phylogenetic position of turtles. By establishing the relationship of ILS to tree parameters such as branch length and ultimately to the genotype-phenotype map, incongruent patterns of morphological expression in early amniote fossils might be reinterpreted as congruent with a more inclusive molecular signal that considers more than just the species tree.

## Sprinters to marathoners: an ontogenetic comparison of leatherback sea turtle swimming kinematics

*Samantha Trail, Jeanette Wyneken*

As hatchling sea turtles emerge from nests on the beach, they exhibit an innate hyperactive state: rapidly crawling to the water, followed by almost continuous swimming for 24-48 hours as they escape coastal, predator-rich waters. This “frenzy” is dominated by powerstroking – characterized by bilateral “flapping” with elaborate ranges of motion of both forelimbs (flippers). Cheloniid sea turtles switch to dogpaddling or “rear-flipper kicking” for routine swimming; in contrast, leatherbacks continue powerstroking almost exclusively throughout ontogeny. Their open-ocean life history makes the study of ontogenetic shifts and dispersal challenging and rare. We compared the powerstroke of leatherbacks hatchlings and neonates in Southeast Florida. We hypothesize that morphological and behavioral shifts are reflected in kinematic differences in the powerstroke at different life stages. To test this hypothesis, hatchlings were collected on the day of emergence, measured, marked with high-contrast dots for tracking, placed in a sea water-filled tank, and swimming was video recorded at high resolution. Force data sampled at a high rate were collected synchronously with videos to measure thrust patterns in concert with flipper motions as hatchlings and after 4-8 weeks of growth. We found (1) ratios of flipper length to straight carapace length decreased with age. (2) Flipper movements and thrust patterns (force/time per stroke) differ across life stages and among individuals at the same life stage suggesting ontogenetic shifts and individual variation exist.

## Does the shape of fish scales influence their penetrative resistance?

*Sean Trainor, Kory Evans*

The defensive arms race between predator and prey has been an ongoing struggle for over 600 million years.

Armor was first seen in invertebrates, but it eventually appeared in vertebrates during the Silurian period of the Paleozoic era. Specifically in fishes, armor is sometimes seen as a tradeoff between defense and speed. Different shapes and weights of these armors have been shown to influence the penetrative resistance, the ability to resist water currents when immobile, and faster overall swim speeds. We are investigating whether scale shape specifically influences penetration resistance, and we suspect that penetrative resistance is directly proportional to scale thickness. Through the use of 3D printed models and material testing systems, we explore our hypothesis that scale shape and penetrative resistance are related.

## The onset of laziness: intrinsic motivation and local cues interact to mitigate traffic in fire ants

*Laura Treers, Michael Goodisman, Daniel Goldman*

Many animals rely on excavation and deposition of material to create structures necessary for survival. For example, social insects like ants and termites build complex nests composed of subsurface tunnels and a porous mound above. Prior studies have shown that social insect collectives leverage unequal workload distribution to enhance group performance in confined conditions. In this work, we explore how this “idleness” might arise in social insect groups, due to both local interactions and variation in intrinsic motivation. In experiment, groups of between 2 and 25 Solenopsis invicta fire ants dig in 75-400$\mu$m diameter sand, saturated with water 20% by mass. We introduce an experimental technique for estimating each ants’ workload by tracking individual grain depositions. We then present results which suggest that workload sharing becomes more unequal for increasing group size. For example, the Gini coefficient (a measure of unequalness in groups) for 20 hours of excavation was $0.16\pm0.03$ for groups of 2 ants, vs $0.60\pm0.08$ for 10 ants. We then implement a cellular automata model, based on ideas presented by Avinery et al (2023). By introducing unequal “intrinsic motivation” into the simulation, we show that our model can predict experimental levels of workload inequality. These results suggest that, not only is the onset of laziness in collectives advantageous, but also that this onset is derived from both intrinsic variation and local decision making.

## A tale of two love songs: female wing-dimorphic crickets prefer faster songs of short-winged males

*Lisa Treidel, Leo Lu, Colin Meiklejohn, Kristi Montooth*

The flight-oogenesis syndrome is a common reproductive life history tradeoff observed broadly among female insects. Long-winged (LW) female Gryllus field crickets prioritize resource allocations to flight instead of ovarian development, resulting in reduced ovary mass and fecundity in early adulthood, compared to flightless short-winged (SW) females. Male field crickets are similarly dimorphic in wing length and flight-capability. However, whether or not there are differences in song production and reproductive success of LW and SW males remains an open question. To test for a flight-reproductive trade-off in males, we first compared the characteristics of calling songs produced by LW and SW male variable field crickets (Gryllus lineaticeps) to attract mates. Calling songs of LW males had a similar average dominant frequency and number of pulses per chirp, but a slower chirp rate and duration compared to calling songs of SW males. We next conducted mate-choice behavioral trials in the lab and a phonotaxis choice test in the field, which confirmed that differences in song quality of the morphs affects mate attraction. The slow paced calls of LW males attracted fewer females compared to the fast paced calls of SW males. Taken together, our results provide new evidence of a flight-reproductive trade-off in male wing dimorphic field crickets and suggest flightless SW males may gain a reproductive advantage by investing in more energetically costly faster calling songs.

## The lateral line according to ‘Coop’

*Timothy Tricas*

The lateral line of most elasmobranch fishes is anatomically complex, but early work provided few experimental studies to model proximate and behavioral functions. I will present the anatomical and physiological contributions in the early career of Karen Maruska that helped to crystalize this area of sensory research, particularly the enigmatic ventral non-pored lateral line canal system. Her early interest with colleagues in seasonal cycling of gonad development and steroid expression in wild stingray populations set the basic groundwork for our current understanding of the modulation vertebrate acoustico-lateralis systems by steroid and peptide hormones.

## Patterns of jaw diversification in early bony fishes

*Emily Troyer, Rafael Rivero-Vega, Xindong Cui, Min Zhu, Alice Clement, Oleg Lebedev, Robert Higgins, Benjamin Igielman, Stephanie Pierce, Sam Giles, Matt Friedman*

The over 60,000 living species of osteichthyans are divided roughly evenly between actinopterygians (ray-finned fishes) and sarcopterygians (lobe-finned fishes and tetrapods). The vast majority of primitively aquatic osteichthyans–meaning those bony fishes that never left the water–are actinopterygians, which represent over half of all vertebrates and include species as disparate as eels, flounders, anglerfishes, and pufferfishes. By contrast, living lobe-finned fishes number six species of lungfishes and coelacanths, groups often called "living fossils." Paleontology is essential to understanding the evolution of today's diversity because it reveals patterns unpredictable from living species alone. For the first 60 million years of bony fish evolution, lobe-finned fishes far outnumbered their ray-finned cousins, representing an inversion of today's pattern. Here, we explore this pronounced contrast by investigating differences in tempo and mode of phenotypic evolution in early osteichthyans. We utilize three-dimensional geometric morphometric data from CT scans of well-preserved mandibles of over 90 species, representing all major lineages. Lower jaws are taphonomically robust and taxonomically identifiable, and can provide key insights into biomechanical and ecomorphological diversification. We confirm that early actinopterygians are less morphologically diverse and display slower rates of evolution compared to early sarcopterygians, with lungfishes representing the principal contributors to high disparity and rates of change in lobe-finned fishes. This work was supported by NSF grants EAR-2219069 and EAR-2219007, and NERC award NE/X016633/1.

## Impacts of climate change on melanin and near-infrared reflectance on the wings of *Vanessa cardui*

*Ashlyn Trujillo, Amanda Carter*

Understanding organismal responses to climate change is key to mitigating biodiversity loss, and is particularly pressing in species that provide ecosystem services, like pollinators. Insects are responsible for pollinating more than 80% of plants, and butterflies are a major contributor. As such, it is imperative to know how butterflies might respond to increasing temperatures. The wings of butterflies play a crucial role in thermoregulation via solar absorptivity, heat gain, and heat loss. Melanin and near-infrared (NIR) reflectance are particularly important in this regard; however, it is unclear if these traits are shifting due to climate change. To determine if butterflies are responding to climate change via shifts in wing melanin or NIR reflectance, we analyzed 156 museum specimens of Vanessa cardui, a globally distributed butterfly, across 109 years. We focused our efforts on V. cardui collected in Arizona because average temperatures in the Southwest are increasing more rapidly than in other regions. We measured the surface area of each forewing covered in melanin and melanin intensity using ImageJ. We also photographed for NIR reflectance and measured average intensity. Analyses are ongoing, however, we hypothesize that the amount of melanin and melanin intensity will decrease over time, and average NIR reflectance will increase. Taken together, our results will provide much-needed insight into potential mechanisms of response to climate change in a globally important pollinator.

## Effects of climate change on the population dynamics of *Eriocheir sinensis* in the San Francisco Bay

*Brian Tsukimura, Jacob Perry*

Since its introduction in 1992, Chinese mitten crab, Eriocheir sinensis, population booms have led to many negative environmental/economic effects including competition with and predation on native species, as well as bank/levee erosion. To better understand their population dynamics and how climate change might affect them, two monthly plankton tows taken from the California Department of Fish and Wildlife (station D41) from 1998 to 2023 were examined for E. sinensis zoeae/megalopa. Brachyuran zoeae/megalopa were keyed to species using a dichotomous key (Rice and Tsukimura, 2007; Gonzales et al, 2009). E. sinensis zoeae/megalopa were then cross-analyzed against temperature (°C) and salinity (ppt), obtained from the National Estuarine Research Reserve System monitoring gauge (China Camp, CA), as well as monthly outflow, obtained from the California Natural Resource Agency Dayflow Program website. Data have shown that E. sinensis zoeae populations decline in temperatures below 11.7°C and salinities below 15 ppt, indicating that changes in climate may dictate population dynamics. Strong El Niño events, which result in decreased salinity levels, as well as strong La Niña events, which result in decreased water temperatures, have been shown to be negatively correlated with E. sinensis zoeae populations. If weather patterns can be used to predict population dynamics, then preparations can be made to mitigate the negative effects caused by the downstream migration of mitten crab juveniles.

## Deadly Embrace: Predating Fast-Escaping Aquatic Worms from Leech Spirals to Planarian Wraps

*Harry Tuazon, Hiteshri Chudasama, Saad Bhamla*

We investigate how freshwater planarians capture and consume Lumbriculus variegatus blackworms, despite the worms' rapid swimming abilities. In this talk, we explore the contrasting predation methods employed by leeches and planarians to capture fast-moving prey such as blackworms. Unlike Helobdella sp. leeches, which require anchoring by their posterior sucker to initiate a spiral "entombment" of a single worm within its ventral fold, planarians employ a "wrapping" strategy using their entire bodies. We hypothesize that this method results in higher predation success compared to leeches. The wrapping is facilitated by an extensible pharynx positioned along their ventral midsection, enhancing their effectiveness and mobility in capturing agile prey. High-speed cameras capture this rapid envelopment, while image analysis further investigates the functional role of the pharynx's position, including how planarians reposition to consume the entire prey. This adaptive strategy allows planarians to maintain a grip on rapidly moving prey, providing them a significant advantage in predation success compared to leeches. Our study highlights the diverse predation strategies and the adaptability of soft-bodied hydrostatics in complex environments. These insights not only deepen our understanding of aquatic ecological interactions but also inform the development of innovative soft robots inspired by natural hydrostatic mechanisms.

## Exploiting Surface Tension: Aquatic Worms and the Formation of Large Floating Buoys

*Harry Tuazon, Emily Kaufman, Tuhin Chakrabortty, Vishal Patil, Saad Bhamla*

Emergent collective behaviors often arise from unexpected interactions within simple systems, allowing organisms to adapt and survive in challenging environments. California blackworms (Lumbriculus variegatus), typically found in freshwater systems and detritus, exemplify such adaptability by forming dense, floating collectives known as "worm buoys" at the air-water interface. Oxygenation experiments with 100 worms show that this behavior is driven by low dissolved oxygen ($<$4mg/L), enabling worms to overcome anoxia by exposing their tails and absorbing oxygen directly from the air. Through coordinated tail-latching at the interface, the worms enhance buoyancy and maintain oxygen supply, ensuring survival in large groups.

We explore how the worms' tail geometry alone enables them to hang freely at the air-water interface, exploiting surface tension to remain suspended. We hypothesize that this latching mechanism is crucial for supporting the collective weight and maintaining buoy integrity. Interfacial fluid dynamics modeling suggests that a single blackworm's tail can support up to 40 times its apparent mass ($\sim$0.5 mg). Remarkably, population experiments with up to 50,000 worms show no limit to how many can be supported by the buoy, suggesting robust collective scaling. Our studies also reveal that increasing entanglement complexity within the buoy contributes to a topological lift mechanism, further stabilizing the structure. These findings offer insights into the mechanics of collective behavior and soft-bodied systems, with potential applications in soft robotics.

## From Roots to Rafts: Ecological Strategies of Aquatic Worms in Tangling on Duckweed Roots - Part I

*Harry Tuazon, Ivy Li, Prathyusha Kokkoorakunnel Ramankutty, Nicholas Correcha, Saad Bhamla*

California blackworms (Lumbriculus variegatus) are notable for their ability to condense into a worm "blob," protecting themselves from external threats as an active matter collective. In their natural environment, blackworms inhabit shallow freshwater, burrowing into benthic sediment and accessing floating vegetation like algae and duckweed. This talk explores the bioinspired strategies of blackworms, focusing on their ability to climb and entangle within duckweed roots, facilitating collective locomotion. We discover that blackworms travel 3-3.5X faster with duckweed than without, as the floating "raft" reduces friction with the bottom substrate. In addition to enhanced mobility, blackworms may be drawn to the rhizosphere of duckweed roots for its radial oxygen loss (ROL), providing a critical oxygen source in hypoxic conditions. The rhizosphere also offers an abundance of microorganisms and vegetative food, along with a height advantage for predator avoidance. We hypothesize that duckweed roots with lower stiffness and greater flexibility improve the worms' grasp and mobility strength. The blackworm's manipulation of environmental structures offers insights into adaptation dynamics, revealing how these organisms utilize their surroundings for survival and efficiency just below the water's surface.

## Assessing the impact of biologging devices on hummingbird flight performance and survivorship

*Mary Tucker, Chris Clark*

Compact biologging devices have revolutionized the study of animal behavior, movement, and physiology, but ethical concerns regarding their impact on animal welfare persist. The widely adopted "3–5% rule," which mandates that these devices should weigh less than 3–5% of the animal's body weight has been criticized due to its overly simplistic approach and insufficient evidential support. This rule overlooks other factors like aerodynamic drag and flight performance, risk of entanglement, and survivorship. Studies attaching biologgers onto hummingbirds have been limited to time budget analysis for a few hours or days; while these studies can be useful, they lack empirical data on flight performance that can be obtained using wind tunnels and survivorship data from long term aviary studies. This study measures the effects of biologging devices on the flight performance and survivorship of small hummingbird species. This study monitored the birds' performance over time after attaching a biologging device and their survivorship over weeks in an outdoor aviary. This approach seeks to provide empirical data that will contribute to refining the standards for biologging device attachment, ensuring the welfare of the animals involved.

## Citalopram exposure alters social behavior, fear, and learning in fathead minnows

*Leah Turner, Jessica Ward*

A growing number of active pharmaceutical ingredients are entering waterways, but the impacts of these contaminants at the population level remain largely unknown. Citalopram, a selective serotonin reuptake inhibitor (SSRI), has been shown to have adverse effects on juvenile and adult fish; however, little is known about how exposure to citalopram during embryogenesis and larval development alters innate behaviors, such as conspecific shoaling preferences, fear responses, and learning. These changes are critical because they directly correlate with survival.

We conducted a factorial experiment that systematically varied the timing of exposure to citalopram during the embryonic and larval stages of development in fathead minnows, Pimephales promelas. We tested embryos in activity assays and larvae in a social shoaling preference assay, a light-dark preference (fear response) assay, and a learning maze apparatus. Embryos exposed to citalopram exhibited higher inactivity, and larvae displayed heightened risk-taking tendencies, decreased shoaling tendencies, and more errors in an associative learning task. This research helps to fill a gap in our understanding of how developmental exposure to SSRIs affects the behavior of animals in contaminated waterways.

## Soft-tissues Predict Bone Shape and Modularity in the Cichlid Feeding Apparatus

*Mauryn Tyack, Craig Albertson, David Matthews*

Bone is a dynamic tissue that undergoes constant remodeling over the life of an organism. It is well established that mechanical load can influence remodeling, but the specific roles for tendons and ligaments in meditating this process are not well understood. Here we explore this question using an F2 recombinant hybrid population generated from crossing two cichlid species from Lake Malawi with divergent morphologies and feeding ecologies. Astatotilapia calliptera is a riverine foraging generalist with a relatively long and gracile feeding apparatus, whereas Tropheops sp. "red cheek" is a benthic specialist with a relatively short and stout craniofacial skeleton. We used μ-CT scanning (with and without a contrast agent) to obtain soft and hard-tissue models respectively. 3D landmark-based geometric morphometrics was used to quantify shape of the mandible and maxilla, and volumetric data were obtained for the muscles, tendons, and ligaments that insert onto these bones. With these data we asked two general questions: Are certain soft tissues better predictors of bone shape than others? Do soft tissue insertion sites predict patterns of modularity within individual bones? Our results point to a complex and nuanced relationship between soft- and hard-tissue shapes, set the stage for genetic mapping studies, and underscore the importance of soft-tissues in determining bone geometry.

## Behavioral mechanisms underlying thermal acclimation of metabolism in eusocial bumble bees

*Tamara Tyner-Swanson, Eric Riddell, Amy Toth*

An organism's ability to acclimate is crucial in determining survival and performance in response to environmental variation. Acclimation can occur through many means, including shifting physiological or behavioral traits to cope with changing conditions. Eusociality in bumble bees has also been shown as a beneficial strategy for coping with thermal stress through behavioral thermoregulation. To further explore how these eusocial organisms respond to thermal stress, we performed an acclimation experiment in which Bombus impatiens nests experienced an initial thermal ramping experiment (acute temperatures of 10°, 20°, 25°, 30°, and 35°C) followed by a twenty-one day acclimation period (10°, 20°, or 30°C), and then finally a second thermal ramping experiment. We found significant effects of acclimation treatment on the nest's ability to adjust metabolic rate, water loss rate, and nest temperature. To identify the underlying mechanisms, we performed a behavioral analysis using videos taken during the acute temperature treatments. We analyzed five periods of observation for each nest at each temperature and categorized the behavior of each bee as immobile, fanning, honey-pot usage, moving, grooming, or unknown. We found significant differences in behaviors between acclimation treatments and at acute temperatures. These findings, in combination with the physiological results suggest that eusocial bumble bees acclimate to thermal stress through a combination of behavioral and physiological processes.

## Connecting individual body mechanics with swimming performance in scup Stenotomus chrysops

*Eric Tytell, Yordano Jimenez, Martha Sutter, Erik Anderson*

Fish swimming kinematics are often studied across many species, but even different individuals within the same species swim differently from one another. We hypothesized that these individual kinematic differences may be associated with individual differences in body mechanics. We therefore studied individual scup swimming in a flow tunnel over a wide range of speeds, then measured the body mechanics of the same individuals. We stimulated the muscles to estimate how muscle activity can change the effective body mechanics. From the kinematics, we quantified tail beat amplitude and frequency, as well as body curvature, wavelength, and wave speed. From the mechanical tests, we estimated body stiffness as a function of body curvature, frequency, and the pattern of muscle stimulation. By comparing the two types of data, we will determine whether individual swimming preferences reflect internal body dynamics.

## Phylogenetic reconstruction of Holothuroidea evolution using a target-capture approach

*Abigail Uehling, Joseph Ryan, Gustav Paulay, Jessica Whelpley, Jesse Breinholt*

Sea cucumbers (Holothuroidea: Echinodermata) are an ecologically important and diverse group of marine invertebrates found across all ocean depths. They have a wide array of unique morphological features including a worm-like body plan, Cuvierian tubules, modified tube feet, and mutable connective tissue. There are currently more than 1700 described species. Despite the incredible diversity in this group, holothuroid evolution has been challenging to decipher, and the placement of some groups is debated. Here we used a target-capture approach to recover informative loci across the entire class. We designed a probe set using 3 genomes, 36 ingroup transcriptomes, and 15 outgroup transcriptomes as a reference. A total of 657 loci were selected and targeted with a final set of 53,455 probes. Final data matrices included targeted loci from 362 specimens, which represent all orders of Holothuroidea. We constructed nucleotide, amino acid, and codon alignments from the resulting sequence data. We ran phylogenies for each of these alignments, and compared the tree topologies that result from each approach. Our phylogenies largely agree with previous phylogenies based on marker genes and transcriptomes. In addition to providing an important resource for understanding the evolution of the fascinating novelties that have evolved within the sea cucumber lineage, this study also provides valuable insight regarding analysis of multiple character recodings from target capture data.

## Does migration constrain glucocorticoid phenotypes?

*Jennifer Uehling, Emma Regnier, Maren Vitousek*

Corticosterone, the main glucocorticoid in birds, is a major mediator of the incredible physiological feat of migration. Corticosterone plays important roles in migration, from preparation to in-flight energy mobilization to refueling, and corticosterone levels often show distinct elevations or depressions during certain stages of migration. Here, we ask whether corticosterone's role in migration shapes its modulation during other life-history stages, as is the case with some other phenotypically flexible traits involved in migration. Specifically, we use a global dataset of corticosterone measures to test whether birds' migratory status (migrant versus resident) predicts corticosterone levels during breeding. Our results indicate that migratory status predicts neither baseline nor stress-induced corticosterone levels in breeding birds; despite corticosterone's role in migration, we find no evidence that migratory corticosterone phenotypes carry over to breeding. We encourage future studies to continue to explore corticosterone in migrants versus residents across the annual cycle. Additionally, future efforts should aim to disentangle the potentially interacting effects of environmental conditions and migratory status on corticosterone phenotypes. Overall, insights from work in this area could demonstrate whether migration shapes traits during other important life stages, identify tradeoffs or limitations associated with the migratory lifestyle, and ultimately shed light on the evolution of flexible traits and migration. This abstract is a modified version of a previous synopsis published in Integrative and Comparative Biology: https://doi.org/10.1093/icb/icae110

## Biomechanics of campaniform sensilla: a functional interpretation of strain sensing on insect wings

*Myriam Uhrhan, Huai-Ti Lin*

Insect wings undergo continuous deformations during flight, caused by the interplay of aerodynamic, inertial, and elastic forces on the wing. Beyond lift production, insect wings are sensory organs, equipped with a high number and diverse array of sensors. Together with flow sensors, strain sensing campaniform sensilla (CS) rapidly encode complex wing states. In this study, we explore the activation mechanism of CS and how their sensitivity can be mechanically fine-tuned on the dragonfly wing, through a series of finite element analyses.

First, we examine the functional morphology of individual CS, supporting the pinching hypothesis as the primary mechanism for exciting the associated neuron. Next, we focus on the specific sensor morphology of dragonfly wing CS and the impact of their local environment on sensing properties. Specifically, we investigate how the presence of a bump structure near a CS conveys directional selectivity and how the CS field configurations (e.g. density, sensor-to-sensor distance, and orientation) affect individual strain perception. Finally, we present a high-fidelity wing base model that emphasizes the significance of sensor location on the activation sequence. Our finding suggests that single CS-bumps on dragonfly wings fire during spanwise bending, while sensilla fields on the wing base monitor loading patterns associated with different flight modes. This detailed biomechanical analysis supports the wing deformation encoding scheme we proposed based on electrophysiological data in a separate study.

## Analysis of biosynthetic gene clusters (BGCs) from rhizosphere-derived bacteria

*Katherine Ulbricht, Mentewab Ayalew, Tobias Hoffmann*

Plant roots are colonized by a subset of microorganisms from soil at high density. While antibiotics are known to be important mediators of microbial interactions, their potential role in shaping the bacterial community in roots is not known. This project aims to assess which antibiotics may be preferentially produced in Arabidopsis roots through the analysis of antibiotic biosynthetic gene cluster (BGC) abundance in metagenomic sequence data. Eighty seven bacteria were isolated from 4 soil samples collected in the Metro Atlanta area and from Arabidopsis roots grown in these soils. The isolates were sequenced using Nanopore technology and bioinformatic analysis conducted in Galaxy. Reads were assembled with Flye, polished with Racon and antibiotic BGCs identified with AntiSMASH. A total of 546 antibiotic BGCs associated with 229 unique compounds were identified. The abundance of each gene from these BGCs was assessed in Arabidopsis roots using Kallisto. Genes originating from multiple species of Pseudomonas were observed in high abundance in roots, including those from Pseudomonas sp. NIBRBAC000502773, Pseudomonas sp. TUM18999, and Pseudomonas syringae CC1557. The associated bioactive compounds were fragin, L-2-amino-4-methoxy-trans-3-butenoic-acid, and Bacillomycin-D, with some bioactive compounds present across multiple isolates. These findings underscore the importance of Pseudomonas species in plant roots and the potential of the bioactive compounds they produce in shaping the root microbiome.

## Differences in vertebral shape due to nonflight locomotion in Old World and New World fruit bats

*Jessica Upham, Richard Carter*

Understandably, flight is the dominant form of locomotion that bat biomechanists tend to study. Other forms of movement, such as quadrupedal locomotion, are not often observed in wild bats, and historically, bats are considered to move poorly on the ground. The few studies focusing on nonflight locomotion have found that quadrupedal locomotion ability varies among bats. Bat species in the suborder Yinpterochiroptera (Old World Fruit Bats) are more efficient at climbing vertically than species in the suborder Yangochiroptera (New World Fruit Bats). However, Yangochiroptera bats were found to move more efficiently on horizontal surfaces than Yinpterochiroptera bats. Frugivorous species in both suborders occupy similar niches and would be expected to maintain equal locomotion abilities, such as climbing to obtain fruit in trees. Using geometric morphometrics, the differing shapes of selected thoracolumbar vertebrae of the varying bat species were quantified and compared among families. Our findings thus far suggest a difference in vertebral shape of the thoracolumbar region that is seemingly associated with nonflight locomotion. The implications of this study can provide insights on how the ancestor to flying bats moved.

## Fatal attraction: exploring the interaction between *Aedes japonicus* and *Amianthium muscitoxicum*

*Irving Upshur, James Moloney, Simone de Montigny, Chloe Lahondere*

Aedes japonicus is a mosquito species that has recently invaded Eastern North America and Europe. Despite its potential as a vector for pathogens such as West Nile and La Crosse viruses, this species remains understudied, and no control strategies have been developed to limit its populations. Since phytophagy significantly influences mosquito biology, including survival and reproductive success, we investigated the plants that Ae. japonicus feeds on in the wild. Notably, we observed this species landing on Amianthium muscitoxicum (fly poison), a toxic perennial commonly found throughout the Appalachian Mountains (USA). This observation led us to explore the following questions: 1) Does Ae. japonicus feed on fly poison? 2) Does the plant's nectar affect mosquito survival? 3) Is Ae. japonicus a nectar thief or a pollinator of fly poison? 4) What olfactory cues emitted by the plant can Ae. japonicus detect and potentially be attracted to? Through laboratory and field assays, we found that Ae. japonicus uses fly poison as a carbohydrate source and can act as a pollen carrier, but the toxic properties of the nectar negatively impact their survival. We also determined that several volatile organic compounds emitted by the plant are detected by the mosquitoes and may mediate attraction. The consequences of feeding on a toxic plant on mosquito population dynamics and pathogen transmission will be discussed.

## First characterization of MHC II $\beta$ Exon 2 Diversity in Andean Pristimantis Frogs

*Veronica Urgiles, Anna Savage, Katherine Martin, Juan Sanchez-Nivicela*

Emerging infectious diseases represent a conservation challenge for imperiled species, and characterizing the standing genetic diversity of immune genes such as the Major Histocompatability Complex (MHC) is essential for understanding how species may adapt to pathogen pressure. In high-elevation habitats, pronounced landscape heterogeneity often leads to small terrestrial vertebrates, such as anurans, occupying restricted and specialized habitats, unlike their counterparts in low-elevation ecosystems. Theory predicts that MHC allelic diversity, sequence variation, and copy number variation should reflect these patterns of local adaptation to specific pathogen landscapes. In this study, we characterize MHCII $\beta$ exon 2 in frog species of the Andean Pristimantis genus for the first time, focusing on species restricted to high elevations($>$2000m), low elevations($<$ 1 500m), and species with broad elevational ranges. We identified 68 unique MHCII $\beta$ exon 2 alleles from 42 Pristimantis individuals, with 57% of the 114 base pairs being segregating sites, with an average nucleotide diversity of 0.167$\pm$0.00688. Despite high similarity among some alleles, rarefaction analysis indicates that we have not yet reached allelic saturation, suggesting that Pristimantis MHC II $\beta$ exon 2 is very diverse and that further sampling is necessary to fully uncover the MHC II $\beta$ exon 2 diversity in Pristimantis. Our findings can provide valuable insights into how Andean anurans adapt to challenging environments and pathogen landscapes, and highlight the importance of genetic diversity for their resilience.

## The Immunological Trajectory of Chytridiomycosis in the Highly Susceptible Panamanian Golden Frog

*Julian Urrutia-Carter, Lauren Peiffer, James Steeil, Leon Grayfer, Brian Gratwicke, Patricia Walsh, Carly Muletz-Wolz, Sara Hasenstab, Matthew Evans, Owen Osborne, Amy Ellison*

Panamanian golden frogs (Atelopus zeteki) are extinct in the wild, largely due to chytridiomycosis disease caused by the amphibian chytrid fungus Batrachochytrium dendrobatidis (Bd). However, captive assurances colonies exist, awaiting better reintroduction strategies. We thus performed infection studies to discern the relationship between A. zeteki skin microbiomes and their capacities to deal with Bd, testing the hypothesis that progressive infection will cause (i) decreased bacterial richness and dysbiosis in the microbiome, (ii) upregulation of immune genes, marking a shift from innate to adaptive immunity, and (iii) epithelial cell hyperplasia and hyperkeratosis. Frogs were randomly exposed to Bd ($n = 90$) or a negative control ($n = 40$) at five specific time points (Days 1, 4, 8, 15 and 22), and subsets of frogs were (i) swabbed for skin microbiome characterization with 16S sequencing, (ii) their skins and spleens examined by RNA sequencing for immune gene expression and (iii) their skins assessed histopathologically. Of the 90 challenged animals, 86 developed progressive infections, from average Bd loads of 68 zoospore genome equivalents (ZGE) on Day 1 to 7648 ZGE on Day 22. This study will grant insight on how the microbial-immune interface impacts fungal disease susceptibility in a critically endangered species, paving way for new disease mitigation strategies.

## Legs as linkages to legs as machines

*Jim Usherwood*

The actions of the major human leg muscles are well established. Anatomy, inverse dynamics and computer modelling allow muscles to be described as flexors and extensors, agonists and antagonists, and as motors, brakes and struts. However, the functions of these muscle actions remain unclear; we can describe what muscles do, but not necessarily why. Here, leg muscles, bones, and their connections, are viewed as links and joints of mechanisms and structures meeting the task of a vehicle, of weight support during translation, and the two fundamental demands of an effective machine: to avoid mechanical work, and to supply mechanical work economically. Human legs throughout a running stance are modelled as a sequence of linkages that predict muscle action and indicate the varying muscle functions within the integrated leg. Work avoidance is achieved with isometric muscles and linkages that promote a sliding of the hip over the ground contact. Work economy requires, for muscle with constrained power, contraction over the whole of stance; this function is achieved by the hamstrings without disrupting the linkage geometries necessary for work avoidance. In late stance, the two functions occur simultaneously through coactivation of antagonistic biarticular muscles, providing one answer to Lombard's paradox.

## The human leg in running: legs as linkages and machines. With toys

*Jim Usherwood*

The principles behind the structures and mechanisms - linkages - resulting in economical weight support during translation have previously been described for sprawled reptiles, parasagittal quadruped forelimbs and hindlimbs, and human walking. Here, similar principles are described for human running legs. Additionally, the mechanisms underlying economical powering are also described, extending the analysis from 'legs as linkages' to 'legs as machines'. A sequence of linkages engaged over the course of stance, each loading and unloading different muscles isometrically, result in a 'sliding' weight support, keeping ground reaction force vectors broadly vertical during predominantly horizontal motion. This results in a low mechanical work demand, whether from the perspective of the whole leg (as the body slides over the foot), or of the individual muscles (as they are isometric when loaded). The same structures and mechanisms can be engaged while the hamstrings shorten under load, contributing mechanical power throughout stance without disrupting the work-avoiding geometries. Because of constraints to instantaneous muscle power, the high contraction duration minimises the muscle volume demanded for a given work supply; the hamstrings can contribute the work economically, while apparently antagonistic muscles maintain the work-avoiding sliding action. Toys demonstrating the geometric principles will be provided.

## Do differences in arm morphology in deep-sea and littoral octopuses explain differing behaviors?

*Theodore Uyeno, Janet Voight*

Video recordings taken by deep-sea submersibles and remotely operated vehicles suggest that deep-sea octopuses of Graneledone sp. use their arms with less dexterity than do littoral octopuses (such as Octopus sp.). During locomotion and object manipulations, deep-sea octopus arm movements seem to be slower and performed without the great deformations for which littoral species are known, such as forming bends of tight radii, and great changes in arm length. Are deep-sea species and shallow-water octopods, members of different families, morphologically different or do different neural control paradigms constrain similar mechanisms? Given the difficulty in performing functional experiments on deep-sea species, our initial investigation compares arm morphology using conventional histological techniques, specifically cross-sections of two dorsal arms taken from the mid-length of Graneledone pacifica and Octopus bimaculoides. Preliminary assessments indicate that basic muscle fiber organizations with transverse, longitudinal, and oblique muscle fibers are present in both taxa. However, the relative percentage that each species invests in each of these interdigitating muscle groups and the amount and distribution of connective tissue differ between groups. As the muscle and connective tissue fibers combine to form a muscular hydrostat, small modifications may result in large functional differences. Research is ongoing to characterize these differences.

## Influence of Variation in Individual Capacity on Balance Performance in Walking

*Nishita Vaddella, Ilana Plager, Miguel Santos, Alexandra Voloshina, Monica Daley*

Dynamic balance involves controlling and manipulating the body's center of mass over the base of support to maintain postural control, body position, and orientation. Maintaining balance in the upright position is inherently challenging as minor deviations generate gravitational accelerations that must be counteracted to prevent falling. Here we investigate how the strategies used to maintain balance vary with individual capacity. We hypothesize that individuals with greater ankle proprioception will exhibit less instability in a tandem walking task based on the critical role of foot placement in balance. We measured multiple aspects of individual capacity to investigate which factors most influence balance control mechanisms: range of motion, sensorimotor response times, and proprioceptive accuracy. We had participants perform a series of tandem walking balance trials and measured metrics of balance stability performance: torso sway and center of pressure displacement from the midline. We used linear mixed effects models and correlation measures to test for significant relationships between capacity measures and balance performance. Preliminary results suggest ankle range of motion has the strongest influence on tandem walking balance control across individuals. Future analysis will include testing for joint stiffness as a potential individual capacity metric affecting dynamic balance control.

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## Ontogenetic changes in little gulper sharks observed through tooth morphology

*Ana Vader, Lisa Whitenack*

Changes in tooth shape across a shark's lifetime can reveal information about their diet and how it changes as the individual matures, as well as taxonomy and evolutionary relationships. Gulper sharks (Centrophorus) have been generally understudied because they are deep-water sharks, thus creating taxonomic confusion within the genus and a poor understanding of their diets and feeding ecology. These sharks have also become vulnerable to extinction due to commercial fishing and over-exploitation. For this study, the shape and size of Little Gulper shark teeth (Centrophorus uyato) were measured to better understand how their tooth shape and size change across ontogeny and what predictions can be made about their diet. Jaws were dissected and teeth in odd-numbered positions were photographed and measured for tooth width, distal and mesial cusp lengths, heel length, and notch angle. Cusp inclination was calculated as a ratio between mesial and distal cusp lengths. Tooth shape differed between the palatoquadrate and Meckel's cartilage, and tooth size measurements tended to scale isometrically. There was no significant relationship between tooth shape and the size of the shark, suggesting that C. uyato eats similar prey within the size range studied (63-97.5 cm FL). Further research on Gulper sharks can assist in taxonomic differentiation as well as understanding human impacts on the prey, reducing the possibility of extinction.

## Effect of network structure and adaptive foraging on ecosystem services of plant-pollinator systems

*Fernanda Valdovinos*

Plant-pollinator networks support terrestrial biodiversity with around 300,000 plant and 200,000 pollinator species composing these networks, and are important for human food security as 75% of crops depend on animal pollination. I will present a decades-long research agenda that combines network analysis and mechanistic dynamic modeling to understand the persistence of plant-pollinator networks. I will then present recent theoretical research on how network structure and adaptive pollinator foraging impact pollen deposition. This research quantifies pollen deposition in networks that exhibit structures like the ones of empirical networks (hereafter empirically connected networks) and those with higher connectance and lower nestedness than empirical networks. Nestedness is the tendency of generalist species to interact with both specialist and generalist species, and specialist species to interact with only generalist species. Empirically connected networks exhibit the highest pollen deposition. Increased network connectance reduces pollen deposition as increased number of interactions lead to greater conspecific pollen dilution in the absence of mechanisms like pollinator constancy. High nestedness in moderately connected networks increases the proportion of pollinators visiting only one or two plant species, which are associated with the highest quality visits. Adaptive foraging allows pollinators to quantitatively specialize on specialist plant species which increases conspecific pollen deposition. This research advances pollination biology by elucidating how population dynamics, consumer-resource interactions, adaptive foraging, and network structure affects pollen deposition in a network context.

## Veliger larvae alter swimming patterns in response to vorticity

*Luciana Valencia*

The ocean is an extremely dynamic environment, its constant water movement affecting all species caught in its path. Many marine invertebrates have planktonic early stages that cannot swim actively against currents. And yet, these larvae must navigate moving waters to search for food, find spots to settle, and avoid predators. Turbulence, thus, serves as a potential mechanical cue for larvae to modify their swimming behavior. Here we investigated the larval responses to a single component of turbulence, vorticity, for its relevance to larval size. Using the veliger of the Atlantic slipper limpet, Crepidula fornicata, which are found in turbulent coastal areas, we quantified larval behaviors in varying intensity of vertical and horizontal vorticity through ontogeny. Across 2, 6, and 18 days post-release, veligers responded to vertical vorticity by swimming opposite to the vorticity vector until an intensity threshold. As expected, the older larvae had a higher vorticity threshold. However, when the vorticity vector and gravity were anti-aligned and larvae were spun counterclockwise (topview), larval responses were weakened. Swimming in the opposite direction ceased at a lower threshold. Our work demonstrates larvae are capable of sensing and reacting to mechanical cues and using them to help navigate the water column. These responses highlight the importance of observing larval behaviors to predict dispersal and population dynamics in a changing ocean.

## Performance enhancing drug? Effects of genipin on rat muscle-tendon units

*Miles Valencia, Lauren Infantino, Manny Azizi*

The musculoskeletal system readily remodels due to short factors like exercise or long-term conditions like aging and disease. These factors can shift the properties of specific components of the musculoskeletal system in different ways and at different rates. This makes it difficult to isolate individual effects and study their impacts. Genipin is a relatively novel exogenous collagen cross-linking agent that has been shown to increase tendon mechanical properties ex vivo similarly to maturation effects. The low cytotoxicity of the compound provides the possibility of using the agent to alter properties in vivo to produce a viable phenotype where tendon properties can be systematically altered to better understand muscle tendon performance. To explore genipin's applications, we injected the gastrocnemius tendon of adult rats (6-months) with genipin followed by one week of incubation and recovery. We then conducted a series of muscle contractions in situ to characterize changes in tendon properties as well their implications for muscle contractile performance. Preliminary results suggest that genipin increased tendon stiffness compared to control rats. The effects of the Genipin appear to be isolated to the tendon, as we did not observe a shift in the passive properties of the muscle fascicles. Genipin is a viable method for experimentally altering tendon mechanical properties in vivo, and can be utilized to systematically study their effects on MTU performance.

## Adhesive pad usage in Argentine ants when facing high centrifugal forces

*Agasthya Valluri, Yakun Cao, Andrew Chacon, Nick Gravish*

Insects like ants have been observed to use adhesive pads (arolium) to increase adhesive and shear forces on smooth surfaces, particularly during maneuvers like climbing that require their body torque to be balanced. Prior research on Argentine ants (L. humile) shows that these adhesive pads are utilized when ants traverse up and down a smooth frustrated total internal reflection (FTIR) plate which illuminates the adhesive contact. However, the FTIR observations only provide the contact area of adhesive pads and not the shear/adhesion forces. To better understand the relationship between FTIR adhesive pad illumination and contact force, we created an experimental setup where the Argentine ants are placed on an FTIR plate that is rotated at high speeds (∼800 RPM) generating large centrifugal forces. To record this contact data, we use a macro lens mounted on a mobile phone camera that is rotated at the same rate as the plate, avoiding blur or loss in data due to lag. Using motor encoder data and recorded videos, we can observe the exact rotational speed at which ants start to activate their adhesive pads to maintain contact with the plate. We can also test the limits of these adhesive forces by observing when they lose contact.

## Exploring offspring preference for parental adults in the convict cichlid

*Natalie van Breukelen, Nicholas Santangelo*

In the field we examined offspring preference for parental, alloparental, or non-parental females in the convict cichlid, Amatitlania nigrofasciata. We found fry preferred female over male parents, suggesting fry can discern parental sex. We then tested if fry could discern their own parent from a different parental female (i.e. alloparental female). When the fry were of mixed sizes, there was not a clear choice; we posit this was due to the behavioral response of the alloparental female. Thus, we designed a more complex choice apparatus and used both size-matched and size-mismatched broods to examine both female behavior and fry preference. We presented fry with parental and either alloparental or non-parental females. Overall, fry did not show a preference for the parental versus alloparental female, but did choose parental over non-parental female. When there was a size disparity between the broods, alloparentals showed higher levels of aggression towards the foreign fry; when broods were similar in size, alloparental females reacted similarly to parental females. This suggests that fry who are separated from their broods are attracted to parental females, presumably for the protection afforded if adopted. While females seem to readily accept fry of similar size to their brood, they reject fry that are larger, perhaps because these fry may have an advantage over smaller fry which has been shown in previous research.

## Exploring the Impact of Invasive Coqui Frog Calls on the Phonotactic Response of Endemic Hawaiian Crickets

*Wout van der Heide, Sabrina Chen, Kerry Shaw*

Animals that signal acoustically contend with other noises in the environment, both abiotic and biotic. Invasive species have drawn significant attention due to their capacity to disrupt the communication of native species. While several studies have investigated how invasive frogs and toads impact the acoustic signals of indigenous amphibians, little research has been done on the potential for interference between invasive frogs and the calls of crickets. This study takes advantage of the invasive coquí frog (Eleutherodactylus coqui) that cooccurs with the endemic cricket Laupala kona on Hawaii island. We evaluated the sensitivity and adaptive capacity of L. kona to coqui frog calls through choice trials, where female L. kona choice and response latency were recorded between a conspecific control song and a conspecific song that included coqui calls.

## A biophysical muscle model to explain short-range stiffness and its history dependence

*Tim van der Zee, Lena Ting, Surabhi Simha, Friedl De Groote*

The force produced by activated skeletal muscle increases considerably upon small stretches to its half sarcomeres, and plateaus upon further stretching. The initial rise in force is known as short-range stiffness and can help stabilize movements before neurally-mediated changes in muscle activity occur. Short-range stiffness is difficult to assess during movements but may be predicted using computer simulations. However, state-of-the-art simulations rely on phenomenological Hill-type muscle models that do not predict behaviorally-relevant history-dependent changes in short-range stiffness with prior shortening. In contrast, biophysical crossbridge models exhibit history dependence, but have not been widely implemented in musculoskeletal simulations due to their high computational cost. We tested a range of biophysical models to predict muscle forces during behaviorally-relevant stretches in rat soleus muscle fibers, in comparison to existing data. We found that a minimum of four crossbridge states was required to predict history-dependent changes in short-range stiffness, and propose a model with the following states: super-relaxed, detached, attached and forcibly-detached. The super-relaxed and forcibly-detached states were required to explain the slow recovery of short-range stiffness after prior shortening, and the rapid convergence to a plateau force during stretch, respectively. We applied a distribution-moment approximation to reduce the model's computational cost to only 3-4 times that of a Hill-type model. Next, we will implement computationally-tractable biophysical models in musculoskeletal simulations to elucidate how muscle properties shape movement biomechanics.

## Variation in hydrodynamic performance among boxfish carapace shapes

*Merel Van Gorp, Igor Bij de Vaate, Pim Boute, Eize Stamhuis, Sam Van Wassenbergh*

The clade of boxfish (Ostraciidae and Aracanidae) are reef-dwelling fish that share a unique feature, the carapace. The body of Ostraciidae is completely covered by a bony shell of fused hexagonal plates. In Aracanidae, the carapace also covers the body, but is not completely closed at the caudal peduncle for some of the species. The carapace provides protection against predators, but its shape also defines their hydrodynamic characteristics. Among the many extant species, shapes vary between boxes with major lateral keels, over wedges with dorsal and ventrolateral keels, to more disc-like shapes with major dorsoventral keels. Here, we studied how hydrodynamic performance differs among twenty-four species of boxfish. Drag forces and moments were calculated using computational fluid dynamics simulations based on 3D laser-scans of museum specimens, which were all digitally rescaled to the same carapace volume. Up to 40% difference was observed between boxfish species with the lowest drag force and those with the highest drag force. We found a strong positive correlation between drag force and frontal-projected area and a negative correlation between drag force and carapace length. The strong variability in drag force related to the degree of axial compression of boxfish shapes, together with the relatively high coefficients of drag in boxfish in general, suggests that weak selection pressures on drag-reduction are common in this group.

## How does head shape affect burial performance in swamp eels (Synbranchidae)

*Merel Van Gorp, Cassandra Donatelli, Meg Vandenberg, Spencer Truman, Charbel El Khoury, Sarah Arnette, Matthew Kolmann*

Synbranchidae is a family of finless, eel-like fishes, in which many species create and live in burrows (i.e., fossorial). Like many fossorial animals that burrow head first, there is a high selection pressure on head shape for effectively penetrating the substrate. Heads need to be streamlined enough to slide into the substrate efficiently, but strong enough to withstand the forces exerted on it. We compared the burrowing performance of species that live primarily underground to species that only occasionally burrow and hypothesized that obligate fossorial species have head shapes which require less force to penetrate sediment and have stronger skulls. We created and 3D printed models of real swamp eels using computed tomography (CT) scans as well as idealized models using computer assisted design (CAD). We also evaluated the strength of the cranium using finite element analysis (FEA) of CT-scanned skulls. We measured the force required for burial using a 6-axis force transducer mounted onto a robot arm that guided models into sediment using an undulatory motion, analogous to live synbranchid behaviour. We found that S. marmoratus (a burrower) has a significantly higher burial performance than Monopterus roseni, Ophisternon aenigmaticum, and O. bengalense. We found that the shape of the urohyal/basihyal skeleton alters head shape and therefore, burial performance. We also document differences in cranial strength between burrowing and non-burrowing species.

## Salamander Skull Scans Show How Habitats Have Honed Heads

*Rahel Van Kanegan, Hannah Darcy, Philip Anderson*

Ambystomatidae is a family of North American salamanders, known colloquially as Mole salamanders, that has diversified into three distinct environments: terrestrial, burrowing, and aquatic. Each of these life habitats likely applied different evolutionary pressures that we expect to be reflected in the morphological diversity of the clade. This diversity should be particularly evident in the skull considering salamanders use their crania differently when performing suction feeding, biting, or burrowing. Cranial variation in salamanders is further complicated by varying amounts of ossification found across species. We sought to evaluate the observed morphological differences in the cranial structure between species. We hypothesized that these differences in morphology were due to the divergent evolution of Ambystomatidae into habitats that require different functions. We collected 22 morphological variables from CT scans of 19 species to capture the overall diversity in the clade. To understand how this morphological variation relates to potential lifestyle, we utilized Finite Element Analysis (FEA) to evaluate the potential performance of different cranial shapes under different pressures. In particular, we assessed performance under biting, suction, and burrowing loads. The results of our study highlight the impact these morphological differences have on resisting environmental pressures applied to the skulls. Our results also illustrate how the variations in cartilaginous versus ossified structural components contribute to the cranial performance of species in their environments.

## Simply the best; how armor morphologies reduce drag in poachers (Agonidae)

*Meg Vandenberg, Olivia Hawkins, Bart Boom, Adam Summers, Cassandra Donatelli*

Across engineering and within biological systems there is a unified goal of reducing drag– a common way to do this is to add surface rugosity. Rugosity increases turbulence, creating micro-vortices that draw the boundary layer closer to the surface, helping the boundary layer to remain attached longer. Increased surface roughness can be achieved through the addition of riblets, like those added to boat hulls and plane fuselages, or denticles, like those found in shark skin. In fishes, delayed boundary separation is observed within poachers (Agonidae), a family of heavily armored benthic fishes. Poachers are covered in hundreds of small spines that have the capacity to decrease drag. Here we aim to quantify the effect of different armor morphologies on drag by characterizing the boundary layer thickness. We use micro-computed tomography, 3D printing, and particle image velocimetry to visualize the flow over 20 different species of poachers to assess the hydrodynamic impacts of different shaped armor. We found that more complex armor shapes, including ridges, knobs, or intricacies additional to the main spine such as added rugosity in the form of small bumps, increases boundary layer thickness and therefore increases drag. This suggests that a simple spine might be a better drag reduction tool.

## Morphological exaggeration through sexual selection may affect the maintenance of thermal balance

*Alexandre Varaschin Palaoro, Danilo Giacometti, Glenn Tattersall*

Sexual selection is often invoked to explain the evolution of extravagant morphologies, such as antlers and horns. While the focus is typically on the exaggeration of these morphologies, how this exaggeration affects their functional roles remains a topic of debate. One aspect that has been largely overlooked is how exaggerated traits might impact heat exchange. For example, as a structure increases in size, its surface area-to-volume ratio changes, and so does its potential for heat dissipation. However, if muscles are involved in supporting this exaggerated structure, heat generated by muscle contraction may alter the extent to which an enlarged structure may act as a heat dissipator. Therefore, we propose that morphological exaggeration may have thermoregulatory consequences, as it may mediate how animals that bear such structures maintain thermal balance. Our essay is divided into three sections. First, we examine macroecological and experimental data to explore whether sexually selected morphologies vary in size with changes in environmental temperature. Second, we discuss how enlarging various morphologies affects heat dissipation and production across different invertebrates. Finally, we synthesize this evidence to identify where these differences are most likely to have significant ecological implications. Through this essay, we aim to ignite discussion on how sexual selection-driven morphological changes can lead to innovations, not only in the functional role of morphologies but also in the ecological context of individuals.

## Population Genetics and Distribution of the cave-dwelling Typhlatya spp of the Yucatan Peninsula

*Gabrielle Vaughn, Elizabeth Borda, Fernando Calderon Gutierrez, Lauren Ballou, Thomas Iliffe, David Brankovits, Nuno Simões, Efrain Chavez-Solis*

Subterranean estuaries are groundwater ecosystems with a vertical stratification fresh/brackish and saline water. Species of the cave-dwelling shrimp genus Typhlatya (Atyidae) are endemic to subterranean estuaries and marine caves, and commonly observed throughout the aquifer of the Yucatan Peninsula, Mexico & Belize. Recent phylogenetic analyses identify at least five species, with four (T. pearsei, T. mitchelli, Typhlatya sp. A, Typhlatya sp. B) associated with the meteoric water lens of inland and coastal caves, and one (T. dzilamensis) identified as a salinity generalist and restricted to coastal caves with a distribution extending into marine caves in Belize (>840km). This study assesses population genetics and structure through extensive sampling from ∼30 inland and coastal caves in the Yucatán Peninsula and marine caves in Belize, aiming to improve understanding of species distributions and connectivity among cave systems across the peninsula and beyond. T. pearsei and T. mitchelli have similar distributional ranges (>480km and >375km, respectively), with only T. pearsei specimens found in northern parts of Campeche state. Haplotype analysis of mitochondrial 16S rRNA, CYTB, and COI gene data for T. pearsei, T. mitchelli, and T. dzilamensis reveals high genetic diversity, with no genetic isolation among distant caves. In contrast, nuclear 28S and ITS (for T. mitchelli only) data show moderate to no genetic diversity, yet still indicate connectivity across distant caves, further supporting the lack of isolation between them.

## Uncovering the drivers of temperature-dependent sprint performance in urban lizards

*Princeton Vaughn, Andrea Rummel, Shane Campbell-Staton*

The process of urbanization drastically alters habitat along many different dimensions and in response, urban organisms must adapt to many novel selective pressures. In case of anole lizards, urban environments contain wider perches, leading to anoles in the city possessing longer limbs and increased sprint speed. Additionally, the urban heat island effect, which causes cities to be hotter than surrounding natural areas, results in urban anoles developing higher maximum heat tolerance compared to their forest counterparts. These trait shifts have been observed consistently in several independent transitions from forest to urban habitats. While the effects of temperature and limb morphology on sprinting performance are well-studied in anoles, urban environments provide a unique opportunity to explore the complex interplay between these factors under new selective pressures. To examine the interaction of these factors, we captured Anolis cristatellus from 3 urban-forest pairs around the island of Puerto Rico. We conducted sprint trials at each of four temperatures (20°, 25°, 30°, 35° C) and used x-ray images to precisely measure the length of individual limb bones. Recording the sprint trials, we extracted maximum sprint speed and several kinematic variables. Combining these data, we can begin to disentangle the complexities of adaptation to urban environments.

## Don't wanna be your bony wrench: phylogenetic inferences from skeletal morphology of dwarfgobies

*Diego Vaz, Christopher Goatley, Luke Tornabene*

The genus Eviota is a speciose group of cryptobenthic fishes distributed across Indo-Pacific coral reefs. Commonly known as dwarfgobies because of their diminutive size (< 30 mm), species of this genus are characterized by for having a very short life span of less than 100 days. Integrative taxonomy in conjunction with underwater photography employed in the last thirty years has led to an explosion in descriptions of new species. The genus currently contains 129 species. Despite the recent advances on the taxonomy of Eviota, skeletal anatomy and variation is poorly known. This study presents accounts of the skeleton of more than 30 species of Eviota in addition to comparisons with Gobiodon, Paragobiodon, Pleurosicya, and Brianinops. The interopercle of all examined species of Eviota extends anteriorly and contacts the lower jaw, completely lacking the retroarticular-interopercle ligament, whereas in other gobies the interopercle does not contact and is connected to the lower jaw through the retroarticular-interopercle ligament. Species in a clade of Eviota united by branched pectoral-fin rays have the posterior tip of the interopercle shaped like a wrench, which articulates directly with a process in the posterior ceratohyal. This condition is different than the observed in any other Gobiidae (and Telestei) to date. The phylogenetic significance and implications resulting from these and other observed skeletal variations are discussed.

## Searching for biting performance peaks on a multi-species form-function landscape

*Eli Vazquez, James Stroud*

Biting performance is crucial for many lizard species, integral to resource use (i.e., diet) and antagonistic biotic interactions. We investigate the relationship between head morphology and biting performance across a community of five Anolis lizard species, representing four ecomorphs. Linear discriminant analysis will be used to plot 800 individuals in multivariate space based on head size and shape traits. We expect species to form distinct clusters in this multivariate traitspace. Biting performance will be mapped onto this morphological trait space to identify local performance peaks. This study explores how morphological diversity in head shape relates to biting performance and resource partitioning within a diverse lizard community

## Elucidating the control mechanisms of snake slithering during perturbations

*Christine Vega, Kelsey Garner, Henry Astley*

Snakes move easily through complex environments using terrestrial lateral undulation, also known as slithering, using highly variable waveforms. Coordinating body posture across hundreds of vertebrae to control the reaction forces across many push points is a significant challenge, yet the many potential control mechanisms of snake slithering remain untested. We will examine the response to the sudden loss of contact, mirroring "tripping" tests in limbed animals, to distinguish between control mechanisms. We recorded kinematics as snakes slithered through a rigid, flat substrate with equally spaced vertical pegs, a subset of which will break free when triggered. Responses of the body immediately adjacent to the missing peg as well as along the total body length can distinguish between local vs global control, respectively. When contact is lost, a local area of the snake's body no longer has a peg to push against and continues to slide past the peg hole. Postures assumed from loss of contact may constrain snakes such that a trade-off between control & muscle mechanics occurs to maintain net force. Insights into these control mechanisms have implications for the evolution and diversity of snakes and other limbless taxa, as well as bio-inspired snake robot control.

## Effects of thermal stress on reproduction with investigations in mitigation by methyl farnesoate

*Abraham Velazquez, Brian Tsukimura*

The rocky intertidal zone is a thermally dynamic habitat characterized by significant seasonal temperature fluctuations. The anomuran crab, Petrolisthes cinctipes, resides in the upper intertidal zone and experiences daily thermal stress with temperatures approaching its thermal threshold. Methyl farnesoate (MF), a sesquiterpenoid hormone, is involved in regulating crustacean reproduction. This study aimed to assess the effects of short-term thermal stress and stress mitigation by MF administration on P. cinctipes reproduction during the summer and winter periods. Crabs were exposed to two temperature conditions (12°C and 20°C) and were treated with varying concentrations of methyl farnesoate (0, 1, 3, 10, and 30 ng/ml) to evaluate stress mitigation. The parameters used to measure reproduction were the hemolymph vitellogenin (VG) levels and the gonadosomatic index (GSI). Results showed that both VG and GSI levels were significantly higher in the winter group compared to the summer group (p 0.05). Our findings suggest that MF effectively mitigates the adverse effects of seasonal thermal stress on reproduction, facilitating normal reproductive activity under stress conditions.

## Mechanisms associated with short-term thermal acclimation in European green crab (C. maenas)

*Yaamini Venkataraman, Sara Shapiro, Sarah Zuidema, Heidi Freitas, Julia Kelso, Catlin Payne, Lauren Stephenson, Carolyn Tepolt*

European green crabs (Carcinus maenas) are a nonindigenous species in North America that negatively impact aquaculture and tribal food sovereignty. Their success is due in part to broad population-level thermal tolerance across short and long timescales. As individual variation shapes population-level responses, characterizing thermal tolerance differences within and across populations will provide a holistic understanding of C. maenas thermal tolerance. This talk investigates potential mechanisms underpinning short-term thermal tolerance in C. maenas populations from Massachusetts, New Hampshire, Maine, and Washington, USA. Crabs were acclimated to 15°C for at least a week. Righting response was assessed before and after 24 hours of exposure to either 1.5°C, 5°C, 25°C, or 30°C. Time-to-right increased after exposure to 1.5°C, 5°C, and 30°C, but decreased at 25°C. Massachusetts and Washington crabs were maintained at 1.5°C or 5°C for an additional 36 hours to understand medium-term cold acclimation. Populations differed in cold tolerance: a higher proportion of Massachusetts crabs were unable to right themselves at 1.5°C when compared to crabs from Washington. At the individual level, we explored triglyceride storage and genotype at a putative chromosomal inversion strongly linked with thermal tolerance for their potential impact on short-term acclimatory plasticity. This work illustrates the importance of understanding factors that contribute to individual stress tolerance, as individual variation may improve population fitness and influence C. maenas spread.

## Neurocranial Variation in Canids: Insights on Artificial Selection from Geometric Morphometrics

*Stella Venn, Sophia Kessler, Nicholas Hebdon, Kelly Diamond*

Artificial selection in modern dogs (Canis lupus familiaris) has radically altered their cranial anatomy compared to their Canid ancestors. Previous studies have concentrated on rostral traits, focusing on the relative shortening (brachycephalic) or lengthening (dolichocephalic) of the rostrum. We are interested in quantifying how selective breeding may influence aspects of the skull that are not directly related to the length of the rostrum. To investigate neurocranial variation associated with artificial selection in domestic dogs, we use landmark-based 3D geometric morphometrics of 139 individuals representing 48 dog breeds and 10 additional Canid species. 3D Slicer was used to create models and place traditional landmarks and patch-based semi-landmarks. We then used a generalized Procrustes analysis followed by a principal component analysis on these landmarks to quantify neurocranium shape. Finally, we compared principal component axes across species and American Kennel Club-associated breeding groups. In our dataset, the variation was most extensively along the sagittal crest and in the relative width of the zygomatic arch. Across the morphospace we see the clearest separation in the toy breeding group from other associated breeding groups. The toy group has a wider zygomatic arch, and a shorter, broader sagittal crest positioned more superiorly, indicative of their retention of a paedomorphic forehead. This study highlights the impact of human-driven breeding practices on cranial anatomy beyond that of the aspect of the rostrum.

## Characterizing gene expression and methylation shifts in cold stressed Bombus vosnesenskii

*Kelton Verble*

When faced with stressful abiotic situations, rapid plastic responses can determine an organism's probability of survival. Dynamic temperature fluctuations, as might be experienced during seasonal transitions, may require responses to the onset, duration, and recovery from temperature change. Cold tolerance is especially interesting, as many insects show individual and population level variation in response to cold, while upper temperature thresholds are often conserved. Bumble bees (Bombus) are important early season pollinators and can experience intermittent cold events. Molecular mechanisms, in particular gene expression regulation, can aid individual's responses to thermal stress, however, we still require a better understanding of the mechanisms that drive these transcriptional shifts. The role that epigenetic modifications such as DNA methylation can play in regulating the response to thermal stress are largely unexplored. For this study, we used laboratory-reared colonies from a wild population of the bumble bee Bombus vosnesenskii to investigate the transcriptional and methylation changes of bees subjected to cooling, induction of chill coma, and recovery from a chilled state. RNA-Seq and EM-Seq data were generated from the thorax and brains of workers to characterize differential patterns between individuals across control and treatment groups. These data will be used to help establish correlations between differentially expressed genes and methylation patterns to determine the influence methylation has, if any, on the rapid response of bumble bees to cold stress.

## Exploring Microbial Communities of an Urban Ecosystem and Culturally Responsive Science Teaching

*Ethell Vereen*

Over the last century, many streams and rivers have been subjected to rapid urbanization and anthropogenic development of their drainage basins, which has exposed them to frequent external inputs in the form of wastewater treatment plant (WWTP) effluent, industrial discharge, and sewer/stormwater overflows. These inputs often negatively impact stream hydrological, physicochemical, and biological characteristics. However, the effects of these anthropogenic inputs on indigenous microbial communities and the pathogen load of natural freshwater systems remain far from understood. The overarching goal of this project was to determine within an urban ecosystem, how do microbial communities vary and how the diversity (or functions) of microbial species is affected by pollution? During the first phase of this project, we conducted a watershed assessment and evaluation of microbial water quality indicators in Proctor Creek, an urban watershed in Northwest Atlanta, Georgia (USA). Preliminary results indicate varying degrees of ecological health throughout the watershed. Water quality was generally worse in more polluted areas of the watershed. There is also evidence of environmental justice disparities in communities. Microbial indicators (E. coli and enterococci) were detected at all sites with their concentrations increasing after rainfall events. In this talk, we will also discuss a model for the implementation of authentic laboratory research in the undergraduate teaching laboratory using a culturally responsive approach to engage students.

## Urbanization and vector-borne disease dynamics in overwintering migratory sparrow assemblages

*Taylor Verrett, Sydney Austin, Anna Fagre, Bret Demory, Kristin Dyer, Daniel Becker*

Using urban habitats can alter disease dynamics in wild birds by influencing contact with parasites and susceptibility to infection. Land-use changes associated with urbanization may structure parasite transmission by altering the distribution of arthropod vectors and/or by moderating host immunity. We investigated how urbanization drives disease dynamics in migratory birds by collecting infection data from overwintering sparrow assemblages across rural, suburban, and urban habitats in central Oklahoma. We sampled birds during both winter and pre-migration spring, when infection patterns are expected to be governed by distinct seasonal processes (pre-migration immunosuppression and active vector transmission). We used PCR of a novel subgenomic RNA marker to test birds for recent infection with West Nile virus (WNV), and both microscopy and PCR to test for haemosporidian infections. Using generalized linear mixed effect models, we tested how urbanization affects vector-borne parasitism across seasons. We predicted infection prevalence and intensity to be higher in urban sites because of habitat-related stressors, especially before spring migration. In 2022 and 2023, we found birds wintering in rural habitats had more intense haemosporidian infections, but wintering in suburban habitats amplified spring infection prevalence. Ongoing 2024 research contributes an additional sampling year and WNV diagnostics. This study provides insights on how vector-borne disease dynamics may respond to urbanization in tandem with seasonal stressors in songbirds, which is timely given the rapid expansion of urbanized landscapes.

## Seasonal changes in brain activation patterns in plainfin midshipman fish

*Brooke Vetter, Jonathan Perelmuter, Nicholas Lozier, Joseph Sisneros, Paul Forlano*

Plainfin midshipman rely on the production and reception of social acoustic signals for reproductive success. During spawning, nesting male midshipman produce advertisement calls to attract females. While seasonal changes in inner-ear auditory sensitivity and frequency encoding in midshipman is well documented, little is known about seasonal changes in central auditory sensitivity and auditory neural responsiveness to conspecific advertisement calls. We tested the hypothesis that exposure to the male advertisement call would elicit differential activation in auditory brain nuclei and in the forebrain auditory-projecting dopaminergic nucleus in reproductive vs. non-reproductive male midshipman. Fish were collected during the summer reproductive and winter non-reproductive months and were exposed to a playback of the advertisement call or ambient noise (control). Immunohistochemistry staining identified activated neurons (pS6-ir; proxy for neural activation) in midbrain and forebrain auditory and dopaminergic nuclei. Our results revealed that in key auditory areas, the greatest activation (most pS6-ir cells) occurred in reproductive males exposed to the advertisement call and we observed seasonal changes in dopaminergic activation.

## Nestling growth is influenced by local weather in two avian aerial insectivores

*Manon Vezinet, Valerie Brewer, James Rivers, Jamie Cornelius, Suzanne Austin*

As climate change continues to alter regional patterns of temperature and precipitation, animals face new challenges worldwide. One consequence is the disruption of the availability of food sources, such as insects. Flying insects are particularly sensitive to weather, yet they serve as a primary food source for avian aerial insectivores, a declining group of conservation concern. Although aerial insectivores are declining faster than other avian guilds, the mechanism(s) behind these declines are understudied. In this study, we investigated the impact of temperature and precipitation on the nestling growth rates of three avian species: the violet-green swallow (Tachycineta thalassina) and tree swallow (T. bicolor), whose diet is dominated by flying insects, and the western bluebird (Sialia mexicana), a species whose broader diet makes it less dependent on weather-sensitive prey. Thus, we hypothesized that the growth rates of swallow nestlings would be more sensitive to weather variables than western bluebird nestlings. Our results indicated that weather variables significantly affected the growth rate of the swallow nestlings while western bluebird nestling growth was most affected by brood size and showed no interaction with weather variables. These results highlight that changes in weather conditions may disproportionately impact avian aerial insectivores more than the western bluebird in this system, which calls for greater monitoring efforts to enable more adaptive conservation responses.

## Ecological and evolutionary predictors of Neotropical bat immunity

*Amanda Vicente Santos, Caroline Cummings, Gábor Czirják, Paula Ledezma-Campos, Lilla Jordán, Lauren Lock, Jorge Carrera, Kristin Dyer, Sonia Altizer, Daniel Streicker, Brock Fenton, Nancy Simmons, Thomas Gillespie, Daniel Becker*

Bat immunology has gained attention as an emerging field of research due to bats' potential to act as reservoir hosts for zoonotic pathogens. A crucial need remains to understand factors that predict the diversity and uniqueness of bat immune systems. Here, we examined ecological and evolutionary predictors of bat immune system diversity. We sampled 2519 individual bats from 41 species and seven families in Belize, Costa Rica, and Peru between 2014 and 2023. We focus on Neotropical bats due to their extraordinary diversity within the Chiroptera order. We assessed immunological metrics, including total white blood cell counts (n=1477), immunoglobulin G (n=1477) and lysozyme (n=1254) levels, and bacterial killing ability (n=568). Utilizing our extensive dataset, we asked whether evolutionary history (i.e., phylogenetic relatedness) or ecology better predicts bats' diverse immunology. Specifically, we explore if diet, species distributions, and/or roosting behavior directly impact bat immunology or if they do so by increasing exposure to pathogens. To test our hypothesis, we use weighted phylogenetic multilevel models and the Global Virome in One Network (VIRION) to include pathogen exposure risk per species as a covariate in statistical models. Our study aims to enhance scientific understanding of the factors influencing bat immune system diversity, crucial for addressing the transmission of zoonotic pathogens and safeguarding human and wildlife health.

## How did the honeybees respond to the stay-at-home policy during the COVID-19 pandemic?

*Joao Pedro Vieira Fornasari, Lewis J. Bartlett, Vladimir Eliodoro Costa, Raul Costa Pereira*

The honeybees (Apis mellifera Linnaeus, 1758) use carbohydrate-rich anthropogenic food as supplementary energy sources. However, we know little about how they balance their diet with this resource in trophically complex systems. By temporarily changing the availability of human-derived food for wildlife in urban settings, the COVID-19 lockdown created a singular scenario to study the honeybees' reliance on this resource over time.

We investigated how the lockdown affected the honeybee`s seasonal trophic dynamics in a tropical city. We expected: (i) bees would rely more on anthropogenic resources during the dry season when nectar is scarce; and (ii) the lockdown would reduce the contribution of human-derived food to the bees' diet across both seasons. We captured 256 individuals across the wet and dry seasons during and after lockdown (periods a, b, c, and d, respectively) and assessed their foraging decisions by combining stable isotope analysis and statistical modeling.

The honeybees consumed more anthropogenic food in the dry (Bayesian mixing model, d: $37.1 \pm 2.8\%$) than in the wet season (c: $22.4 \pm 2.1\%$). Even though they did not consume significantly less human-derived sugar during the lockdown (b: $39 \pm 2.4\%$; a: $26.3 \pm 2.4\%$), they had more homogenous diets in this period (pairwise Tukey test, a: $t244 = 3.086$, $p = 0.0121$, b: $t244 = 2.909$, $p = 0.0205$). Our findings support that anthropogenic and floral resources shape the honeybee's foraging ecology and large-scale changes in human activity can influence this complex relationship.

## A simulated short-term heat wave alters estrogen signaling to impair oogenesis in a eurythermal fish

*Isabel Villafuerte, Olivia Martin, Sean Lema*

Short-term heatwave events are increasing in prevalence and severity with climate change. Exposure to high temperatures can impair reproduction in many fish taxa, but it remains unclear how short-term heat waves may affect fish reproduction. Here, we examined how a simulated heatwave impacted the reproductive status and endocrine physiology of the pupfish Cyprinodon nevadensis amargosae, a species with one of the highest thermal limits for reproduction among fishes. Adult pupfish in mixed-sex groups were maintained under ecologically relevant fluctuating temperatures that cycled diurnally from a morning low of 20-21°C to an afternoon high of 31-32°C. After 54 d under these temperatures, a subset of fish was exposed to a simulated heatwave for 6 d by elevating maximum and minimum daily temperatures by 6°C. Female pupfish exposed to the simulated heatwave had reduced ovarian gonadosomatic index (GSI) values, as well as lower plasma 17-estradiol (E2) and diminished liver expression of vitellogenin egg yolk and choriogenin egg envelope genes, which are essential for oocyte development. The downregulation of vitellogenin and choriogenin genes appears to be partly mediated by reduced liver estrogen receptor $\alpha$ (esr1) expression. Male pupfish, however, showed no changes in testicular GSI values. These results suggest that short-term exposure to higher temperatures can diminish egg production in female pupfish and corroborate concerns that anomalous heatwaves may impair thermally sensitive reproductive processes in certain fishes.

## Genomic resources for pentastomes: a comparative study of native and invasive species

*Stephanie Villella, Jenna Palmisano, Robert Fitak*

Pentastomes, or tongue worms, are parasitic crustaceans that primarily infect the upper respiratory tracts of their hosts. These parasites commonly infect vertebrates, including fishes, mammals, and amphibians, with snakes most often serving as their definitive hosts. The introduction of the non-native pentastome Raillietiella orientalis to South Florida has led to its rapid geographical expansion and invasion of naïve host species, causing population declines, increased morbidity, and disease in already threatened snake species. In contrast, native pentastomes in the southeastern United States, Porocephalus crotali and Kiricephalus coarctatus, typically cause milder infections compared to R. orientalis. Pentastomes, as a clade, remain enigmatic, with limited genomic resources available to support research. This study aims to sequence and annotate the nuclear and mitochondrial genomes of three pentastome species—two native and one non-native. Prior studies support that pentastomes are closely related to parasitic fish lice (Argulus americanus), which can be treated by therapeutics targeting the nervous system or chitin synthesis of the parasite. Comparing these same biological pathways in pentastomes could offer insights into developing treatments for affected wild snake populations. Additionally, it is hypothesized that naïve hosts lack the immune response needed to combat R. orientalis infections. The resulting genomic resources will facilitate comparative genomic analyses between native and non-native parasites, particularly focusing on parasite surface-level antigens and host immune responses.

## Eyeing Complexity: Determining morphological components of eyes across Cnidarian eye origins

*Bridget Vincent, Nicolas Noel, Rishima Tewari, Alexandra Curatolo, Todd Oakley*

Convergent traits arise when distantly-related taxa separately evolve similar phenotypes. A long standing question is to what extent the components of convergent traits are themselves convergent. In the case of cnidarian eyes, which have evolved at least 9 times (Picciani et al., 2018), morphologies range from simple ocelli to camera-like eyes. Although these structures could contain a multitude of different morphological components, very few species have detailed descriptions of their eye ultrastructure, thus limiting our knowledge of which components are shared between species and whether they are convergent. Here, we use a combination of fluorescence microscopy techniques including immunolabeling and fluorescence lifetime imaging microscopy (FLIM) to determine the presence of diagnostic features such as pigment cells and photoreceptors, in cnidarian eyes across phylogenetically independent origins. Ongoing work includes adding additional samples and acquiring the ultrastructure of key species' eyes through transmission electron microscopy (TEM). Characterizing the breadth of cnidarian eye morphology allows us to better understand the evolution of complex traits through an understanding of its parts.

## Movement strategies under directional drift in environments with heterogenous resource and toxicant

*Leah Vitale, Bo Zhang*

Environmental stress forces populations to move away from oppressive regions and look for desirable environments. Different species in the same spatial distributions of resource and toxicant can respond using distinct movement strategies. However, the optimal behavior strategy may differ when a resource and a stressor occur simultaneously or if they distribute in different patterns. Additionally, more empirical work is needed to identify the role of dispersal on species responses to a gradient of distributions of stressor and resource, along different directions of advection, to ultimately develop a more realistic movement ecology theory. We compared the total abundance of two strains of Caenorhabditis elegans with different locomotion speeds foraging in various spatial distributions of resource and toxicant. We predict that fast movers will have an advantage over slow movers in response to the application of water drifts in both an environment of separate toxicant and resource, and an environment of overlapping toxicant and resource. This study seeks to provides a better model to predict how species with different movement strategies respond to environmental stressors in natural systems.

## DNA methylation as a mechanism of environmentally-induced phenotypic flexibility in free-living bird

*Maren Vitousek, Conor Taff, Sabrina McNew, Leonardo Campagna*

Brief challenges can have long-term impacts on phenotype, but the mechanisms of these phenotypic adjustments are often poorly understood. Work in vertebrate model systems has revealed that DNA methylation – a stable epigenetic mark that can be inherited through multiple cell divisions and alter gene expression – can be affected by exposure to stressors, including outside of development. Much less is known about the role of DNA methylation in natural populations, but studies in wild birds have begun to link methylation patterns to phenotype, and to developmental exposure to challenges. Here we describe the results of several recent studies in free-living songbirds (tree swallows; Tachycineta bicolor) that have shown that challenges experienced in adulthood can have both rapid and long-lasting effects on DNA methylation. These findings provide support for the role of DNA methylation in mediating environmentally-induced phenotypic flexibility throughout the lifetime, a mechanism that could help organisms to cope with variable or changing environments.

## Impacts of autotomy and surface on locomotor and prey capture performance in a pad-bearing gecko

*Marina Vollin, Tim Higham*

Caudal autotomy, or the voluntary severance of the tail, is a common antipredator behavior in lizards. Although autotomy may provide a chance to escape predation, the loss of the tail can incur a variety of costs, including decreased performance while running, jumping, climbing, and capturing prey items. The gold dust day gecko (Phelsuma laticauda) is an arboreal gecko with adhesive toepads and a large, mobile tail. Arboreal geckos must traverse complex environments featuring numerous challenges to the locomotor system, including vertical and rough surfaces. The tail plays an essential role in steadying arboreal geckos while climbing vertical inclines and gold dust day gecko adhesive strength is reduced on rough surfaces. However, despite lacking a tail, autotomized geckos are still able to successfully traverse rough vertical surfaces. How, or if, autotomized arboreal geckos compensate while running, climbing or capturing prey is poorly understood. We used high-speed videography to quantify locomotor and prey capture performance in the gold dust day gecko at 30- and 90-degree inclines and on rough and smooth surfaces both before and after autotomy. Kinematic and performance variables related to locomotion were examined, and include maximum running velocity and acceleration, stride length, and stride frequency. Prey capture variables include strike velocity and post-capture prey shake velocity. Our results highlight the context-dependent effects of autotomy in geckos.

## Mechanisms driving differences in suction generation during feeding in infant and preterm pigs

*Emily Volpe, Elska Kaczmarek, Dylan Anderson, Maressa Kennedy, Holly Sabato, Hannah Shideler, Ani Smith, Thomas Stroud, Skyler Wallace, Shanique Yazzie, Christopher Mayerl, Harlow Smith*

Infant mammalian feeding requires successful suction generation which is caused by the tongue sealing around a nipple in order to acquire milk. Premature infants often struggle to generate enough suction to feed successfully, leading to reduced feeding performance. This is especially true during breastfeeding, and as a result preterm infants often must be bottle-fed. However, we have a poor understanding of why some infants generate less suction. One potential mechanism is nipple design: human breasts are ducted, whereas bottles are hollow cisterns. We used high-speed biplanar videofluoroscopy synchronized with intraoral pressure recording to evaluate the relationships between suction generation, seal characteristics, and tongue kinematics in preterm and term pigs feeding on two bottle nipple types: a ducted, biomimetic nipple and a hollow, cisternic nipple. We found that preterm pigs feeding on a cisternic nipple generated little to no suction, but generated more suction on the ducted nipple. Term pigs generated twice as much suction as preterm pigs on both nipple types and also generated greater suction on the ducted nipple than the cisternic nipple. We did not find variation in the pigs' seal length between nipple types, but found that preterms tended to have a deeper seal on the nipple. These data suggest that one potential mechanism for decreased suction generation in premature infants is how they position the nipple in their mouths during feeding.

## To predict the long-term consequences of bacteria consumption in raw local fish in Columbus, Georgia

*Andy Vu, Ensaf Taha, Craig Harbin, Trinity Smith, Nylah Phillips*

It is imperative to understand what bacteria is in local fishes and waterways, as well as the risks associated with the consumption of contaminated fishes. In this study, we cultured the bacteria from the organs of the fish and study the damage that bacteria caused. Our findings from the isolates showed a heavy presence of Aeromonas hydrophilia, and by using antibacterial resistance test, we determined that

Aeromonas is susceptible to gentamicin, chloramphenicol, and ciprofloxacin. Our results were based on the culturing of bacteria taken from fish lesions and blood on sheep blood agar, using gram staining to view the bacteria's shape. We then tested the cultured Aeromonas with oxidase and catalse to confirm the presence of cytochrome oxidase and confirm catalase enzyme. Triple Sugar Iron was used testing Aeromonas's ability to ferment carbohydrates. We tested Aeromonas motility in Benton, Dickinson and Co. SIM slant agars, we found motility and indole but no sulfide in Aeromonas. We found out that the liver of Lepomis cyanellus showed signs of repairable damage and aggregated macrophages in the spleen. The scanning electron microscopy showed the properties of lab-grown Aeromonas, as well as their possible growth and survival in certain agars. Aeromonas appeared to be in a filamentous state when exposed to carbon dioxide, we speculate that Aeromonas is developing the filaments as a type of resistant and survival in unfavorable environment.

## Algorithmic construction of topologically complex biomineral lattices via cellular syncytia

*Pranav Vyas, Charlotte Brannon, Laurent Formery, Chris Lowe, Manu Prakash*

Biomineralization, observed in unicellular and multicellular systems, remains elusive due to limited understanding of physicochemical and biomolecular processes. Echinoderms, with diverse calcite structures, exemplify the challenge of understanding cellular mechanisms shaping biominerals. In holothurians (sea cucumbers), multi-cellular clusters construct discrete single-crystal calcite "ossicles" ($\sim$ 100 μm), with diverse morphologies across species and within an individual. Through our work, we establish juvenile stage Apostichopus parvimensis as a new model system to study biomineralization and morphogenesis of topologically complex lattices and simultaneously explore the cellular physiological context. We demonstrate, how cytoskeleton enabled intra-cellular transport and tip guidance, enables growth of ossicles from small (1-2 μm) seeds into complex topologies within tightly wrapped membrane bound spaces. Constructing a topological description of ossicle geometries from 3D micro-CT data reveals the hidden growth history and conserved patterns across ossicle types. Using coupled reaction-advection-diffusion equations we model the tip growth process as a coordination between passive diffusion and active transport within the syncytium. Finally, using reduced order models of conserved transport on self-closing branching networks, we highlight the hidden universality in the growth process of distinct ossicles. The system presented serves as a unique example of "cellular masonry" merging top-down cellular physiology and classical branching morphogenesis with bottom-up non-equilibrium mineralization processes at the interface of living and non-living matter.

## Hyperuniform networks in Ophiuroid communities in the Arctic benthic environments

*Pranav Vyas, Ethan Li, Manu Prakash*

Extreme environments facilitate innovation of extreme survival strategies by animals. During one of our expeditions in the Chukchi Sea in June-July 2023, direct underwater imaging of the shallow ($\sim$50 m) sea floor below ice sheets revealed extensive assemblages of brittle stars (Ophiuria sarsii). These extremely stable assemblages resemble contiguous disordered lattices spanning tens of kilometers, facilitated by arm-to-arm contacts. By analyzing benthic imaging data and employing statistical approaches, we discovered suppression of animal density fluctuations at larger length scales, indicating hyperuniformity in these lattices. This finding suggests a unique spatial organization of brittle stars in polar aquatic environments, characterized by extreme polar nights and surface ice cover, making them distinct from other marine communities. Comparative studies with fossil data of ophiuroid communities and laboratory experiments using miniature brittle stars offer insights into potential evolutionary and ecological mechanisms driving this phenomenon. These results contribute to our understanding of how large-scale patterns in marine invertebrates can emerge from individual interactions in extreme environments.

## Investigating sex differences in the effect of habitat structure on nest site selection

*Erin Wagner, Paris Lopez, Joseph Leese*

One of the most important decisions many animals face in their lifetime is determining where to raise their offspring. For egg laying species, this involves selecting a nest site that is secure with appropriate resources. Within monogamous species, nest site selection can be decided collaboratively or one sex may have more influence over the process. For convict cichlids (Amatitlania nigrofasciata), our preliminary research has shown that when acclimated to equivalent nest sites, males tend to prefer their own site while females do not appear to have a strong preference for their own site. In a follow-up experiment, we explored how nest site quality might effect nest site selection. Specifically, we sought to determine if increasing habitat complexity (adding artificial plants) would influence the nest site selection in a pair. We hypothesized that when nest sites were enhanced, both members of a pair would prefer the higher quality nest site. Our results suggest that while males significantly preferred their site when enhanced, females appeared again to not have a significant preference and split their time on both nest sites. The reverse treatment study (female enhanced) is ongoing. The ambivalence of females for a specific nest site could indicate that factors other than nest site quality, such as mate quality or strength of a pair bond, could play an important role in how nest sites are selected.

## Nothing in EvoDevo makes sense except in the light of cell biology

*Gunter Wagner*

The first big wave of evolutionary developmental biology was the discovery of conserved transcription factors. The central concept of early EvoDevo research was the "gene regulatory network" and evolution by cis-regulatory changes, the cis-regulatory paradigm. At this point we have a large and solid bedrock of research based on this paradigm. The question I want to discuss in this contribution is how our field can move forward, benefiting from research on gene regulatory networks, but still conquering new territory. My proposal is that gene regulatory network evolution needs to be embedded in a more explicit appreciation of the cell biological constraints facing animal development and evolution. This position is informed by the research my lab has conducted on the evolution of mammalian pregnancy, including questions about the origin of novel cell types critical for mammalian pregnancy, the decidual cell.

The evolution of mammalian embryo implantation faces the "inflammation paradox." Embryo-implantation causes an injury to the maternal tissue and is eliciting an inflammation. The key innovation of eutherian mammals was to tame this inflammatory reaction which allowed for extended gestation.

On a more general level this example suggests that evolutionary novelties face constraints that result from the cell biological cohesion of the organism. Understanding evolutionary innovations requires the study of organismal self-maintenance and how evolution is able to overcome them.

## Temporally dynamic landscapes of fear and safety alter prey shelter use

*Madison Wagner, Paul Moore*

Non-consumptive effects often evoke changes in prey behavior, including shelter preference and sheltering behavior. Similarly, prey may choose refuges that are of relatively higher quality when threat is high and vice versa. However, many studies focus on prey shelter usage as a function of the presence or absence of relatively large, lethal-sized prey, while ignoring how shelter arrangement and quality may also affect behavioral alterations. In this study, we exposed rusty crayfish (Faxonius rusticus) to sublethal sized largemouth bass (Micropterus salmoides) odor in two different exposure patterns while also presenting crayfish with shelters of varying quality in two different arrangements. We then quantified crayfish shelter usage patterns by examining time spent in each shelter and the total number of visits to each shelter. We found that shelter behavior was altered by a combination of our four independent factors: predator presence, exposure pattern, shelter quality, and shelter arrangement. These findings add evidence to the broader field of predator-prey ecology on how fear and safety affect prey behavior and decision-making paradigms directly related to shelter use.

## Insights into the morphological diversity of fish scales using reef fishes

*Dylan Wainwright, David Collar*

The scales of bony fishes are mineralized plates that form overlapping patterns on the skin. Scale diversity has been appreciated for centuries – we know species have distinct scale morphology, and we have a general sense that differences among species may reflect phylogeny. The primary way of describing scales is by using categories that divide scales into spiny-edged and smooth-edged varieties, and these categories have created a useful language for morphological descriptions. However, to explore beyond these classic categories we have been using topographic imaging methods to quantify the morphology of embedded fish scales. In this study, we used topographic measurements of nearly 400 reef fishes to examine two questions: 1) how important are spiny-edged and smooth-edged categories for scale diversity, and 2) does morphological diversity across species closely follow phylogeny? Our focus on reef fishes allowed us to examine these questions using a wide range of phylogenetic, ecological, and functional diversity, and we found that spiny vs smooth-edged scale categories represent just a small portion of overall scale diversity, indicating that scale forms extend well beyond these classic types. In addition, scale morphology exhibited high phylogenetic signal but with variation in the clustering of different clades. Our work highlights that new discoveries await in scale diversity and a broad comparative approach will help us elucidate the diversity of these structures.

## Morphological and kinematic novelties underlie proficient herbivory in surgeonfishes, Acanthuridae

*Peter Wainwright, Michalis Mihalitsis*

Acanthuridae are a highly speciose and ecologically diverse group of primarily herbivorous coral reef fishes. To better understand their success we studied the morphology and kinematics of their benthic algae grazing. We document feeding kinematics of 15 species using 1000 Hz video. Herbivory in this group is enhanced by the evolution of short jaws, multicusped teeth, and a suite of novel head, body and jaw movements that enhance algae grazing. Several novel movements are used that help detach algae without major movements by the entire body. Slight ventral flexion of the head is commonly used as fish grip the algae, sometimes also invoking contractions of abdominal body regions. Some species flex an intramandibular joint, producing ventral rotation of the closed jaws. Most species rotate their upper jaw from side to side once the jaws are closed. Remarkably, the sistergroup to Acanthuridae, the Moorish Idol, a reef spongivore, can flex its upper and lower jaws laterally when it feeds benthically. The mechanism for this appears to be the same as lateral jaw rotation in acanthurids and indicates that the major kinematic novelties used by acanthurids evolved in a stepwise fashion. These novelties shape a dexterous feeding system that allows these fish to efficiently crop turf algae, one of the most important ecosystem processes on coral reefs.

## Characterizing the flow and motion resulting from cardiac action in the tunicate *Ciona savignyi*

*Lindsay Waldrop, Aaron Thi*

The flow and forces produced by the pumping of the tubular heart of early vertebrates are key drivers of developmental processes, including the development of the heart itself. Despite its importance, the fluid flow driven by these tubular hearts is understudied. Tunicates in the genus Ciona are used as a model organism to study many aspects of early vertebrate development, and since the hearts of these animals also share physical features of vertebrate embryo hearts, their use can be extended as a model for the fluid flow of cardiac development. Many basic features of this model are uncharacterized, including the speed and spread of cardiac action potentials, the resulting kinematics of heart contraction, and the flow produced by these contractions. Two techniques are used here to study cardiac action potentials produced by the hearts of Ciona savignyi and the resulting tissue movement and fluid flow. Optical mapping, a technique that uses voltage-sensitive dyes to visualize depolarization movement across tissue, is used to measure the speed of action potentials through the myocardium, allowing for visualization of action potentials decoupled from cardiac movement. Micro particle image velocimetry is used to quantify the flow fields produced by movements of the heart tissue within the heart and throughout the circulatory system. These values can inform computational models of circulatory-system flow driven by tubular hearts.

## Snake Fungal Disease (Ophidiomycosis) alters the skin microbiome across two experimental scales

*Donald Walker, Alexander Romer, Matt Grisnik, Jason Dallas, William Sutton, Christopher Murray, Rebecca Hardman, Tom Blanchard, Ryan Hanscom, Rulon Clark, Cody Godwin, N. Reed Alexander, Kylie Moe, Vincent Cobb, Jesse Eaker, Rob Colvin, Chris Ogle, Joshua Campbell, Carlin Frost, Rachel Brubaker, Shawn Snyder, Alexander Rurik, Chloe Cummins, David Ludwig, Joshua Phillips*

Emerging infectious diseases are increasingly recognized as a significant threat to global biodiversity conservation. The epidermal microbiome is known to influence host health through immunomodulation and exclusion of pathogens. Pathogens can alter the host microbiome by inducing dysbiosis, an ecological state characterized by a reduction in bacterial alpha diversity, an increase in pathobionts, and/or a shift in beta diversity. We used the Snake Fungal Disease (Ophidiomycosis) system to understand how an emerging pathogen induces dysbiosis across two major experimental scales. We characterized the skin microbiome of free-ranging snakes across a broad phylogenetic and spatial extent, in conjunction with a laboratory study of Northern Watersnakes examining temporal changes in the skin microbiome following experimental inoculation with Ophidiomyces ophidiicola. Patterns characteristic of dysbiosis emerged at both scales, including non-linear changes in alpha, and alterations to beta diversity, although some patterns differed between experimental contexts. A deep learning neural network trained on the skin microbiome was more accurate in predicting disease state than other traditional analytic techniques. Environmental niche models identified snakes from geographic regions suitable for O. ophidiicola had high pathogen loads. We demonstrated pathogen induced dysbiosis of the microbiome follows predictable trends, that disease state can be classified with neural network analyses, and environmental niche models predict suitable habitat for the snake fungal disease pathogen.

## The young and the resilient: investigating coral thermal resilience in early life stages

*Nia Walker, Lys Isma, Nepsis Garcia, Aliyah True, Taylor Walker, Joyah Watkins*

Global ocean warming is affecting keystone species distributions and fitness, resulting in the degradation of marine ecosystems. Coral reefs are one of the most diverse and productive marine ecosystems. However, reef-building corals, the foundational taxa of coral reef ecosystems, are severely threatened by thermal stress. Models predict 40–80% of global coral cover will be lost by 2100, which highlights the urgent need for widespread interventions to preserve coral reef functionality. There has been extensive research on coral thermal stress and resilience, but 95% of studies have focused on adult corals. It is necessary to understand stress during early life stages (larvae, recruits, and juveniles), which will better inform selective breeding programs that aim to replenish reefs with resilient stock. In this review, we surveyed the literature on coral thermal resilience in early life stages, and we highlight that studies have been conducted on relatively few species (commonly Acropora spp.) and in limited regions (mainly Australia). Reef-building coral management will be improved by comprehensively understanding coral thermal resilience and fitness across life stages, as well as in diverse species and regions.

## The relationship between spectral signals and retinal sensitivity in dendrobatid frogs

*Whitney Walkowski, Corinne Richards-Zawacki, William Gordon, Nicolas Bazan, Hamilton Farris*

Research on visually driven behavior in anurans has often focused on Dendrobatoidea, a clade with extensive variation in skin reflectance, which is perceived to range from cryptic to conspicuous coloration. Because these skin patterns are important in intraspecific and interspecific communication, we hypothesized that the visual spectral sensitivity of dendrobatids should vary with conspecific skin spectrum. Consistent with the matched filter hypothesis, we predicted that the physiological response of frog retinas would be tuned to portions of the visible light spectrum that match their body reflectance. Using wavelength-specific electroretinograms (ERGs; from 350-650 nm), spectrometer measurements, and color-calibrated photography of the skin, we compared retinal sensitivity and reflectance of two cryptic species (Allobates talamancae and Silverstoneia flotator), two intermediate species (Colostethus panamansis and Phyllobates lugubris), and two conspicuous aposematic species (Dendrobates tinctorius and Oophaga pumilio). Consistent with the matched filter hypothesis, the retinas of cryptic and intermediate species were sensitive across the spectrum, without evidence of spectral tuning to specific wavelengths, yielding low-threshold broadband sensitivity. In contrast, spectral tuning was found to be different between morphologically distinct populations of O. pumilio, where frogs exhibited retinal sensitivity better matching their morph's reflectance. This sensory specialization is particularly interesting given the rapid phenotypic divergence exhibited by this species and their behavioral preference for sympatric skin reflectances. Overall, this study suggests that retinal sensitivity is coevolving with reflective strategy and spectral reflectance in dendrobatids.

## Dimorphic Development and Neural Circuitry Insights from Streblospio benedicti's Larval Life History

*Robert Walsmith, Christina Zakas*

Studying a model with dimorphic development offers an opportunity to understand how neural circuitry evolves in response to developmental and environmental constraints. Comparing dimorphic development within a species can reveal variations that may influence behavior and sensory processing. The marine annelid model system, Streblospio benedicti, provides a unique opportunity to contrast neural development in larvae with different developmental modes and life histories. Lecithotrophic larvae of S. benedicti rely on yolk storage partitioned from the mother and may express accelerated developmental strategies compared to their planktotrophic counterparts, which rely on particle feeding. Planktotrophic larvae also have developmental traits (e.g., swimming chaetae, anal cirri) and behaviors (positive phototaxis) not found in the lecithotrophic morph.

We aim to address the extent to which neural differences underlie the larval morphologies and sensory processing. We analyzed the nervous system of larvae using immunohistochemistry with 5-HT and FMRF-amide markers to label neural anatomy. We compare the extent to which different neurons are present in both larval types. In addition, our investigation aims to explore the addition of the adult feeding appendages (palps) and gill structures (branchia) through metamorphosis. By studying neuronal development in this model species, we can begin to uncover the differences underlying a suite of behaviors linked to larval life history. We can also begin to understand the molecular underpinnings of life-history diversification at the behavioral level.

## Risk analysis of elasmobranch species as biovectors using satellite telemetry

*Alyssa Walter, Elizabeth Duncan, Morgan Youngblood, Chris Caldow, Christopher Lowe, Ryan Logan, Emily Spurgeon, Kady Lyons, Ryan Freedman, Varenka Lorenzi*

Bioaccumulation of Persistent Organic Pollutants (POPs) in seafood is a topic of concern in Southern California and the recent discovery of a Deep Water Dumpsite off Catalina Island with Dichlorodiphenyltrichloroethane (DDT) has heightened public concern. The high trophic position of elasmobranchs mean they can bioaccumulate POPs, presenting an unknown risk to humans if consumed. This study utilized satellite telemetry to compare the movements of Bat Rays (Myliobatis californica), Leopard Sharks (Triakis semifasciata), and Angel Sharks (Squatina californica), predator species commonly caught by sustenance fishers off of local piers that could be potential biovectors of POPs. Fourteen Pop-Up Archival Satellite Transmitting tags were deployed, providing depth, temperature, and estimated location data on these three species. Angel Sharks ($n = 5$) and Leopard Sharks ($n = 4$) used a limited shallower depth range, while Bat Rays ($n = 5$) made a number of deep dives (over 300 feet). Using Minimum Convex Polygons we found that Bat Rays had large home ranges ($avg = 7231.285 \pm 6084.04$ km2) that encompass five of the eight Channel Islands offshore in Southern California. The high movement capacity observed in Bat Rays shows their ability to forage in distant locations with unknown contaminant levels before time of capture. Testing of contaminant levels in tissue samples for these species is underway, as well as further tracking of Angel and Leopard Shark movement to assess seafood.

## The allometry of cutting efficiency in *Atta cephalotes* leaf-cutter ants

*Olivia Walthaus, Finn Wagner-Douglas, Lina Rhmari Tlemcani, David Labonte*

Leaf-cutter ants are the dominant herbivores of the Neotropics, responsible for an astonishing 15% of defoliation. Central to leaf-cutter foraging behaviour is cutting - if an ant cannot cut into a leaf, it cannot harvest the plant fragments needed to sustain the colony's fungus gardens. To generate the considerable forces necessary to cut leaves, ants use large mandible closer muscles; leaf-cutting is thus not only mechanically challenging but also metabolically costly. The ratio between the mechanical work output and the metabolic expenditure defines the efficiency of the process. Are all worker sizes equally efficient leaf-cutters?

To assess cutting efficiency across the polymorphic workforce of Atta cephalotes, we measured the mechanical power output and metabolic demand of leaf-cutting using pseudoleaves made from PDMS. Metabolic power, measured via flow-through respirometry, increased with worker size but was independent of pseudoleaf properties, suggesting that ants of all sizes exert maximum effort regardless of cutting difficulty. Mechanical power, estimated from measured cutting force and speed, was driven by pseudoleaf toughness and thickness, and varied non-trivially with size, leading to a local maximum in cutting efficiency: intermediate-sized workers were the most efficient cutters. The optimal worker size can be predicted directly from physical modelling using only leaf traits as variable input, enabling the comparison of field data with optimal foraging theory.

## A longitudinal behavioral analysis of aquarium whale sharks (*Rhincodon typus*)

*Celeste Walton, Connor Gallimore, Richard Nugent, Maury Fradkin, Laurie Poppell, Christopher Schreiber, Christopher Coco, Mathew Grober, Bruce Carlson, Alistair Dove, Michael Black*

Rhincodon typus, or the whale shark, is the largest extant fish in the world. Due to their enormous size and conservation status, whale sharks are rarely housed in aquaria. Here we present a behavioral analysis recorded by 89 volunteers from 2008–2012 to study four R. typus (ID codes: AL, TA, TR, YU) in an aquarium setting. Behavioral metrics such as swim speed, depth occupation, swimming direction, and lead-follow interactions demonstrated individual variation and responses to habitat changes. All sharks displayed an increased swim speed 30-minutes before regimented feed times when food was distributed to other animals in the same habitat. YU was recorded swimming more at depth, faster, almost exclusively clockwise, and engaged in fewer close proximity interactions with others than expected by chance. In contrast, AL was observed swimming the slowest, at the surface more than others, led other sharks more than she followed, and had strong lead-follow interactions with another shark of the opposite sex. TA and TR did not differ from each other in depth profiles or speed, but did differ in their proclivity to lead or follow. Depth preferences and lead-follow interactions suggest some partitioning of the habitat and the possibility of social hierarchy in this species. These results represent the first longitudinal behavioral analysis of aquarium R. typus, offering meaningful similarities and contrasts to field observations.

## Avian physiological and behavioral responses to an annual nighttime event at Zoo Atlanta

*Celeste Walton, Marieke Gartner, Alexz Allen, Laura Carruth, Rachel Santymire*

Light is a powerful and consistent environmental signal that communicates important daily and seasonal changes to an organism. In recent decades, the combination of population growth, economic development, and urbanization have increased the density and distribution of artificial light at night (ALAN) in both natural and urban settings, causing circadian disruption to wildlife, particularly in avian species. Our goal was to determine how ALAN affects avian behavior and glucocorticoid production. We used Zoo Atlanta's annual lantern holiday event called "Illuminights," as an opportunity to study the effects of ALAN on four avian species: the Chilean flamingos (Phoenicopterus chilensis), milky eagle owls (Ketupa lactea), blue-throated macaws (Ara glaucogularis), and the tawny frogmouths (Podargus strigoides). Illuminights was held at night from November to January. Our objectives were to collect avian behavior before, during, and after the event from June 2023 through March 2024 using a species-specific ethogram programmed into ZooMonitor(R). Feces and discarded feathers were collected opportunistically to evaluate glucocorticoid production. A corticosterone enzyme immunoassay was used to quantify glucocorticoid metabolites. Findings will elucidate the effects of ALAN on avian behavior to help ensure the best husbandry practices for managing wildlife in zoos. Furthermore, understanding how ALAN impacts avian circadian rhythms can offer insights into its effects on human circadian health and well-being.

## Assessing Seasonal Polyphenisms of Coliadinae Butterflies

*Hannah Walton, Brian Counterman, Ryan Ficarrotta*

Phenotypic plasticity refers to a species' ability to generate different phenotypes under variable environmental conditions. Seasonal polyphenisms are of a form of phenotypic plasticity that is common in butterflies and often denoted by a change in wing coloration with the seasonal changes in temperature and photoperiod. These variations often provide an adaptive advantage in seasonally changing environments. This project aims to identify the phenotypic responses of Coliadinae butterflies (sulphurs) to variable conditions to assess the potential seasonal polyphenisms present across the subfamily. By doing so we can 1) understand the phylogenetic breadth of plasticity in this clade and then 2) test predictions of the ancestral phenotype, to determine if wing pattern plasticity may been an ancestral state of Coliadinae. Individuals were collected across an single year in northeast Alabama to capture the seasonal variation in phenotypes. The colors and patterns of the wings were characterized using color and UV photography, as well as spectrophotometry. Preliminary analyses suggest that although the seasonal polyphenism of wing patterns may be common among the species, most species exhibit highly divergent plastic responses.

## Cockroach runs with smaller stride length and larger stride frequency on checkerboards

*Ruiqi Wang, Glenna Clifton, Nick Gravish*

Small invertebrates, such as the cockroach Blaberus discoidalis, can maintain high-speed locomotion even when navigating complex terrains in their natural habitats. These environments present two primary challenges: 1) encountering obstacles during the swing phase and 2) failing to achieve stance-phase touchdown. To induce limb collisions, cockroaches with a flat ground stride length of 2.8-0.4cm were challenged to walk on 1.27cm, 2.54cm and 3.81cm width checkerboard patterned substrates with a height of 0.64cm. We tested N=5 cockroaches over 5 trials per substrate. High-speed multi-camera video analysis allowed us to reconstruct 3D trajectories and measure stride-by-stride kinematics. The mean stride lengths on the three small to large width checkerboard are 2.67-0.46cm, 2.61-0.57cm and 2.72-0.51cm.The mixed effect regression models revealed that at the same body speed, the front legs exhibited shorter stride lengths and faster stepping on checkerboard patterns compared to flat ground, with little change in duty factor. We found no significant difference in the linear relationship between stride length, or stride frequency vs. velocity between all checkerboard substrates. Additionally, our study delved into how leg mechanisms responded to collisions by building physics-based models and simulations. Future investigations into how the underlying leg mechanisms contribute to maintaining high speed despite collisions may provide deeper insights into cockroaches' locomotion strategies.

## Mechanically intelligent undulatory robotic locomotion in complex aquatic environments

*Tianyu Wang, Matthew Fernandez, Galen Tunnicliffe, Donoven Dortilus, Daniel Goldman*

The undulatory swimming of elongate limbless robots has been well-explored in open hydrodynamic environments; however, their locomotion in complex, cluttered aquatic settings remains less studied. Observing that mechanical intelligence facilitates obstacle navigation in terrestrial limbless locomotion [Wang et al., 2023], we hypothesize that these principles can be extended to cluttered hydrodynamic environments. To investigate this, we developed AquaMILR+, a 1-meter-long untethered limbless swimming robot. The robot employs a bilateral cable-driven mechanism inspired by the muscle actuation morphology observed in biological organisms, enabling programmable, anisotropic body compliance. Additionally, AquaMILR+ incorporates a depth control system modeled after bladder structures of anguilliform swimmers, which works with pressure and attitude sensors to provide precise depth and pitch control. Through robophysical experiments conducted in model heterogeneous terrains (lattices composed of 7.6-cm-wide posts), we demonstrate that appropriate body compliance facilitates emergent swimming behavior in complex hydrodynamic environments under open-loop control. Furthermore, our findings indicate that swimming performance is highly dependent on undulation frequency, with effective locomotion restricted to a specific frequency range (< 0 .1 Hz)—a notable difference from highly damped terrestrial locomotion, where inertial effects can often be ignored. To further improve performance in environments with nondeterministic obstacle distributions, we incorporated computational intelligence via a real-time compliance tuning controller based on cable tension feedback. This addition significantly improves the robot's robustness and overall speed in heterogeneous hydrodynamic environments.

## Testing for adaptive plasticity in the thermal performance of lizard sperm

*Wayne Wang, Alex Gunderson*

Adaptive phenotypic plasticity can help organisms cope with global warming by increasing their heat tolerance. This plasticity is well documented at the diploid whole organism level. However, we know very little about thermal plasticity at the gamete level, despite increasing evidence that reproduction, and particularly sperm function, is compromised by warming. Theoretically, adaptive heat tolerance plasticity in sperm can be induced at two stages: 1) Spermatogenesis stage, such that sperm produced at high temperature perform better under heat stress, and/or 2) Post-ejaculated stage, such that mature sperm exposed to high temperatures after ejaculation adjust to perform better under heat stress (i.e., heat hardening). We tested for both forms of plasticity in the sperm of brown anole lizards (Anolis sagrei). We found evidence for pre-ejaculate plasticity in sperm heat tolerance, with higher sperm heat tolerance when males were acclimated to a simulated warming thermal regime. However, We found no evidence for post-ejaculated sperm heat hardening. Overall, these results provide evidence for adaptive thermal plasticity in sperm traits that is dependent on the timing of heat exposure and highlights the importance of considering gamete-level plasticity in studies of thermal adaptation and the effects of global change.

## A potential energy landscape-based, bio-inspired control algorithm to traverse cluttered obstacles

*Yaqing Wang, Xiyuan Wang, Chen Li*

Cockroaches are excellent at traversing complex 3-D terrains with cluttered large obstacles, outperforming even the most advanced robots, by transitioning across locomotor modes. Our previous work discovered that such locomotor transitions correspond with barrier-crossing transitions on a potential energy landscape resulting from locomotor-obstacle physical interaction. If an animal/robot crosses barriers near saddle points, it faces the least resistance. However, the potential landscape-based control literature largely focuses on finding minima and maxima, whereas saddle-finding algorithms in physical chemistry assume perfect knowledge of the landscape and do not control an agent to cross saddles. Here, we developed a bio-inspired control algorithm for finding and crossing saddles for least-resistance obstacle traversal, and tested it in a simulation of a self-propelled ellipsoidal robot (similar to a cockroach) traversing grass-like beam obstacles. Inspired by the animal's behavior of wedging into cracks between cluttered obstacles, the simulated robot physically pushes and oscillates against the obstacles to sense contact forces and torques, which provide good estimates of landscape gradients. This allows reconstruction of a local piece of the landscape and shows the direction to a nearby saddle. Inspired by the animal's behavior of frequent turning when looking for the plume direction of interest, the simulated robot turns when saddle direction is not detectable. Our algorithm enables the robot to traverse like the cockroach, with increased probability and reduced time and energetic cost.

## Spawning is regulated by light level regardless of morphology in the ctenophore Mnemiopsis leidyi

*Yinghui Wang, Allison Edgar*

The ctenophore Mnemiopsis leidyi is emerging as an important model for understanding the evolution of animal life histories. It is native to the western Atlantic but also well known for successfully invading seas in western Asia and Europe. M. leidyi are self-fertile simultaneous hermaphrodites that can spawn prolifically at larger body sizes (10-100+ mm) but are also able to reproduce starting from a relatively small size (∼1 mm). They also undergo an obvious morphological change as they grow between these size categories (i.e. ∼1 - 10 mm). Reproduction at small and large sizes was formerly thought to be discontinuous, but recent work shows continuity of reproduction across body sizes. However, many outstanding questions remain about what physiological differences, if any, define these morphological stages. While it is well known that transition from light to darkness regulates spawning of larger M. leidyi, we investigated whether light cues similarly regulate reproduction at earlier stages. We found that constant exposure to light inhibits M. leidyi's reproduction and that the transition from light to darkness initiates spawning, regardless of size or morphology. These results indicate continuity in the mechanism that regulates reproduction across M. leidyi's lifetime.

## Integrating phylogenetic information reveals new insights into "Diversity-Disease" relationships

*Yingying Wang, Kevin Matson, Fred de Boer*

Biodiversity loss is impacting the frequency and magnitude of disease emergence events. However, the general effect of biodiversity on disease risk remains controversial, for example, biodiversity can either increase (amplify) or decrease (dilute) disease risk. The phylogenetic structure in the host community (e.g., phylogenetic relatedness) might allow us to make better predictions of whether changes in host (phylogenetic) diversity will result in increases or decreases in disease risk. For example, in an analysis of mean pairwise distances (i.e., MPD) within communities of wild ungulates and herbivores in Africa, our results demonstrated that higher levels of disease in livestock correlated with greater phylogenetic clustering of the different wildlife species. This finding supports the hypothesis of disease amplification among closely related wildlife reservoir hosts. We further tested the generality of the effect of phylogenetic relatedness on disease risk in the Lyme disease system, the model system for many studies on the dilution effect. We found that the impact of phylogenetic relatedness is consistent over different spatial scales. To conclude, my talk will highlight the importance and generality of the effect of phylogenetic relatedness on disease risk.

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## Developmental onset and social mechanisms of embryonic predator recognition in a freshwater fish

*Jessica Ward, Brooke Karasch*

Oviparous aquatic vertebrates can obtain information about potential threats through direct exposure to predators or their products. However, the nest environment also presents an opportunity for learning through social mechanisms. In this study, we identified the behavioral onset of embryonic learning in a freshwater fish, fathead minnows (Pimephales promelas), and determined whether social features of the clutch influence the acquisition of learned predator information. We also evaluated evidence for socially acquired predator recognition using a 3-phase conditioning and testing procedure. In the first phase, we conditioned a group of embryos to recognize the odor of a predator via associative learning. In the second phase, naïve embryos were interspersed among conditioned embryos and conditioned to the predatory cue. In the third phase, we tested for evidence of learned predator recognition in the socially conditioned group alone. Behavioral evidence of learned predator recognition first emerged among predator-conditioned embryos at 4 dpf. Both the number and proximity of neighboring eggs influenced embryonic activity levels, but not on the onset of predator recognition. Activity patterns of naïve embryos were correlated with those of predator-conditioned clutch mates (i.e., social copying), but were not retained when tested alone (i.e., no observational conditioning). These findings contribute to our knowledge of embryonic learning in oviparous aquatic species by suggesting that embryonic fish are sensitive to the social nest environment and adjust their behavior accordingly.

## Opsin-expressing cells in the skin of the summer flounder (Paralichthys dentatus)

*Russell Ward, Maureen Howard, Lorian Schweikert*

Many animals capable of rapidly changing color appearance (i.e., dynamic color change) have a light detecting capacity of the skin that appears coupled to their ability to change color. For some animals, gene expression studies have suggested the presence of light-sensitive proteins, or opsins, in the skin, but the cell types that express the opsin, and whether these cells are specialized for photoreception, remain unknown. To this end, we investigated the cellular architecture of opsin expression in the skin of the summer flounder (Paralichthys dentatus), a bilaterally asymmetric flatfish. We first localized three opsin classes to distinct cells in the skin of the dorsal (pigmented) and ventral (non-pigmented) surfaces. We then contextualized these cells to the overall cellular architecture of the skin using hematoxylin and eosin staining. Lastly, we examined the ultrastructure of the cells using transmission electron microscopy. Our analyses show that opsins are selectively expressed in surface epithelial cells in ventral skin, and in cells directly beneath pigmented cells in dorsal skin. Organelles in opsin-positive ventral skin cells were densely packed around the nucleus but absent near cell margins. TEM images of the dorsal surface suggest that opsins may be localized to reflective cells called iridophores. Together, these results describe localization of opsins to specific dermal cell types, which, in addition to their known functions, may also be photoreceptive.

## Gut microbiomes in animal ecology: Advances, assumptions, and opportunities

*Robin Warne*

Gut microbiota are increasingly recognized as essential factors in shaping the physiology, life histories, behavior, and ecology of their animal hosts. In the past decade, there has been an explosion of research into the roles of gut microbes for influencing and regulating their host function that has resulted in a rapid expansion of approaches and methods for probing these interactions. However, the measurement, analyses, and interpretation of the expansive data resulting from these efforts often rely on assumptions that are not often widely considered. The purpose of this study is to review the impressive and expansive literature probing gut microbiomes in animal host function, and to identify the common assumptions, as well as provide suggestions for testing and improving understanding of these datasets. The growing popularity, and increasing ease of exploring microbiomes will continue to generate large amounts of data. The robust interpretation of these data demands that we identify opportunities for validating and clarifying the increasingly integrative approaches and the assumptions underlying them.

## Legacy effects of orphaned oil wells on vegetative community and deer mice physiology

*Jess Warr, Richard Dolman, Christopher Goodchild*

While catastrophic large marine oil spills often receive considerable media attention, smaller-scale inland spills occur much more frequently, resulting in legacy polycyclic aromatic hydrocarbon (PAH) contamination. Oklahoma currently has 15,965 documented orphaned oil rigs that were operated under less regulatory oversight. Oklahoma Energy Resources Board (OERB) is working diligently to plug orphaned wells. However, the toxic legacy effects on surrounding ecosystems are not well understood. Using two separate field sites in Payne County Oklahoma, we assessed site-specific disturbance by conducting vegetative surveys to generate Floristic Quality Assessments (FQAs) for each site. Further, we measured hematological damage, immune traits, and organismal metabolic rates in free-living deer mice (Peromyscus maniculatus) populations inhabiting sites with orphaned wells. Collectively, these data will allow us to evaluate the legacy effects of unplugged oil wells on the vegetative community and physiology of resident deer mice.

## Effects of early heat exposure on heat-shock protein responsiveness in turtle embryos

*Clinton Warren, Madison Wilken, Ryan Paitz, Rachel Bowden*

The induction of heat-shock proteins (HSP) during the development of oviparous ectothermic vertebrates, such as turtles, may be an important compensatory response during exposures to transient heat. However, it is not well known when the embryos of such species develop the capacity to induce HSPs in response to heat or how early incubation temperatures might affect their responsiveness to subsequent exposures. From a recent study using red-eared slider turtles (Trachemys scripta), we have observed that the expression of several HSP genes in the trunks of embryos markedly declined during early development at both control (no transient heat) temperatures and those repeatedly exposed to transient heat. Surprisingly, the rate of this decline in HSP expression appeared to be faster in embryos exposed to transient heat which may be tied to an increase in their developmental rate. In our current study, we expand upon these findings by examining HSP expression following different heat exposures (0, 1, 2, or 3 exposures to transient heat) and extending sampling to later in development to better characterize ontogenetic changes. By characterizing patterns of HSP expression and disentangling how temperature and stage affect it, we hope that these findings will expand our understanding on the development of the heat-shock response in turtles.

## The effects of glyphosate exposure on mosquitofish (*Gambusia affinis*) behavior

*Lauren Wartluft, Isaac Ligocki*

Wildlife are being exposed to an increasing number and diversity of chemical pollutants. Glyphosate-based herbicides are chemical pollutants widely used in agricultural practices. Previous work has found that these herbicides interact with steroid hormone receptors. Previous work determined that mosquitofish (Gambusia affinis) display greater risk aversion behavior (time spent on the “edge” of an arena) when exposed to glyphosate-based herbicides. We exposed G. affinis to 250 mg/L of glyphosate alone and a glyphosate-based herbicide containing an equivalent concentration of glyphosate, and then carried out a behavioral trial in which we measured two other behaviors associated with risk aversion (latency to leave an initial refuge and latency to approach a novel object), as well as general activity levels. In contrast to previous work, we did not find evidence of behavioral changes in mosquitofish as a result of exposure to glyphosate and glyphosate-based herbicides. This work highlights the importance of using multiple behavioral endpoints when evaluating the impacts of chemical pollutants on wildlife.

## Assessing generalizable, locomotor-related morphological patterns in gecko claws

*Benjamin Wasiljew, Anthony Russell, Austin Garner*

Arboreal habitats are particularly demanding for their inhabitants because of the complex three-dimensionality inherent in highly variable inclines, overhangs, obstacles, and surface properties. Such environmental parameters present significant challenges to locomotion that can lead to falling, which may have severe energetic and/or physical consequences. As such, scansorial animals often exhibit morphological and functional adaptations that enable them to reversibly attach to surfaces. Geckos are widely known for their subdigital pads that generate temporary adhesion, and much research has focused on the morphology and mechanics of this system. Most geckos also possess claws, which mechanically interlock with rough substrates, puncture soft substrates, and generate friction to enable reversible attachment, but their form and associated function have been largely overlooked. A recent study investigated variation in claw morphology of padless Cyrtodactylus geckos, revealing intriguing inter- and intraspecific patterns. However, that study was restricted to four congeneric species, raising the question of whether these trends are exhibited by geckos more generally. Here we assess intra- and interspecific variation in claw morphology across the Gekkota by examining 16 species representing its six limbed families, along with eight species representing three limbed, lepidosaur outgroups. We report not only on the identification of general intraspecific and intraindividual patterns in gecko claw morphology but also provide baseline data pertinent to future work on the ecomorphology of geckos.

## Microarachnids enlightening macro-patterns: new biogeographic advances on North American schizomids

*Grant Wass, Rodrigo Monjaraz-Ruedas, Marshal Hedin*

Schizomida, or short-tailed whipscorpions, are cryptic predatory microarachnids with limited dispersal abilities which encompass over two hundred species with a largely pantropical distribution. Due to their restricted geographic distributions, schizomids are excellent candidates for analyzing biogeographic patterns. For various reasons, current Schizomida biogeographic analyses are incomplete (e.g., lacking important fossils, incorrect phylogenetic placement of key taxa, etc). Here we combined fossil data with previously published DNA sequences from specimens from the family Protoschizomidae, a broader sampling of Caribbean and Mexican Hubbardiidae, along with novel data from the genus Hubbardia to re-evaluate the divergence times and biogeography of North American schizomids. Our results revealed an earlier divergence time for the family Hubbardiidae and new diversification times for Protoschizomidae, Hubbardia, Surazomus and Mexican Hubbardiids. Additionally, our results suggest that North American schizomids potentially originated from an area shared between the Mexican Transition Zone and Mesoamerica, with some descendants dispersing northward over time. Considering the low vagility and tropical origin of schizomids, this project aims to contribute to a standing biogeographic framework for other relictual North American taxa stranded in relatively arid biomes.

## Assessing the potential for hybridization of three *Syngnathus* species in Sarasota Bay

*Megan Waters, Samantha Levell*

Sarasota Bay, located in Southwest Florida, is home to three congeneric species of pipefish: Syngnathus scovelli, Syngnathus louisianae, and Syngnathus floridae. These species share overlapping habitats, creating opportunities for hybridization, which could lead to the decline or potential extinction of a species due to mismatched matings. Sex ratios among these species are highly female-biased, a critical factor given that males carry the embryos. A shortage of males, combined with mismatched matings, could negatively impact the reinforcement and stability of existing species. Our experiment aims to assess the potential for these pipefish to hybridize under laboratory conditions. We collected live specimens from several sites around Sarasota Bay and initially housed groups of males and females of the same species together to encourage mating, recording the frequency of successful copulation attempts. Once pregnant, males were moved to separate aquariums where we recorded the viability of the offspring. After giving birth, the males were returned to mixed-sex aquariums. With successful control crosses, we have now begun interspecific hybridization trials. Our research aims to evaluate the viability of hybrid offspring and understand the broader implications of hybridization on genetic diversity and species reinforcement within these overlapping pipefish populations.

## Does it take two to tango? Self-fertilization in a solitary tunicate, Ciona intestinalis

*Kai Watkins, Markus Frederich*

Many marine invertebrates are hermaphroditic broadcast spawners. This successful reproductive strategy could potentially lead to self-fertilization, which limits genetic variability and over time, success of the species. Therefore, mechanisms evolved that prevent self-fertilization by preventing the fusion of gametes. These mechanisms are well described in the tunicate Ciona intestinalis, a species of great interest, due to its status as a model organism, but also as an invasive species in many places. Our study explores the rates of self-fertilization in C. intestinalis individuals collected in the Gulf of Maine, along with the development and hatching rates of self-fertilized eggs compared to those with two parents. We find that while self-fertilization occurs in many individuals at a rate of anywhere from 4-90+%, the hatching rates of these self-fertilized eggs are less than 0.1%. We interpret our results as an indication for the presence of a secondary mechanism against self-fertilization causing eggs to fail before hatching. The nature of the secondary mechanism is subject of current investigations.

## Finding common ground: a discussion of methodological standardization in lizard thermal physiology

*Charles Watson*

Many of us routinely characterize the thermal physiology of ectotherms in our laboratories using similar, but not necessarily the same, methodologies. The reason for choosing experimental temperatures vary from those with specific ecological significance to simply choosing the temperature of the laboratory. While compiling a dataset for a larger comparative study, we found that direct comparisons across multiple temperatures were difficult due to variation in experimental temperatures and methodology. At best, we were able to compare across a couple of temperatures that did not span the entire range of tolerance or temperatures experienced in the wild. This led us to standardize the methodology for describing thermal physiology, or what we refer to as "physiotyping," of lizards in our laboratory. This adds to the dataset while training students in following protocols and gaining experience with laboratory instruments by taking standard measurements across species. We use a set of temperatures that span the active body temperatures of most species for metabolic rate and performance. This allows us to establish thermal sensitivity (Q10) of both measurements at multiple intervals. Additionally, we measure voluntary thermal maximum, critical thermal minimum, and preferred temperature. Here, I provide "physiotypes" of an array of species and discuss interpretation and ecological significance of these data.

## Does the eelgrass isopod *Pentidotea resecata* get nutrition from gut photosynthesis?

*Elise Watts, David Cowles*

The isopod Pentidotea resecata is a large, marine isopod that lives along the west coast of the United States. Individuals commonly live in Zostera marina eelgrass beds. Those that do are usually green in color and live and feed on the eelgrass and on epiphytic diatoms. Previous research in our lab has shown that substantial amounts of what appear to be viable eelgrass and diatom cells remain in their hindgut for days to weeks and that their pattern of aerobic metabolism suggests that these cells may be photosynthesizing. In this meeting we plan to present data from our 13C stable isotope study from summer of 2024, in which we investigated whether P. resecata obtains its food mainly from the eelgrass or the epiphytic diatoms found on eelgrass and whether the ingested cells in their hindgut continue to photosynthesize and provide organic nutrients to the isopod for extended periods after ingestion.

## Fitness consequences of maternal nest site choice in a widespread invasive lizard

*Sydney Wayne, Mike Norris, Anthony Gilbert, Daniel Warner*

Environmental heterogeneity imposes numerous challenges to individuals that could reduce Darwinian fitness. Consequently, natural selection has favored several routes that enable organisms to overcome these challenges. One solution to this is that behavior can reduce variation in environmental exposure, thereby limiting environmentally induced phenotypic variation even in heterogeneous habitats. This process could be achieved via parental reproductive behaviors that buffer developing offspring from a wide range of environments, thereby exposing offspring to good developmental environments that have life-long positive effects regardless of post-developmental environments; this is the crux of the Silver Spoon Hypothesis (SSH) – individuals that experience 'good' early-life environments maintain a fitness advantage throughout life. The primary goal of this research was to understand how selection shapes individual responses to environmental heterogeneity. This experiment tested the SSH by quantifying whether maternal nesting behavior shields embryos from suboptimal environments and facilitates offspring phenotypes and survival. To achieve this goal, this research integrated novel lab and field experiments using a brown anole lizard population that inhabits a small island with various maternal nest sites. This work provides insight into basic evolutionary phenomena and helps to identify how organisms will deal with environmental change.

## Precipitation moderates the effect of high temperatures on activity in a desert lizard

*Savannah Weaver, Emily Taylor, Eric Riddell*

The lost opportunity hypothesis posits that when animals must seek refuge due to extreme temperatures, they cannot carry out key behaviors such as foraging, defending territory, and mating, thereby increasing the extinction risk of the species. However, temperature could be confounded by, or interact with, the effect of water availability. We aimed to disentangle the effects of temperature and precipitation on activity restriction in endangered Blunt-nosed Leopard Lizards (Gambelia sila). We radio-tracked lizards for four consecutive years to observe microhabitat use throughout their season; one wet year and one dry year. In dry years, lizards increased burrow use with increased temperature, but in wet years, lizards maintained relatively stable, high levels of activity. An increase of 5°C in a dry year led to 30% more time belowground, compared to only 6% in a wet year. Wetter years were greener with many more arthropod prey available, which likely improved lizard energy balance and hydration. We also calculated the probability of lizards being belowground in contemporary and projected climates. In 2090, the lost opportunities due to drought limitations on activity will be 2-fold greater than lost opportunities due to drought today. Even desert lizards are subject to immense opportunity costs due to the interaction of temperature and precipitation. We must account for this complexity in ecological studies and climate vulnerability assessments.

## 'Alternative' flame retardants alter avian embryonic heart development and function

*Alex Webb, Melville Vaughan, Christopher Goodchild*

Flame retardants are pervasive global contaminants that leach from common household items, including furniture, car seats, and crib mattresses. In 2004, concerns regarding the toxicity of traditional flame retardants, such as polybrominated diphenyl ethers (PBDEs), led to their replacement with 'alternative' flame retardants. However, the ecotoxicity of alternative flame retardants in wildlife is unclear. A particular concern is developmental toxicity from maternal transfer, as these flame retardants have been detected in egg contents of wild birds. This study investigated whether two alternative flame retardants, triphenyl phosphate (TPP) and tris 2-chloroethyl phosphate (TCEP), were associated with congenital heart defects using in ovo and in vitro experiments. We employed in vitro assays to measure aortic smooth muscle cell migration and proliferation. To better understand adverse outcomes on cardiac function, we conducted in ovo experiments with chicken (Gallus gallus) embryos to examine the effects of TPP and TCEP on embryonic heart rate and mass. Our findings suggest that TPP and TCEP may inhibit aortic smooth muscle cell function, which could potentially impair proper heart development and function. These results highlight the importance of further investigation into the environmental toxicity of alternative flame retardants.

## Beyond goldfish and blind cavefish: superficial neuromasts in cypriniform and characiform fishes

*Jacqueline Webb, Maxwell Hampton, Gus Bienenfeld*

Flow sensing by the mechanosensory lateral line (LL) system is mediated by two types of receptor organs: canal neuromasts found within bony canals (CNs, accelerometers) and superficial neuromasts on the skin (SNs, velocimeters). The use of a vital fluorescent stain (4-di-2-ASP), which allows the simultaneous visualization of all neuromasts, has revealed that SNs are found in more species, in higher numbers, and in more complex patterns than previously thought. For instance,1000's of SNs are well-documented in two important model species: the goldfish (Carassius auratus; Cypriniformes, Cyprinidae) and in both surface and cave forms of the Mexican tetra (Astyanax mexicanus; Characiformes, Characidae). We tested the hypothesis that similarly high numbers of SNs are found across the more inclusive taxa to which these fishes belong by studying SN distributions in "barbs" (10 spp.; Cyprinidae) and tetras (Characidae; 30 spp.), which are readily available in the pet trade. Results showed that SN number ranged from $\sim$300 to $>$3800 SNs on one side of the head, trunk, and tail among all species examined. Further, SNs on the head occurred in distinct lines, diffuse lines, or in clusters or fields among barbs and among tetras. Phylogenetic trends within the Cyprinidae and Characidae and correlations with ecological and behavioral traits are being sought to explain variation in SN number and distribution patterns in these two ostariophysan lineages.

## Shark Scales & Tails: morphology, flow, and kinematics investigations at the nostril and caudal fin

*Amani Webber-Schultz, Lauren Simonitis, Kayla Hall, Audrey Kellogg, Brooke Flammang*

Dermal denticles, placoid scales covering the bodies of sharks, have long been a subject of biomimetic and bio-inspired studies. Using microcomputed tomography and 3D printing, previous research has found that denticle shape, size, layering, and direction heavily influence fluid flow. However, this research has largely focused on boundary layer interactions over both real and replicated skin where a singular denticle shape was duplicated and embedded in flexible sheets. Despite important findings from these studies, there are still large gaps in knowledge about fluid interactions over other locations on a shark's body including our study sites: the nostrils and caudal fin. Dermal denticles at the nostrils of sharks have yet to be investigated. Using microCT, scanning electron microscopy, 3D printing, and 2D particle image velocimetry we investigated denticle morphology and visualized fluid interactions at the nostril of Squalus suckleyi finding scale orientations not previously described in the literature and vortex formation at the incurrent naris. On the other end, caudal fin denticle morphology has been described on multiple species but the overall fluid interactions have not. As a precursor to investigating denticle morphological effects on flow, we performed kinematic analyses of the caudal fin on three ecologically and morphologically different species using live-video collection and DeepLabCut. We then compared overall movement across species including pitch, beat frequency, and movement at 15 individual points along the tail.

## A point in parasitoids' favor: evolutionary correlations between ovipositor tip morphology and host

*Abby Weber, Philip Anderson*

The massively diverse subgroup of Hymenoptera known as parasitoid wasps utilize an ovipositor to lay eggs on host insects. These host insect materials span from the soft membrane of caterpillars, to the intersegmental membrane of cockroaches, to even the sclerotized cuticle of an adult beetle. It is widely speculated that the diversity seen in ovipositor morphology is correlated to this diversity of host insects, but this remains largely untested on a comparative scale. In this project I aim to ask the following: Do host insect material properties influence the morphological evolution of the ovipositor in the Braconid subfamily Euphorinae? Sharpness, found using radius of curvature, and the included angle at the tip of a puncture tool are good predictors of puncture performance; therefore we hypothesize that wasps who parasitize similar host materials have evolved similar ovipositor tip morphologies to overcome similar energetic barriers required to produce a successful puncture. To test this hypothesis, I conducted phylogenetic ANOVAs for each of the measured tip morphology traits with host insect as the independent factor. I then fit Ornstein-Uhlenbeck (OU) models to the tip morphology traits to determine if these traits are evolving towards similar shapes if similar hosts. The preliminary results indicate support for this hypothesis. These results represent the first phylogenetic comparative analysis of parasitoid ovipositors using biomechanical principles to explore the diversity of ovipositor morphology.

## Comparative Skull Anatomy of Adult Zebrafish (Danio rerio) and Functionally Jawless Mutant

*Alexandra Weber, Tetsuto Miyashita*

Zebrafish (Danio rerio) are a widely used model organism in molecular genetics and developmental biology. However, both normal and abnormal zebrafish anatomy have been poorly documented, and most phenotypes are only followed to the larval phase. We describe normal and abnormal skull anatomy of zebrafish at the adult phase to: a) provide a resource for late development phenotype analysis; and b) understand the morphological changes that occur in a mutant line with a drastic adult phenotype. We compare wildtype and nkx3.2-/- mutant zebrafish, which are functionally jawless (upper and lower jaw fused together). To do this, we developed µCT-based 3D anatomical atlases for both lines. This allowed for direct visual comparison of the two skulls in each individual element. The most striking changes occur in the mandibular arch, particularly in the palatoquadrate. These changes include the fusion of the dentary, the functional separation of the maxilla and premaxilla from the dentary, and the hyper-ossified jaw joint. These phenotypes arise through plastic remodeling and facilitate bizarre skull morphology that mimics some extinct jawless vertebrates. Using these models, we will next reconstruct skull kinematics in the nkx3.2-/- mutant zebrafish in 3D.

## Pre-gastrulation development and epiblast lumen formation in the veiled chameleon (*C. calyptratus*)

*Antonia Weberling, Natalia Shylo, Hannah Wilson, Melainia McClain, Florian Hollfelder, Paul Trainor*

Non-avian reptile embryogenesis is conventionally thought to follow chicken embryogenesis by following the Eyal-Giladi-Kochav (EGK) and Hamburger-Hamilton (HH) stages of development. In chicken, a multi-layered blastoderm develops through cleavage divisions, which then forms a flat, monolayered disk, the epiblast, that undergoes anterior-posterior patterning and initiates gastrulation. Here, we focus on pre- and early peri-gastrulation morphogenesis of the veiled chameleon (C. calyptratus), which diverges significantly from chicken development. The veiled chameleon has recently emerged as novel representative species for gastrulation and post-gastrulation development of the non-avian reptile squamate clade as its embryos are at early gastrulation stages upon oviposition. In contrast to chicken, the veiled chameleon forms an epiblast lumen resulting in an embryo of human-like morphology. Using whole mount immunofluorescence confocal imaging, cross section analysis and in situ hybridisations, we provide the first molecular characterisation of pre-oviposition morphogenesis of the veiled chameleon embryo. We describe the closure of the amnion and the formation of the amniotic cavity through a supracellular actin ring reminiscent of the contractile “drawstring” found in wound healing. Analysing Nodal1, Nodal2, Cerberus, Brachyury, and BMP2 expression over time, we could describe the patterns of these key signalling pathway components leading up to gastrulation. Taken together, we provide the first in depth analysis of chameleon pre- and early peri-gastrulation morphogenesis.

## Lightweight Wearable Accelerometer for Real-Time Monitoring of Animal Movement

*Timothy Weigman, James Stroud*

We developed a lightweight, wearable instrument for real-time monitoring of lizard movement via a 6-axis accelerometer. The miniaturized sensor captures high-resolution data on acceleration, orientation, and activity patterns, which are wirelessly transmitted via Bluetooth Low Energy communication to a nearby receiver. We designed the non-invasive sensor to minimize impact on natural movements. We conducted laboratory experiments to validate the sensor’s ability to accurately capture fine-scale behaviors using captive lizards. Our technology enables continuous, high-resolution data collection, providing valuable insights into lizard ecology and behavior.

## Urbanization and the gut microbiome: insights from Anna’s Hummingbirds (Calypte anna) in California

*Olivia Weklar, Tiana Bishop, Valentina Alaasam, Kristin Winchell, Jenny Hazlehurst*

Complex environmental characteristics shape the gut microbiome of wildlife with critical implications for host health, pathogen resistance, digestion, and overall fitness. While foundational avian microbiome research has largely focused on domestic birds and poultry due to their proximity to humans and the associated zoonotic risks from imbalanced microbiomes, studying the gut microbiome of wild birds is also essential. Wild birds not only serve as reservoirs for disease that can spread to other wildlife and humans, but also act as important bioindicators of ecosystem health. Despite this, their gut microbiomes remain less explored, particularly concerning how urban expansion affects their composition, diversity, and the health of birds in urban habitats. This study investigates the gut microbiome of Anna's hummingbirds (Calypte anna), a species that thrives in both urban and rural environments across the West Coast. We amplified the V1-V3 region of bacterial 16S rRNA extracted from fecal samples and used the QIIME2 platform to characterize these bacterial communities. By analyzing bacterial communities from birds along an urban-rural gradient, we aimed to uncover correlations between microbiome composition and various habitat characteristics (e.g. NDVI, land cover, air pollution, and percent imperviousness). These findings show that heterogeneous urban landscapes impact the microbiome composition of resident birds and offer insights into why certain birds thrive in cities while others struggle to colonize urban spaces.

## The impacts of iron oxide nanoparticles on the antipredator behaviors of house sparrows

*John Wenderski, Liam Hanlon, Shae Johnston, Chisom Okogbue, Natalia Gonzalez-Pech, Kelly Ronald*

The past 50 years have led to a significant increase in urbanization to accommodate increasing human populations. This increase has had multiple detrimental effects on the environment including a decrease in North American bird populations by 29%. Loss of habitat, predation from cats, and agricultural chemicals are just some of the previously studied causes for the observed loss. Air pollution is an insufficiently studied repercussion of urbanization in the context of bird decline. The solid portion of air pollution is called particulate matter (PM). PM can have a diameter as small as 2.5 $\mu$m or even smaller (i.e., PM2.5). Nanoparticles within PM2.5 are small enough to bypass the blood-gas barrier, and once in the bloodstream can additionally bypass the blood-brain barrier. Once in the brain, these nanoparticles can functionally alter species-appropriate behavior. We predicted that house sparrows (Passer domesticus) exposed to aerosolized iron oxide nanoparticles would show less antipredator responses (e.g. scanning and fleeing) and less exploration (i.e. movement) compared to controls. These results will help shed light on the drastic decrease in bird populations and help to determine the effects that pollution has on avian species. House sparrows, in particular, may serve as a sentinel species for other downstream consequences of urbanization.

## The influence of boating noise on parental care behaviors of smallmouth bass (*Micropterus dolomieu*)

*Alexandria West, Paul Moore, Alexandria West*

Noise pollution is an environmental hazard that alters bird song, changes mammalian behavior, and disrupts mating behavior. Within aquatic environments, drilling, boating, construction, and searching for natural resources are sources of external sound. The impact of these sources on animal behavior is poorly understood, particularly at critical periods of mating and parental care. In small inland lakes, recreational boating is a common source of anthropogenic noise, but its effect on common lake fish is unknown. Smallmouth bass (Micropterus dolomieu) are known to construct and defend nests, and we were interested in examining smallmouth bass parental care behaviors when exposed to recreational boating. We collected data on 14 smallmouth bass nests in Lake Douglas at the University of Michigan's Biological Station. Bass parental care behavior was monitored using an underwater drone (QYSEA FIFISH V6), while a hydrophone (DolphinEar DE200) was utilized to record sound. After a baseline of behavior was established, a boat ran past the nest as an experimental manipulation. Pre, during, and post parental care behavior was examined and correlated with sound recordings. Preliminary results state that there is a significant difference when comparing parental care exhibited swimming on and off the nest throughout the during and post boat phases, but there is no relationship between the behaviors of being stationary on and off the nest when comparing during and post boat phases.

## Convergent soft tissue structure dictates patterns of skull shape evolution in teleosts

*JoJo West, Rose Faucher, Kory Evans, Ricardo Betancur-R, Dahiana Arcila, Elizabeth Miller, Stacy Farina*

Key innovations are thought to promote the diversification of lineages by allowing them to exploit their environment in a previously unexplored way. The more popular interpretation, defined by a trait that provides access to novel resources, excludes innovations which merely increase the rate of diversification or levels of phenotypic diversity. Restricted gill openings (RGOs) are a modification of the teleost branchiostegal membrane which results in smaller gill openings, which may promote more rapid evolution of bones and tissues that were previously limited by gill size and shape. Here we use 3D geometric morphometrics and phylogenetic comparative methods to investigate the influence of branchiostegal membrane state on shape evolution of the lower jaw, hyomandibula, and urohyal within Eupercaria, a large clade of acanthomorph fishes that includes groups such as Tetraodontiformes, Centrarchiformes, and the eponymous Perciformes. We found higher rates of evolution in lineages with RGO than other gill membrane states and varying levels of disparity across states.

## Tadpole gut microbiota acquired from natural environmental sources are responsive to dietary tannins

*Rosemary Westcott, Elizabeth Rudzki, Kyle Emerson, Sarah Woodley, Kevin Kohl*

Tannins are plant-secondary compounds that, when consumed, can have toxic effects on herbivorous amphibian larvae. Tannins can also interact with the gut microbiota and induce changes to the gut microbial community structure. Previous studies on the effects of tannins on tadpoles have been performed in laboratory water, which is largely devoid of natural microbes. Given that tadpoles acquire much of their gut microbial diversity from the aquatic environment, we sought to understand the effects of tannins on tadpole gut microbiota when animals were exposed to natural pond water, supplying a repertoire of microbes that are not present in laboratory water. We raised green frog (Lithobates clamitans) tadpoles in either natural (microbially-rich) or autoclaved (microbially-depleted) pond water for 4 weeks. Animals in these treatments were fed either control diets or diets containing 2% tannic acid. Gut microbial diversity was profiled using 16S rRNA sequencing. The gut microbial community from tadpoles raised in natural pond water was considerably more diverse than that of tadpoles raised in autoclaved pond water. Also, dietary tannin treatment had a greater effect on gut microbial diversity in the natural compared to the autoclaved pond water group. These results indicate that the gut microbiota acquired from natural environmental sources are relatively responsive to dietary tannins, perhaps due to greater opportunities for biotic interactions between tannins and the gut microbiota.

## Acquisition of neurotoxin-producing bacteria by newt hosts

*Samantha Westcott, Joshua Iizuka, Gary Bucciarelli, Elizabeth Heath-Heckman, Heather Eisthen*

Newts in the genus Taricha possess a potent neurotoxin, tetrodotoxin (TTX). Decades of research show how newts use TTX as a defensive compound against potential predators, but the mechanisms shaping newt toxicity are poorly understood. Newts have long been thought to make TTX endogenously; however, researchers recently isolated TTX-producing bacteria from the skin of rough-skinned newts (Taricha granulosa), raising questions about how the newt-microbe symbiosis shapes host TTX concentrations. We are investigating how newts acquire these TTX-producing bacteria.

To determine whether Taricha obtain TTX-producing bacteria through horizontal transmission, we are rearing larvae in the presence or absence of an adult conspecific. Under natural conditions, larvae possess TTX as embryos which decreases through metamorphosis. We are comparing TTX concentration with larval skin and gut microbial communities across host developmental stages, from eggs to early juveniles. Additionally, we are studying development of their toxin-storing glands to examine the relationships among gland formation, animal toxin concentration, and microbiome composition. Immature toxin glands first appear during metamorphosis, potentially explaining why larvae lose most of their initial TTX stores during early developmental stages. Increasing glandular volume may increase the newt capacity to accumulate TTX from their microbial symbionts. These data will be the first systematic investigation of bacterial transmission in toxic Taricha newts. By characterizing the mode of transmission, we will be able to further explore mechanisms shaping newt toxicity.

## A unified data set of domestic dog skulls for investigating the morphology of purpose-bred traits

*Nichole Wheeler, Eusabeia Silfanus, Alexa Ortega, Alexander Orlove, Vivian Nguyen, Mia Pham, Melissa Singletary, Michelle Aono, Nicholas Hebdon, Lindsay Waldrop*

Humans have created remarkable morphological diversity in the domestic dog over a very short timescale through selective breeding. Many breeds of dog are purpose bred for functional tasks that should be reflected in the morphology of the skull, such as protection, scent work, or hunting. Kennel clubs group these breeds based on general functional tasks (e.g., herding, working). Here we present a unified data set of three-dimensional reconstructions from computed tomography (CT) and magnetic resonance imaging (MRI) of dog skulls. These skulls are landmarked and analyzed with geometric morphometric techniques. Our analysis shows that most kennel-club groupings share substantial overlap, indicating that these groups do not exhibit task specialization. When breeds are based on task-specific historic function (e.g., scent work and bite work), these overlaps remain. Performance estimates at specific functional tasks (e.g., bite force) are also not different between task-specialized groups and non-specialized groups. These results indicate that humans have not driven morphological specialization at functional tasks.

## The life and death of dentition: tooth replacement and damage across diets (Stichaeidae)

*Brian Whelan, Richard Hoover, Kassandra Ford*

Tooth morphology reflects the relationship between a fish and its prey, with different teeth suited for different tasks like piercing, slicing, and crushing. However, dental function is mediated by replacement (i.e. polyphyodonty) and damage to teeth (loss, breakage, blunting, etc). This study investigates tooth replacement patterns and damage across four species of Stichaeidae (Xiphister mucosus, Xiphister atropurpureus, Phytichthys chirus, and Anoplarchus purpurescens), a group of fishes exhibiting ontogenetic dietary variation and differences in jaw and tooth morphology/mechanics. We assessed patterns of tooth replacement and functional damage across species and ontogenetic dietary differences. Our preliminary results indicate consistent replacement patterns across species, but differences in the proportion of teeth undergoing replacement. Species display differences in tooth damage, as fish that have a crushing morphotype incur more damage than fishes with a piercing morphotype. Finally, we compared replacement and damage proportions, and found that replacement is uncoupled from damage. These findings suggest that, while tooth damage reflects the forces placed upon teeth during feeding, tooth replacement remains an internally regulated process, independent of tooth condition.

## Phylogenetics and museum records reveal misplaced conservation priorities for Pleuroceridae snails

*Nathan Whelan, Annika Baldwin, Jeffrey Garner, Paul Johnson, Ellen Strong*

Research on freshwater gastropods lags far behind that of most other mollusk groups. This results in imperiled freshwater gastropods not receiving adequate conservation attention. One such species is the pleurocerid Black Mudalia, Elimia melanoides, which is restricted to the upper Black Warrior River drainage in Alabama, USA. In 2016, U.S. Fish and Wildlife Service concluded that E. melanoides could not be listed under the U.S. Endangered Species Act because of taxonomic uncertainty. Yet, a high risk of extinction for E. melanoides was undisputed. To clarify the taxonomic status of E. melanoides, we generated a genome-scale dataset and thoroughly evaluated historical material. Phylogenomic analyses revealed three distinct lineages of E. melanoides sensu lato. Several populations of E. melanoides were determined to be upstream clinal variants of a widespread species, Elimia hydeii. The two other lineages were determined to be E. melanoides and a synonym of E. melanoides. Through examination of historical records that had been identified as E. melanoides, we also determined that another unrecognized, and extinct, species was historically present in the Black Warrior River drainage. This glimpse into the taxonomy of Pleuroceridae underscores the amount of work that will be required to adequately address pleurocerid systematics. It also emphasizes the reality of the often-stated phrase “we cannot conserve what we do not know exists”. More broadly, our findings have implications for our understanding of clinal variation, the true level of gastropod extinctions, and the importance of combining genomics and traditional museum work for conservation.

## The influence of symbiosis and heterotrophy on energy reserves in *Aiptasia* pedal lacerates

*Erick White, Virginia Weis*

The coral-dinoflagellate symbiosis is the foundation of coral reef ecosystems and is based on nutrient exchange between the partners. A key to the success of corals is their diverse life history strategies that include both sexual and asexual reproductive modes. While there are many studies that examine the effects of symbiosis on nutritional provisioning in coral larvae, the effects of these processes in asexually produced offspring are unclear. We used the model system Exaiptasia diaphana (commonly called Aiptasia) to study the effects of symbiosis and heterotrophy on total energy reserves in asexual buds, known as pedal lacerates, throughout development. We tracked changes in adult size, carbohydrate, protein, and lipid content, and algal density in pedal lacerates after adults were subject to one month of different feeding regimens. Our results indicate that both symbiosis and heterotrophy are drivers for nutritional provisioning in pedal lacerates. When we compared total lipid content to energy-rich lipid content, symbiotic animals consume lipids in a different way compared to aposymbiotic anemones. Upcoming experiments will track the changes in growth and energy reserves over time as pedal lacerates develop into adults.

## Biological mirrors in transparent frogs

*William White, Claire Downing, Jesse Delia, Carlos Taboada*

In fish, amphibians and reptiles, purine crystals in skin cells called iridophores are responsible for structural coloration. Glassfrogs, however, don't have many iridophores in their transparent skins. Instead, they have mirrored structures covering organs which can broadly reflect light across the whole visible spectrum. Within the centrolenids, there's a broad diversity in the anatomical distribution of these mirrors, which can be extended to the parietal peritoneum and visceral peritoneum around intestines and stomach, liver, and heart. It has been suggested that these mirrors might play different physiological roles in coloration, osmoregulation or thermoregulation. While it has been hypothesized that these mirrors contain guanine crystals, the chemical identification of the components responsible for the mirror like properties of their tissues has not been tested. In this study, we purified the crystals, and characterized them by SEM with energy dispersive X-ray spectroscopy, liquid chromatography-mass spectrometry, and UV-VIS spectroscopy. We found that the mirrored peritonea contain crystals of 600-2000 nm in diameter and 40-100 nm thick made of guanine, hypoxanthine and xanthine. The relative concentration of each component was determined using non-linear least squares minimization and mass spectrometry. To further understand how these mirrors reflect light in tissue, we conducted optical simulations. Some biochemical interpretations for the presence of non-guanine purines, as well as the biological roles of mirrored tissue in terrestrial vertebrates, will be discussed.

## Explorations of myoglianin's role in regulating larval growth in M. sexta

*Christel Whitehead, Peggy Biga*

Manduca sexta, the tobacco hornworm, are crop pests commonly found in the Southeastern United States. The larvae can cause widespread destruction to crops due to their large appetite as they defoliate the plants and feed on unripe fruit. Knowing factors that contribute to their growth and development allows researchers to determine better methods of pest control. This study focuses on the developmental and metabolic roles of myoglianin in M. sexta. The exact role of myoglianin in these insects is not well studied, but studies in fruit flies, Drosophila melanogaster, demonstrate it acts similarly to myostatin in vertebrates. Myostatin is a TGF-beta protein responsible for negatively regulating muscle growth, ensuring optimum muscle mass for the organism. A study with D. melanogaster demonstrated that during the larval stage, myoglianin suppressed synaptic transmissions at the neuromuscular joint, thus suppressing growth. The knockdown of myoglianin resulted in increased muscle and overall body size, indicating the gene's potential role in muscle growth regulation. Since myoglianin has been linked to muscle growth, it is possible that M. sexta would also experience a difference in metabolic rates and overall size if the gene has been altered. Antibody development and siRNA techniques will be used to knock out myoglianin expression. Larvae with myo knockout will be compared to wild-type larvae to better understand the role of myoglianin in insect development and metabolic regulation.

## Bowfin spin prey right 'round: kinematics of prey transport and swallowing in Amia ocellicauda

*Katrina Whitlow, Emily Volpe*

Fishes use their complex, highly mobile skulls to manipulate water in and around their oral cavity; creating jets to capture prey during suction feeding and to reorient prey for esophageal transport during processing. While the generation of a suction flow is relatively well understood, only a small handful of studies have investigated how predatory fish subdue, manipulate, and swallow their prey. We used XROMM to reconstruct feeding sequences in Amia ocellicauda, enabling visualization of prey handling. We expand upon previously reported kinematics to demonstrate that prey items are consistently reoriented so that the head of the prey enters the esophagus first (despite capture being tail-first). This is accomplished by a kinematic pattern inverted from capture events, where the operculum abducts first, followed by peak gape and hyoid depression. However, it is unclear how reorienting cycles differ from those used to reposition the prey in smaller increments. We also observed frequent, high intensity medio-lateral "head shakes", which may help subdue live prey. We continue exploring the role of the fleshy tongue in this species, which frequently displays higher magnitude motions than the ceratohyal, despite a strong connection to this bone and no direct muscular inputs. These findings both substantiate broad takeaways regarding prey transport in fishes and demonstrate key differences of Amia processing from the few other fish species for which prey processing has been described.

## Life in the fast lane? Demography of a relatively short-lived Emydid turtle

*Dylan Wichman, Ethan Hollender, Donald McKnight, Day Ligon*

Turtles face increasing global threats, with population declines and extirpations necessitating detailed demographic analyses. The Western Chicken Turtle, Deirochelys reticularia miaria, a relatively short-lived freshwater species, has experienced widespread declines and extirpations across its range. Despite studies on its unique life history, long-term demographic data for this species has been lacking. From 2012 to 2022, we studied a metapopulation of Western Chicken Turtles in Oklahoma. Our analysis of annuli growth rings revealed that they are deposited approximately annually, though the rate of annulus formation increases with age. We determined that, consistent with Eastern Chicken Turtles (D.r.reticularia), individuals that do not grow over 3 or more years can accurately be assigned a minimum estimated age of 5 years. Using radio telemetry and PIT tags, we determined that Western Chicken Turtles in Oklahoma have higher survivability than other populations of Chicken Turtles, while their average age remains similar. Maximum longevity is also similar to the short-lived Eastern Chicken Turtle. Additionally, we found that Western Chicken Turtles produced clutch sizes and egg dimensions similar to their Eastern counterparts. However, Western Chicken Turtles also have the potential to reproduce at smaller and/or younger stages than other subspecies, suggesting a wider range of reproductive output. This research highlights this subspecies' relatively high reproductive potential, with reproductive output more strongly correlated with female size than previously described in the genus Deirochelys.

## Understanding fish excretion methodology: The influence of handling stress and short-term fasting

*William Wied, Justin Campbell, Ryenne Hathaway*

Consumer-mediated nutrients (via fish excretion) has been identified as a critical source of nitrogen (N) and phosphorus (P) to many different ecosystems. Accurately quantifying CMN is a critical step towards understanding how the aggregate consumer community mediates nutrient delivery / cycling. However, current methods for quantifying fish excretion are based on freshwater fishes, with limited taxonomic and trophic variability. Further, prior work rarely accounts for the effects of handling stress (removing the fish from water) and short-term fasting. Fish handling can elevate metabolic rates and lead to an overestimation of excretion. While an underestimate of excretion can be obtained if fish are subjected to fasting due to the reduction of digestible material. Using tropical marine fishes across several families (Clupeidae, Lutjanidae, Haemulidae) and differing trophic groups, we quantified the effects of handling stress and short-term fasting on ammonium excretion rates. Our study found a significant effect of handling stress across all fishes tested, showing an initial elevated excretion rate, decreasing with time, while short-term fasting had no effect. Our findings, suggest handling stress affects trophic groups differently and incubation time should be adjusted to account for this variability to obtain an accurate estimate of fish excretion.

## Time-integrated phylogenetic and physiological signatures reveal the history of Life

*Jasmina Wiemann*

Proteins, lipids, and sugars are the fundamental building blocks of life. The tissues they generate contain molecular heterogeneities that inform about organismal relationships (=phylogeny), biomineralization, tissue identity, and metabolic capacity. Although such biological signatures have the potential to provide invaluable evidence of the history of life, molecular information is thought to be lost in deep time.

Here I challenge the paradigm of the deep-time lability of biomolecular signatures based on the first integrative analyses of patterns in the macromolecular composition of n>200 modern organismal tissues and their carbonaceous fossilization products, sampled through time, space, and clades. Statistical analyses of spectroscopic fingerprints, and experimental modelling of observed reaction schemes, reveal that biomolecules transform during fossilization through oxidative crosslinking into N-,O-,S-heterocyclic polymers. Endogenous fossil organic matter preserves heterogeneities reflecting original phylogenetic and physiological signatures in altered, but not unrecognizable form. Based on this new type of biological information integrable across modern and extinct organisms, I will showcase how molecular signatures can be used elucidate the mechanisms of macroevolutionary responses to global change in the past, as a foundation to predict future biotic reactions. The broad range of transformative applications places novel biosignatures at the forefront of tools to access mechanistic data on the interplay between Earth and Life.

## Experimental evaluation of pitch control via center of mass manipulation for tuna-inspired robots

*Blake Wiese, Joseph Zhu, Hilary Bart-Smith*

In the realm of aquatic robotics, depth control is a major challenge for all mechanical platforms. Previous research in the area has explored buoyancy control with bladders, consistent with biological systems, or using control surfaces to alter pitch of the platform. In this research, we explore the manipulation of the center of mass positioning to control pitch angle for a thunniform swimming platform. This mechanism will be evaluated using a simplified model with a linear actuator translating a DC gear motor to change the horizontal center of mass, generating a moment and finding stability at different angles. When applied to our system, this mechanism will present a compact, simple method of adjusting depth for our swimming robot. This experiment will help further understanding of fish-like body pitch control using center of mass manipulations.

## Yolk estrogens and primordial germ cells in a species with temperature-dependent sex determination

*Madison Wilken, Clinton Warren, Rachel Bowden, Ryan Paitz*

During early embryonic development, primordial germ cells (PGCs) originate in the yolk sac and migrate to the gonads where they differentiate into either oocytes (within ovaries) or spermatogonia (within testes). One key difference between spermatogonia and oocytes during embryonic development is that oocytes enter into meiosis, which is thought to be triggered by the local production of estrogens in the ovary that, in turn, initiates meiosis by inducing the expression of Dazl. However, there are other sources of estrogens during development, including maternally derived estrogens present in the yolk, that may also affect PGCs. We used Trachemys scripta, a turtle species with temperature-dependent sex determination (TSD) and known to be sensitive to estrogen exposure, to study how PGCs respond to maternal estrogens. In a previous study we found that Dazl expression was elevated in embryos that were treated with estrogens early in development, but sampling in this study occurred relatively late in development after ovary development had begun. Based on these previous findings, we designed an experiment to see how maternal estrogens affect Dazl expression levels early in development to characterize whether yolk estrogens can affect PGCs prior to any signals from a developed gonad. Preliminary results suggest that maternal estrogens do not induce Dazl expression early in development suggesting PGCs are not sensitive to estrogens until the later stages of development.

## Relationship between metabolic rate and calling behavior in the gray treefrog, *Hyla chrysoscelis*

*Phoebe Will, Michael Reichert*

Energy is a fundamental determinant of behavior, especially for energetically costly sexually selected signals. Even resting levels of metabolism can affect behavioral expression, although there is debate about whether having a higher standard metabolic rate (SMR, one way of measuring resting metabolism in ectotherms) should constrain or increase the expression of energy-demanding behaviors. Individuals often vary in behavioral expression, and consistent among-individual differences in behavior can affect important processes including predator avoidance, foraging and mating. The mechanistic basis for among-individual variation in behavior is poorly understood, but variation in metabolic rate is a likely candidate given the role of metabolism as a constraint or facilitator of behavioral output. We tested the relationship between SMR and acoustic signaling behavior in the gray treefrog, Hyla chrysoscelis, a species in which calling is both under strong sexual selection and highly energetically costly. We predicted that individuals with a higher SMR would produce calls with more energetically costly characteristics (call duration, call rate, call duty cycle). We recorded males calling in the field and then measured their SMR under standardized conditions in the lab. We sampled individuals repeatedly to determine if SMR is repeatable, as some call characteristics are known to be. Our results provide insights into the role of metabolism as a driver of behavioral variation, and reveal how energetic state affects sexual selection.

## Anole gut microbiome composition and stability is associated with thermal tolerance and plasticity

*Claire Williams, Akhila Gopal, Wayne Wang, Michael Logan, Alex Gunderson*

Climate change is one of the greatest threats facing life on earth. Ectotherms, in particular, are highly vulnerable as they rely directly on environmental temperatures to regulate their physiology. One potential pathway by which ectotherms could respond to rapid shifts in temperature is through phenotypic plasticity. Plastic responses are typically defined as the interaction between host genetics and the environment to produce a particular phenotype. However, host-associated microbiota can also play a role in host plasticity as these microbial communities can change within the lifetimes of individual hosts and impact host physiology. We tested the relationship between the composition and stability of gut microbiomes and the plasticity of host thermal tolerance in three species of Anolis lizards: Anolis cristatellus, A. sagrei, and A. carolinensis. We brought wild-caught lizards into the lab and tested how their gut microbiomes responded to short-term warming or cooling. We then examined the relationship between microbiome composition and stability with heat tolerance and its plasticity. Several key aspects of microbiome composition were correlated with baseline host thermal tolerance. Moreover, animals with more variable gut microbiota had higher plasticity in thermal tolerance. Our results suggest that gut microbiota might modulate ectotherm survival under climate change.

## The kinematics and flight behaviors of fruit flies and fungus gnats in a vertical wind tunnel

*Evan Williams, Ignazio Maria Viola, Laura Ross, Robert Baird, David Murphy*

Insects utilize atmospheric flows for long range migration and dispersal. As these beneficial flows are located several kilometers above the ground, tiny insects must use convective upwellings as a transport mechanism to reach them. However, insect flight behaviors and mechanisms in these vertical upwellings are not well understood, prompting questions about how tiny insects control their flight in vertical flows. Here we investigate the flight behavior of two tiny insect species, the 3 mm fruit fly (Drosophila melanogaster) and the 2 mm fungus gnat (Lycoriella ingenua), while exposed to quiescent air and to a steady 0.5 m·s-1 upwards flow (characterized via PIV) within a vertical wind tunnel. We use high-speed 3D photogrammetry, recording at 300 Hz and 4700 Hz, to capture flight trajectories and wingbeat kinematics, respectively. In the upwards flow as compared to quiescent air, both species exhibited a decreased body pitching angle with increased flight speed. With flow, flight trajectory sinuosity increased for the smaller, more weakly flying fungus gnats but decreased for the larger, stronger fruit flies. These results provide insight into how tiny insects may adapt their flight to a convective upwelling.

## Toothy Teleosts: The relationship between tooth complexity and function in fishes

*Keiffer Williams, Lanier Nelson, Joshua Reid, Phong Tran, Kory Evans, Samantha Price*

Fishes demonstrate an incredible range of dental diversity, but their dentitions are vastly under-studied. We expect tooth complexity to correlate with diet based on findings within terrestrial vertebrate lineages but quantitative methods have yet to be applied to fishes to confirm this pattern exists beyond tetrapods. Methods based on advances in 3D-imaging and analysis techniques, known as orientation patch count rotated (OPCR), have been used to reliably measure surface complexity of mammal and reptile teeth. These analyses reveal herbivorous taxa possess higher overall tooth complexity than other dietary groups. We use a combination of novel tooth functional categories, microCT scanning, and OPCR within a phylogenetic comparative framework to determine whether tooth function is associated with tooth complexity across a broad sample of reef-associated fishes. Preliminary results suggest that the fused 'beak' dentition of groups such as parrotfishes serve as the primary driver of tooth complexity, although transitions to beaked dentition are restricted. However, once fused beak species are removed from our sampling, we find little evidence of differences in tooth complexity between functional groups. These early results suggest that while 'herbivorous' clades such as parrotfishes indeed show high tooth complexity, these patterns may be driven more by the trophic novelty of fused dentition, and less so by the specific material properties of plant material.

## The effect of glyphosate and a glyphosate based herbicide on the behavior of two tadpole species

*Mitch Williams, Orion Groff, Madelyn Askey, Joseph Goudy, Isaac Ligocki*

An increasing body of research shows that many of the chemicals used in modern industrial agriculture have unintended consequences for wildlife. The effects of particular compounds may also vary across taxa, so comparative studies looking at individuals from multiple species are necessary if we are to adequately assess the effects of these contaminants in aquatic systems. In this study, larvae of two anurans (Lithobates palustris and Anaxyrus americanus) were exposed to one of three chemical treatments for 48 hours: Glyphosate (250 ug/L), a Glyphosate Based Herbicide (containing equivalent 250 ug/L glyphosate), or fresh water. Tadpoles were then exposed to one of four cues associated with elevated predation risk: conspecific or heterospecific cue, a caged dragonfly nymph, or control. Tadpoles were monitored and behaviors were measured over the course of a 10-minute observation period. The number of gridlines crossed was used as a measure of activity, while the amount of time spent in the edge was used as a measure of risk aversion. In contrast to previous work on other amphibians, no significant differences were observed between the chemical treatments, though A. americanus tadpoles exposed to predators were more active than those exposed to conspecific cues. Further research on the impacts of glyphosate on amphibian populations is warranted to adequately inform wildlife conservation efforts moving forward.

## Should we care about pre-adult mortality?

*Tony Williams*

In a wide range of taxa, variation in lifetime reproductive success (LRS) is highly skewed, most individuals have zero fitness, because they die before reproducing (what Grafen (1988) called the "invisible fraction" in population studies), and a very small number of individuals produce most of the recruiting offspring. In this talk I will discuss what we know about this invisible fraction (life-history's "losers") and how they might differ from "winners" that recruit offspring to the next generation. Do winners and losers differ in 'quality', can we identify phenotypic traits that determine life-time reproductive success and how we might study this phenomenon? For example, in explaining variation in LRS, and given patterns in the literature, a focus on survival traits (e.g. immune function, oxidative state) might be more productive than a focus on reproductive traits per se. As Bennett (1987) stated, I think most physiological ecologists and comparative physiologists assume that the traits we study are adaptive, determining survivorship and reproductive success. However recently, numerous (largely theoretical) studies have developed the argument that variation in LRS is mainly down to chance, such that two individuals with identical phenotype could have very different outcomes. I will discuss how these two scenarios might affect our ability to detect, a) selection, and b) trade-offs (such as cost of reproduction), goals many of us pursue in our experimental studies.

## Predicting the future, mechanisms of anticipatory reproduction in North American red squirrels

*John Williams Soriano, Stan Boutin, Jeffrey Lane, Andrew McAdam, Ben Dantzer*

Microevolutionary changes and phenotypic plasticity can drive responses to changing environments, however, plasticity has been responsible for most of the documented responses to climate change in mammals. Global climate change inherently threatens the persistence of reliable cues and whether organismal responses due to plasticity are adaptive, especially in environments in northern latitudes. In order to understand how animals integrate environmental change, we investigated the coevolutionary relationship between North American red squirrels (Tamiasciurus hudsonicus) and white spruce trees (Picea glauca) as part of the Kluane Red Squirrel Project. Red squirrels are specialized seed predators subject to a resource pulse system where white spruce trees produce a synchronous superabundance of seeds in "mast years" followed by multiple "non-mast" years of minimal seed production. Red squirrels anticipate white spruce seed crops and increase reproductive effort prior to the availability of these new food resources in mast years. Red squirrels exhibit adaptive reproductive plasticity in mast years, yet the mechanism inducing plasticity in this system is unknown. We are testing the hypothesis that a hormonally active phytochemical in spruce buds acts as a cue to modify red squirrel reproductive physiology and behavior in mast years. We will present our initial results testing this hypothesis through behavioral and physiological analyses on red squirrels and chemical analyses on white spruce tissues.

## The Snake Fungal Disease pathogen influences the evolution of the skin microbiome

*Ian Wilson, Tatyana Martinez, Kaitlyn Murphy, Jason Dallas, Marc Chevrette, Donald Walker*

Identifying evolutionary and ecological influences on host-microbiome interactions and their role in host health may prove vital to determining effective means for targeted pathogen remediation and wildlife conservation. Exploring how bacterial-fungal interactions develop over time, within a host-microbiome-pathogen system, can be challenging given a lack of experimental control over environmental variation, host life history characteristics and time scale at which the microbes interact. By implementing a controlled experimental evolution design, we were able to characterize variation in bacterial fitness, colony morphology, and system relationships for two species of bacteria (Stenotrophomonas sp. and Chryseobacterium sp.) in response to metabolites produced by the Snake Fungal Disease pathogen (Ophidiomyces ophidiicola). Strains of Stenotrophomonas and Chryseobacterium were evolved on two media types including a 1% keratin control and fungal spent keratin medium. We passaged each strain independently and in coculture, using a fully factorial design, for eight weeks. We observed divergence in growth rates between both bacteria and media types, and survival in cocultures of Stenotrophomonas and Chryseobacterium over two months. Our results will discuss mutation and growth rate variation for both in response to a fungal pathogen over time, and elucidate mechanisms of pathogen induced dysbiosis on the evolution of the microbiome. A deeper understanding of these microbial interactions within the snake skin microbiome may prove critical for conservation efforts targeting populations threatened by Snake Fungal Disease.

## Mechanical properties of fast fish vertebral columns

*Jacqueline Wilson, Marianne Porter, Aubrey Clark, Maria Laura Habegger*

Swimming modes in fishes were traditionally divided into four categories: anguilliform, subcarangiform, carangiform, and thunniform; determined by the number and size of traveling waves along the body. Despite the foundational impacts this classification had in fish locomotion studies, a small number of biomechanical and kinematic studies have shown that fish species and even individual fish can span these categories. Here, we aimed to further explore this idea by investigating the mechanical properties of the backbone of fast-swimming fishes. We compared the material properties of individual vertebrae along the entire vertebral column among a carangiform Almaco Jack (Seriola rivoliana) and two thunniform swimmers - Blackfin Tuna (Thunnus atlanticus) and Mahi-Mahi (Coryphaena hippurus). We tested individual vertebrae in compression providing stress-strain curves from which stiffness (the ability to resist compression) and toughness (the ability to absorb energy) were calculated. We compared these values intra and interspecifically to assess mechanical regionalization of the vertebral column. We hypothesized that stiffness would be greater near the caudal peduncle in Blackfin Tune and Mahi-Mahi, compared to Almaco Jack, to facilitate thunniform swimming. Conversely, a lack of mechanical regionalization could provide more evidence that fish are able to span categories in the classic classification scheme. This study contributes to a more accurate understanding of fish swimming mechanics, perhaps challenging current stablished swimming modes and amplifying our understanding of fish locomotion.

## The evolution of palatal development in the common ancestor of living birds

*Lauren Wilson, Zachary Morris, Christopher Griffin*

The earliest divergence of crown birds (Neornithes) produced two clades, Palaeognathae (‘ratites’ and tinamous) and Neognathae (all other birds). Paleognaths have a rigid palate, a condition long maintained to be plesiomorphic, whereas the neognathous condition is better suited for cranial kinesis and is morphologically divergent from the palates of non-avian reptiles. Surprisingly, a recently-discovered Cretaceous toothed bird, Janavis finaldens, was found to possess a pterygoid which is remarkably similar to those of extant members of Galloanserae (landfowl + waterfowl). This would suggest that the plesiomorphic condition for Neornithes may be more similar to the neognathous condition, with the paleognathous palate being derived. Developmental patterns can provide insight into evolutionary trends, so to test this hypothesis we characterized the three-dimensional anatomy of crocodylian and neognathous musculoskeletal tissues prior to ossification. Using a high-fidelity clearing and immunostaining protocol to visualize embryonic palatal tissues earlier than previously possible, we found that in both the non-kinetic reptilian (Alligator) and neognathous (Gallus, Coturnix) palate, the embryonic precursors to skeletal tissues resemble their adult form. We will next characterize early palate organogenesis in paleognaths (Nothoprocta) to phylogenetically bracket the ancestral avian developmental condition and test whether the paleognathous condition is also present prior to ossification. Understanding the true nature of this relationship will have important implications for the diagnosis of Palaeognathae and inform expectations for Cretaceous and early Cenozoic fossil discoveries.

## Sprint speed, hematology, and active metabolic rate of juvenile collared lizards

*Megan Wilson, Troy Baird, Christopher Goodchild*

Perinatal physiological shifts occur during critical developmental periods and can have long-lasting life-history consequences for individual animals. We examined a suite of hematological indices in free-living collared lizards (Crotaphytus collaris) 3-5 weeks after hatching in late August-September. Physiological processes (e.g., oxygen delivery to tissues) that directly facilitate energy assimilation are likely essential to support the rapid growth during this period that is critical for juveniles to survive their first winter brumation. However, the immense pressure for rapid growth also may create a potential tradeoff between mass gain and other physiological processes (e.g., investment in immune function). We characterized physiological development in juvenile collared lizards by collecting blood samples in August-September 2021-2023 to measure packed cell volume [PCV], hemoglobin, mean corpuscular hemoglobin concentration [MCHC]) and leukocyte differentials. Juveniles exhibited lower PCV, hemoglobin, and MCHC than adult lizards. However, unlike the sex-specific differences in PCV and hemoglobin observed in adults, hematological indices did not differ between juvenile males and females. Preliminary analysis of leukocyte counts for a subset of juveniles indicates heterophil:lymphocyte (H:L) ratio is lower in juveniles compared to adults. We are currently conducting sprint speed trials and measuring active metabolic rate using a Sable Systems Metabolic Treadmill to understand the relationships among hematological indices and organismal performance traits.

## An easy way to introduce students to scientific research: Science Journal for Kids and Teens

*Miranda Wilson, Tanya Dimitrova*

Many K-12 and undergraduates have a hard time conceptualizing what scientific researchers do and how they communicate their findings. This talk provides information about free teaching resources that educators can use in their classes to help students understand the scientific method, the structure of peer-reviewed research articles, and scientific concepts used in doing research. Science Journal for Kids and Teens creates interesting and current articles from peer-reviewed journals that are adapted to K-12 reading levels. The organization works directly with researchers to ensure accuracy in the adaptations that are produced. It also creates and curates free lesson plans, translations, and videos to accompany those articles, giving teachers easy options for classroom planning. Use of these adapted articles and resources has been shown in classroom case studies to significantly improve student understanding of the scientific method compared to traditional teaching methods. The goal of Science Journal for Kids and Teens is to make scientific research more accessible for classroom teachers, and by extension, enhance scientific learning experiences for students.

## Neural serotonin receptor expression in the white-throated sparrow brain (*Zonotrichia albicollis*)

*Nate Wilson, Brent Horton, Donna Maney*

We have much to learn about how neuroendocrine gene expression underlies behavioral phenotypes in vertebrates. Neural serotonin (5-HT) activity is hypothesized to mediate aggression, whereby low serotonin activity is associated with high aggression, and vice versa. Even though birds have long been models for the study of the mechanistic bases of social behavior, serotonin activity in the avian brain, including the expression of serotonin receptors, remains understudied. Here, we describe for the first time the distribution of gene expression for two serotonin receptors (5-HTR1B and 5-HTR1E) in the brain of the white-throated sparrow (Zonotrichia albicollis), a unique model for understanding the neurogenetic bases of behavior, including aggression. This species exhibits plumage and behavioral polymorphism that is linked to the presence or absence of a chromosomal inversion. This inversion captures the genes for serotonin receptors 1B and 1E as well as a suite of other neuroendocrine genes linked to aggressive behavior in white-throated sparrows. We focus on serotonin receptor mRNA expression measured via in-situ hybridization in behaviorally relevant brain regions, including nuclei of the serotonergic system and the vertebrate Social Behavior Network (SBN). This study lays an important foundation for future investigations on the role of serotonin activity in mediating aggression in birds and other vertebrates.

## A missing piece of the whole: Reproductive traits and local adaptation

*Kathryn Wilsterman*

Reproduction is essential for species persistence and adaptation; however most evolutionary physiologists have focused on survival-related traits that are only indirectly linked to reproductive success. This historical focus has left a large gap in understanding about how reproductive physiology shapes evolutionary processes like adaptation. My lab's research aims to fill this gap by studying reproductive diversity across populations of the North American deer mouse (Peromyscus maniculatus). Deer mice display local adaptation across a range of environments, and my research has shown that their proclivity to adapt has involved reproductive traits. My lab has first focused on resolving reproductive traits that are involved in adaptation to high elevations. High elevation hypoxia leads to low birth weights across mammals, but highland deer mice are resistant to these effects. By studying maternal-fetal physiology and placental development, my lab is discovering the physiological and genetic mechanisms by which adaptation has led to reproductive resilience to hypoxia. The second arm of my lab's research is working to resolve the physiological determinants of natural variation in reproductive traits. I will present new, unpublished data from our lab showing that our well-studied highland and lowland populations exhibit marked differences in reproductive system flexibility. Over the next ten years, we hope to connect these two arms in order to generate a holistic understanding of how the challenges of high elevation influence reproductive traits in a whole population.

## Comparative analysis of collective cohesion and its mechanical origin in aquatic oligochaetes

*Joseph Wiltanger, Emre Guller, Ishant Tiwari, Saad Bhamla*

Tubifex tubifex, commonly known as sludge worms, are segmented aquatic worms that live within lakes and rivers across the world. Tubifex, along with another oligochaete California Blackworms (Lumbriculus variegatus), form blobs, in which groups will entangle amongst each other, which provides them with survival benefits such as desiccation resistance. However, the Blackworms can come apart quickly ($< 1$ second) when transient environmental stress is applied, an ability not displayed by the Tubifex blob. Previous research shows how both the Blackworm's specific gait in response to stress and individual coiling behavior contribute to the blob dispersion phenomenon. This study seeks to explain the fundamental differences in collective behavior within these two different types of worm blobs. We find that the effective stressors for each type of worm are different, with UV illumination causing a response for Blackworms but not for Tubifex. Using high-speed videography, we uncover differences in the gait of the Tubifex worm when compared to the California Blackworm, which we use to explain the differences in each blob's cohesiveness. Finally, we compare the topological entanglement present in each of these types of blobs by using microCT scans of the blobs for each species. This study can help us understand how worms present in different kinds of environments may have different types of stress responses even when similar-looking collective morphologies are shown.

## The influence of experimentally elevated temperatures on telomere dynamics in a free-living songbird

*Hailey Wimberly, Britt Heidinger*

Exposure to rising temperatures during development often has long-term phenotypic and fitness consequences, but the underlying mechanisms are poorly understood. One mechanism that may be important in this context are telomeres, highly conserved repetitive sections at chromosome ends that enhance genome integrity, but shorten during normal cell division and influence cellular and organismal lifespan. Recent research in birds suggests that exposure to warmer temperatures during development could accelerate telomere loss because of faster cell division and/or greater stress exposure. However, most of this research has been conducted on precocial species, often under laboratory conditions, and the extent to which experimentally elevated temperatures influence telomeres in altricial species under free-living conditions remains unknown. Here we experimentally exposed free-living altricial house sparrow (Passer domesticus) nestlings to either acute (3 days) or chronically (6 days) elevated nest temperatures using hand warmers (Uniheat) placed under the nesting material or control conditions (nests moved, but no hand warmers were placed) and examined the potential effects on growth, survival and telomere length and loss. Investigating the relationship between thermal stress, growth rates, and telomere dynamics is crucial to understanding how environmental factors influence long-term biological health. It is also important to explore how altricial species cope with these challenges during vulnerable developmental stages, especially with conditions involving climate change.

## Workshop: Opportunities and challenges in urban fieldwork

*Kristin Winchell, Anthony Snead, Valentina Alaasam*

Whether you are a seasoned urban field researcher or curious about how to get started, join us for a semi-structured discussion about the challenges and opportunities associated with urban fieldwork. We will discuss designing effective studies, research accessibility, tips for low-budget local fieldwork, facilitating undergraduate research, and fieldwork safety in urban environments. We will draw on the experience of urban researchers to help prepare scientists at all career stages with the tools and tips for implementing safe and effective urban evolutionary research. Urban-focused research can be a uniquely accessible field, as field sites can be near university campuses, accessed by roads and public transportation, within cellphone and internet range, and in proximity to basic facilities. As a result, urban research facilitates increased representation of early career researchers, students from under-represented backgrounds, and undergraduate institutions. However, we have found that without guidance from those of us who have worked in these spaces, research can often be hindered in unforeseen ways, jeopardizing the quality of research as well as researcher safety. This workshop aims to address this gap in knowledge sharing. Moreover, by compiling common approaches to guide research, we aim to make results across studies more directly comparable, helping to advance urban evolutionary ecology syntheses and identify future directions in the field.

## Roundtable Discussion: Cities as Natural Experiments

*Kristin Winchell, Anthony Snead, Valentina Alaasam*

Join us for the conclusion of our symposium to find common threads among the presented research. We invite everyone to join us and the symposium speakers in a semi-structured discussion to identify patterns in urban evolutionary ecology research and, together, identify directions for the future of the field. We will specifically focus on how approaching urban evolutionary ecology research from a “natural experiment” perspective can be a powerful tool for understanding evolutionary and ecological processes. We aim to unify researchers through common approaches and objectives so that results across future studies will be more directly comparable, offering more opportunities for meta-analyses and a synthesis of trends. Our discussions will be summarized as the opening perspective for the Integrative and Comparative Biology special issue for the symposium.

## Sniffed them out: can an individual assess fighting prowess through chemical cues before a fight?

*Molly Wingard, Lindsey Wells, Giovanna Lopez, Cera Widener, Mark Garcia*

Fish employ an array of signals to communicate their aggressive intentions and fighting prowess. Of those, the use, composition, and information transmitted via chemical cues remains unclear. The cichlid Neolamprologus pulcher modulate urine production during aggressive contests and blocking olfaction increases fight intensity. Further, circulating testosterone levels rise in mangrove rivulus (Kryptolebias marmoratus) exposed to the chemical cues of a potential opponent. These studies suggest an important role of chemical communication in fish aggression, but the exact information transmitted via these cues remains unknown. Our study aims to examine whether mangrove rivulus mount differential aggressive responses dependent on opponent identity or mount a single response to all opponents regardless of opponent identity. We dosed focal individuals with either 10ml of DI water (control), water laced with the chemical cues of their subsequent opponent (familiar), or water laced with the chemical cues of a different individual (unfamiliar). Following, we created size-matched pairings that resulted in five experimental groups: control-control, control-familiar, control-unfamiliar, familiar-familiar, unfamiliar-unfamiliar. Contest intensity and outcomes were then quantified and compared across combinations. We predict that familiarity with an opponent prior to a contest will reduce contest intensity while lack of information or misinformation will lead to higher intensity contests. Results of our study may provide greater insights into how fish species incorporate chemical cues into aggressive decisions making.

## Expanding engagement in Hong Kong through specimen digitization, 3D modeling, AR technology, and 3D printing of Hong Kong Biodiversity Museum specimens

*Deidra Wirakusumah, Mason Dean, Benoit Guénard*

The digitization of museum specimens is a rapidly growing practice, and provides considerable potential for cataloguing, research, and improving public access to museum collections. The Hong Kong Biodiversity Museum (HKBM) boasts Hong Kong's largest natural history collection, with more than 55,000 specimens across the taxonomic spectrum, from plants to insects to vertebrates. However, constraints to space, funding, and manpower, pose challenges to sharing our resources. In a joint project between HKBM and City University, we are building a digital collection with the goal of expanding accessibility to our collection and creating new ways for public interaction. We have produced more than 30 CT and MicroCT scans of dry specimens, primarily skulls, and utilized open-source software such as 3D Slicer and Blender to create 3D prints used for outreach. A cropped and up-scaled 3D printed model, for instance, was used to teach CityU anatomy students about cranial foramina. Partnering with the local start-up OAO, we have generated more than 15 models of taxidermy and skeletal specimens with their GIMII app, a smartphone 3D scanning and education tool. Beyond using these models in the classroom, we are also taking advantage of GIMII's AR capabilities, giving the museum guests an opportunity to explore our largest specimens on their phones, specimens that cannot physically be displayed within the museum. In these ways, digitization has allowed the museum to modernize, reach a broader audience and transcend limitations, and as we continue to expand the digital collection, we will further implement our new resources in more classes and museum exhibitions.

## Wingtips with a twist: flow physics of Harris's Hawk inspired wingtips

*Hannah Wiswell, Girguis Sedky, Aimy Wissa*

Some birds that are adept at both efficient and maneuverable flight, like the Harris's hawk, have emarginated primary feathers that form slotted wingtips. These wingtips are believed to mitigate tip vortex effects by spreading vorticity and respond to aerodynamic disturbances by twisting while bending out-of-plane. However, we have limited knowledge about the effect of the emarginated feather properties and response on the flow physics and aerodynamic effects related to increased flight efficiency and maneuverability. In this study, we experimentally evaluate several biologically relevant wingtip designs, including those that exhibit similar bending-torsion coupling capabilities to those observed in nature. We investigate the aerodynamic effects of the wingtip slots by acquiring force and moment data and relate these effects to flow physics by collecting both 2D and stereoscopic Particle Image Velocimetry (PIV) measurements of the flow field. Experiments are conducted at Re $= 2 \times$ 105. The results of this study will provide new insight into the aerodynamic role of emarginated wingtips in birds and inform the design of such devices to enhance uncrewed aerial vehicle (UAV) flight.

## Evolution of larger body size in response to consistent natural selection in Anolis sagrei

*Tyler Wittman, Robert Cox*

How selection acts to effect evolutionary change in populations is a central questions of biology. We used a wild pedigreed population of Anolis sagrei to investigate patterns of selection acting on, the of heritability, and evolutionary and phenotypic change in body size. Across five generations selection consistently favored larger body size in both males and females, with selection approximately twice as strong in males. Ther heritability of body size was moderate, approximately 0.5 for both males and females, with a high between sex genetic correlation which was bounded away from 1. We found a significant linear trent for average body size across the five generations, suggesting an evolutionary response to selection. To test for a genetic change underlying this phenotypic change, i.e. evolution, we estimated breeding values for body size across the five generation pedigree. We then tested if the average breeding value for body size increased across the generations. We found a significant positive linear trend in both males and females, which is greater than that expected under drift. Finally we found a significant positive genetic covariance between fitness, estimated as lifetime offspring production, and body size in both males and females. These results contrast many similar studies on body size which tend to find positive selection but a lack of evolutionary response.

## Making a moth flap like a fly with virtual reality for muscle physiology

*Ethan Wold, Rundong Yang, Ellen Liu, Nick Gravish, Simon Sponberg*

In most muscles, contraction is initiated by neural activation. Some groups of insects break this rule, flapping at frequencies far exceeding the neural drive to their flight muscles. These insects' muscles produce force in response to stretch as opposed to neural activation, enabling flight at frequencies that would otherwise be impossible given the slow timescales of intracellular calcium transport. The first flapping insects lacked stretch-activated physiology, which was then layered on top of neural activation dynamics before being reduced again in some groups like moths. Given muscle's myriad state- and history-dependent properties, it remains unclear how neural and stretch-activation interact as a muscle evolves the capacity to be activated by stretch. Building on prior closed-loop muscle physiology platforms, we develop a 'virtual reality' system for muscle, in which we couple real, neurally-activated flight muscle from a hawkmoth, Manduca sexta, to simulated stretch-activation. This allows us to manipulate the degree of stretch-activation in-silico while retaining all other physiological properties of the flight muscle. We find that neurally-activated muscle can produce positive, oscillatory work in near-tetanus, indicating that when calcium dynamics are slow, the two activation modes do not conflict. When stimulated at wingbeat frequency, interference between stretch- and neural activation results in variable work production. However, this interference disappears when we match the two activation timescales, suggesting an evolutionary path of least resistance when evolving stretch-activation.

## Using DNA methylation to explore the environmental drivers of senescence in the wild wood mouse

*Sarah Wolf, Amy Pedersen, Simon Babayan, Riccardo Marioni, Tom Little*

Identifying the drivers of senescence is fundamental to our understanding of natural selection on ageing – accumulating functional decline that increases mortality risk. To explore this question in the wild, an accurate, composite biomarker of the ageing rate is vital, and one such biomarker uses DNA methylation at sites across the genome that change linearly over the lifetime. These 'epigenetic clocks' can estimate age across vertebrates, and furthermore, are perturbed by environmental stressors and predict mortality better than chronological age. Here, we manipulated two environmental stressors in the wild wood mouse (Apodemus sylvaticus): (1) nutrition via diet supplementation and (2) gastrointestinal nematode infection by anthelmintic treatment of Heligmosomoides polygyrus, the most common GI parasite of wood mice. We monitored individuals repeatedly over time to quantify changes in epigenetic age using our laboratory wood mouse clock and measured other key aspects of physiology. We predict these manipulations will slow rates of epigenetic ageing; however, they may have unintended consequences, e.g., increased reproduction, that could speed up the ageing process. We will also consider patterns of methylation across thousands of genomic loci to gain insight into those most sensitive to environmental factors and most relevant for changes in ageing rates. The environmental sensitivity of epigenetic clocks and their capacity to predict mortality offers powerful potential for elucidating the links between ageing, fitness, and the natural environment.

## Segregation of neuromodulatory neurons in the whip spider mushroom body calyx

*Gabriella Wolff, Sidney Ley, Daniel Wiegmann, Verner Bingman*

Unlike insects, arachnids lack antennae, which are useful for active sensing during navigation. Amblypygi (whip spiders) solved this problem by evolving modified “antenniform” forelegs packed with chemo- and mechanosensory receptors. They use these in addition to their eyes to navigate to shelters, the location of which they can remember as demonstrated in long term memory assays. As in insects, sensory information from the periphery is encoded in primary brain structures and then projected to mushroom body calyces for learning and memory. However, amblypygid calyces are comprised of microcircuits that are far more complex than insect calcyal microglomeruli, but there is a lack of information on sensory processing in these structures. Preliminary data show that disruption of serotonin signaling blocks consolidation of long term memory after associative learning in amblypygi. To better understand this learning and memory circuit, we stained brain tissue of Phrynus marginemaculatus amblypygids with antisera against neuromodulators with known roles in sensory integration and learning and memory. We found that serotonergic and GABAergic innervation of the mushroom body calyx differentiates between visual and olfactory input regions, respectively, while other neuromodulators are more homogenously expressed. We compare these results to insect mushroom bodies, especially bees whose calyces are also subdivided by visual and olfactory input. Common themes across these distantly related arthropods may point towards general principals in neuromodulation of sensory integration circuits.

## Song development in hand-reared Bachman’s Sparrows

*Heather Wolverton, Rindy Anderson*

Songbirds have been studied for many years due to their complex vocal learning system that mirrors human language acquisition. A majority of song-learning studies focus on species with small song repertoires. We studied vocal development by male Bachman’s sparrows, a species with a large repertoire (48 song types on average) and population syntax patterns. We collected 13 Bachman’s sparrow nestlings from the wild and tutored them with playback of songs recorded from their natal population. We monitored the physical growth and vocal development of the 7 male birds from 7-120 days of age. To our knowledge, our study is the first to successfully raise Bachman’s sparrows in the lab, and to document their vocal development. We found that Bachman’s sparrows develop songs normally in the laboratory using audio playbacks as tutor stimuli. Future studies should examine factors that may affect repertoire size in lab-reared sparrows, such as the presence of a live tutor or extended playback sessions.

## Fluid-induced vibration patterns in biological structures

*Jasmin Wong, Nicholas Burnett, Shane Windsor, Stacey Combes*

The air around us imposes a dynamic environmental challenge to be used or withstood for function and survival. For instance, flying animals must use fluid movement to generate the necessary forces to control their movement through the air. Meanwhile, sessile organisms must primarily contend with environmental forces that can be destructive. Therefore, a function-dependent balance must be struck between manipulating or withstanding some scales of flow-induced forces and capitalising on others. Previous work has identified common static flexibility patterns among the propulsors in the animal kingdom. However, it remains unclear how dynamic structural responses may vary across species, scale, and function. This work introduces a framework to fill this gap. Using three-dimensional, high-speed videogrammetry, we quantified the aeroelastic response of flexible appendages to a gust as well as the morphological parameters of animals and plants of different sizes and functional behaviours. We found interspecific and interphylum differences between the dominant response modes and notable outliers in functional specialists. These data will help build a parameter framework to help researchers understand how fluid-structure response can vary across a diverse landscape of materials, fluids, and scales, and guide parameter identification for desired fluid-structure responses in bio-inspired engineered structures such as for energy harvesting, flow sensing, and vibration absorption.

## Lifestyles of sharks reflected by functional properties of sensory regions in the neurocranium

*Jake Wood, Kenshu Shimada*

Sharks (Chondrichthyes: Elasmobranchii) exhibit a broad range of lifestyle strategies and ecological niches that are reflected by their complex sensory organs contained in their neurocranium. Yet, the diversity of neurocranial morphology in sharks and how it is potentially related to their sensory abilities have never been sufficiently investigated. Therefore, the purposes of this study were: 1) to investigate whether the relative sizes of the rostral, olfactory, optic, and/or otic regions of shark neurocrania have relation with their ecomorphotypes and/or body form types; and 2) to detect any potential insights and interrelationships into the evolution and ecology of sharks with respect to their neurocranial diversity. Our principal dataset comprised neurocrania of 178 extant species in 37 families and 102 genera. We found a statistically significant difference between each of the four examined neurocranial regions and ecomorphotypes as well as between that and body form types, except for the relationship of the optic region size with the ecomorphotypes and body form types. This study is significant not only because it provides new insights into their evolutionary biology and ecology, but also because the information is relevant to shark conservation biology.

## Are faster muscles all you need for faster locomotion?

*Leo Wood, Simon Sponberg*

What has to change to allow animals to locomote at different frequencies? If faster animals simply play the same motor program, the patterns of neural activation sent to all muscles, faster, eventually muscle physiology has to speed up so force can rise and fall in less time than a single locomotor cycle. Alternatively, the nervous system could compensate for unchanging muscle physiology by producing different motor programs at different frequencies. To understand what balance evolution strikes between these factors, we leveraged the model clade of Bombycoid moths. These moths have diverse ecologies and wingbeat frequencies ranging from 5Hz to more than 60Hz, but crucially with highly conserved flight muscle anatomy. We recorded comprehensive flight motor programs in tethered individuals from 10 different Bombycoid species, and also measured the twitch kinetics of their direct steering muscles and indirect power muscles. We found that twitch kinetics scaled significantly with wingbeat frequency, however this scaling was far slower than wingbeat frequency and could not alone account for faster flapping. Instead, coordination patterns between muscles changed with wingbeat frequency. Spike count and burst length decrease in faster species, enough to accommodate the shift to higher frequency. This indicates that while muscles evolve to be faster, the nervous system has to compensate to enable faster locomotion. Thus the nervous system and muscle physiology both evolve whilst balancing differing constraints.

## Skunk tongue kinematics in response to oral sensory nerve blocks

*Moriah Wood, Stephane Montuelle, Susan Williams, Rachel Olson*

## Is bigger better? Relationship between risky behavior and aspects of size in land hermit crabs

*Riley Wood, Brooke Fitzwater, Laney Woynaroski, Ryan Earley*

Risk-taking behavior can have significant fitness consequences, with risk prone individuals being more likely to explore and exploit new areas or resources, but also to encounter challenges to survival and reproduction than risk averse individuals. As a defense mechanism, hermit crabs retreat into their shells when flipped over; quick latencies to re-emerge indicate risk-taking. This study explored the relationship between various elements of size and risk-taking behavior in wild land hermit crabs (Coenobita clypeatus) on Carrie Bow Caye, Belize. We hypothesize that mass and risk-taking behavior, latency to right themselves, are positively correlated. Individuals were collected at night when active and placed upside down in the center of a shallow plastic arena, where it was recorded until it righted itself. After each trial, crabs were sexed, weighed, measured, and numbered on their shells with animal-safe markers before being released back into their natural habitat. Marked crabs were recaptured nightly and subjected to repeated trials, allowing us to assess variations in their behavior over time. Preliminary results indicate highly significant and consistent individual differences in risk-taking behavior (i.e., personality), and a strong positive association between body mass (including shell) and risk-taking behavior (i.e., bigger animals took longer to re-emerge). Further analysis of photographs will investigate relationships between behavior and chela size, shell crowding, and sex.

## The aquatic microbial environment impacts the gut microbiome and antipredator behavior of tadpoles

*Sarah Woodley, Kyle Emerson*

Host-associated microbial communities impact the brain and behavior through the microbiota-gut-brain (MGB) axis. Most studies of the gut microbiome use mammals in biomedical contexts; much less is known regarding wildlife species. We used larval amphibians to study the impact of the aquatic microbial environment on the gut and skin microbiomes, brain, and behavior. We raised Northern Leopard Frog (Lithobates pipiens) tadpoles in pond water that was autoclaved or not autoclaved (natural) because other studies show that these treatments produce variation in the tadpole microbiota. Tadpoles were also raised in the presence of stressors like predation-derived chemical cues and corticosterone. Compared to tadpoles raised in natural pond water, tadpoles raised in autoclaved pond water had altered gut and skin microbial communities, body size, brain size, brain shape and behavioral responses to alarm pheromones. The gut microbiota, but not the skin, was a significant predictor of many behavioral endpoints. We found few effects of stressors, although stressor treatments interacted with pond water treatments to influence the composition of the gut microbiota. Our findings demonstrate that tadpole behavior is modulated by the aquatic microbial community experienced during development.

## Range expansion phenotypes in a non-native population of *Gambusia affinis*

*Skyler Woodley, Isaac Ligocki*

For many invasive species, individuals at the range expansion front may display “range expansion syndromes” characterized by behavioral, physiological, and life history differences that contribute to the expansion of their distribution. Gambusia affinis, the western mosquitofish, is native to central U.S. and Mexico and has been introduced outside their native range globally causing negative impacts on many native animal species. Here, we investigated the boldness, exploratory, and social behavioral variation between three different populations of G. affinis recently detected within the Susquehanna watershed to determine whether behavioral differences are consistent with a range expansion syndrome paradigm. Our results suggest that longer established mosquitofish populations exhibit higher exploratory behavior than more recently established ones which may contribute to their success as invasives.

## Resourcefulness, robustness, and recovery: tail utilization during climbing behavior in rats

*Brian Woronowicz, Noah Graber, Shahin Lashkari, Noah Cowan*

Robust climbing ability is fundamental for animals traversing complex environments, with tails often playing a key role. We investigated how rats used their tails when climbing onto a ledge from a bottom force platform at varying depth. A “pullup bar” at the ledge could be locked or unlocked, respectively allowing or eliminating forelimb-generated moments. As rats climbed, they routinely used their tails to push off a force plate below the ledge, generating corrective moments about the bar. When the pullup bar was locked, animals relied more on their tails when their initial vertical impulse was lower. To perturb their nominal exit strategy, the bar was unlocked mid-session causing dramatic recoveries. Surprisingly, by the next trial rats had adapted their exit strategy, reducing their initial vertical impulses from the bottom platform and increasing their assistive tail-generated impulses. Conversely, when the bar was subsequently re-locked, it took several trials to return to their previous climbing behavior. During these systematic studies, the animals often deviated from behaviors being investigated, using their tails in a variety of resourceful ways: aiding in near fall recoveries, generating additional bottom platform impulses, and serving as a prehensile gripper to enhance balance while perching at the platform edge. These findings underline the remarkable adaptability of rats’ tail use, revealing a versatile and dynamic morphological feature for navigating complex climbing challenges.

## Conceptualizing project ownership in a research VIP course

*Kasey Wozniak, Devaleena Pradhan, Heather Ray, Anna Grinath*

An authentic research experience allows students to recognize their agency to shape a research project and develop project ownership (PO). Project ownership often leads to shifts in undergraduate science identity, retention in science disciplines, pursuing higher education, create opportunities for students to see themselves as scientists, and see where they fit into the scientific community. While PO in course-based research experiences (CREs) have described 10 components, to fully conceptualize these, diverse CRE models should be incorporated.

Here, we contribute a nuanced conceptualization of PO in the context of a Vertically Integrated Project (VIP) by designing course elements that foster undergraduate students’ feelings of PO toward research. We expect this to aid instructors designing CRE’s, by attuning themselves to recognize, and design ways for students to develop and display PO. This is especially important when students engage in unanticipated ways. Responding and recognizing students’ contributions in moment-to-moment interactions can either invite students into a scientific community or push them out.

We estimate that the development of PO is not just an individual characteristic, but results from a more complex interaction between student and environment. To test this, we used interviews, self-reflections, and discussion recordings. Results indicated that previously described markers appeared, three markers resurfaced, and we created novel PO markers. These findings will be compared to faculty interviews to determine what course design elements foster PO.

## STEM Experiences for All: inclusive outreach through biological activities

*Kasey Wozniak, Claire Wasniewski, Beverlly Victoria, Makenzie Reed, Devaleena Pradhan*

While societal impact of the science community's public engagement is difficult to measure, high-quality science engagement improves science awareness, interest in conservation, and positive public attitudes towards science research. Early intervention using science engagement practices with school children can positively influence STEM participation.

Our lab, through our hands-on "SEA" program, strives to enhance access to science and science literacy for diverse SE Idaho communities through providing an equitable and inclusive learning environment. We design and share activities that are rooted in STEM alongside respecting the role of knowledge gained through cultural experiences. We are passionate about sharing STEM and sparking curiosity about biology to kids and adults alike. Over the last 6 years, we provided activities to hundreds of students through initiatives at ISU and collaborating with the Shoshone-Bannock Boys and Girls Club. Our hands-on "SEA" program includes mini experiments, nature journaling, brain anatomy, lab tours, summer research experiences and more. We aim to create inclusive learning exchanges, increase accessibility and exposure to science, and provide pathways to advance the pursuit of scientific careers by empowering and training the next generation of scientists to become independent researchers and critical thinkers.

## Repeated core circadian gene loss across polar and deep sea fishes

*Daniel Wright, Jacob Daane*

Biological clocks tie changes in daily environmental variation to changes in gene expression. In the deep ocean and in polar winter or summer, marine fishes can experience little to no photoperiod or other conventional timekeepers for circadian entrainment, posing a physiological challenge for species to adapt to these regions. Recently, widespread loss of circadian genes was documented in Antarctic notothenoid fishes, but this studied lacked a broader phylogenetic perspective on how conserved these genes are across fishes. We have generated a multiple sequence alignment of 28 perciform and 5 non-perciform fishes to reconstruct the patterns of circadian gene family expansions and contractions across the phylogeny. We find that Antarctic notothenioids are not unique in having lost numerous circadian genes, as it was also common in several deep-sea species and in sticklebacks, with sporadic instances of loss across Perciformes. As Perciformes are particularly common in high latitude and in deep oceans, this relaxed selection on circadian genes may represent a circadian plasticity that facilitates invasion of these environments in this clade, as non-perciform species had fewer losses. Additionally, we have observed patterns of convergent gene loss in deep sea and polar environments that are outside of known, established circadian genes, presenting novel candidate genes for roles in circadian regulation.

## Physiological and behavioral effects of chemical contraception on feral urban pigeons

*Jessica Wright-Lichter, Lori Donohoe, Rebecca Partan, Allen Rutberg*

Nicarbazin (NCZ), the active ingredient in OvoControl bait in the US and OviStop bait in Europe, has been shown to be an effective and reversible oral contraceptive in feral urban pigeons (Columba livia) in both lab and free ranging birds. NCZ was developed as a coccidiostat for the poultry industry but also causes exposed birds to lay unhatchable eggs. Because it is excreted within 2 days, its effects are reversible. To maintain sustained contraceptive efficacy, constant dosing is required throughout the breeding season, which in pigeons can be year-round. Although NCZ is EPA-approved and widely marketed, no published studies examine the impact of prolonged exposure to NCZ on the pigeons' physiology or behavior beyond the contraceptive effect. Aside from being an improvement over poisoning, the true welfare effects of NCZ on pigeons have not been assessed. As NCZ exposure has also been linked to an impaired ability of exposed animals to cope with heat stress, the increased incidence of rapid changes in temperature associated with global warming elevates the importance of determining whether NCZ- and heat-exposed pigeons can maintain social, behavioral, and physiological processes during challenging weather events. In this study, we exposed NCZ-exposed and non-exposed birds to a rapid change in ambient temperature and assessed plasma NCZ and cort levels. We also measured the timing of onset, frequency, and duration of heat-mediating behaviors.

## Complex terrain negotiation during escape locomotion in the Namib day gecko

*Joseph Wu, Tim Higham*

Structural complexity is found across all natural habitats, and the ability to maintain dynamic stability across heterogeneous substrates is crucial to routine locomotion and survival in terrestrial animals. Small animals are likely to encounter substantial changes in substrate level relative to their leg length, including both increases (up-steps) and decreases (down-steps) in height. However, few studies have compared differences in locomotor performance and kinematics between these two common perturbations. After capturing escapes in nature, we investigated the effects of sudden drops and rises during high-speed locomotion in the Namib day gecko (Rhoptropus afer), a cursorial gecko known for sprinting long distances across complex horizontal terrain. Field observations of escapes indicated that these geckos encounter down-steps more often than up-steps. In the lab, we used a high-speed video camera (500 frames per second) to record the provoked escape of geckos (N=11) across a trackway with changes in substrate level comparable to those found in the gecko's natural habitat, as well as a flat control trackway. We found significant differences (before and after the perturbation) in body pitch angle, hip height, and duty factor among the conditions, indicating that different control strategies were used to negotiate the up and down-steps. Forward velocity decreased when negotiating the up-step, but not the down-step. Overall, our results suggest that performance across complex terrain may inform optimal escape strategies.

## Phenotypic plasticity in the circadian rhythm of heat tolerance and its basis in gene expression

*Kelly Wuthrich, Carrie Alfonso, Karla Alujevic, Leah Bakewell, Brandon Buitrago, Albert Chung, Samantha Fontaine, Catherine Grey, Elizabeth Hoffman, Jaden Keller, Yanileth Lopez, John Nguyen, Nathaly Ponce, Adam Rosso, Alejandro Vivas, Claire Williams, W. Owen McMillan, Michael Logan, Christian Cox*

Tropical organisms have evolved under relatively stable climatic conditions, and therefore, many of these species will be negatively impacted by climate change. Ectotherms are particularly at risk as their physiological processes are tightly linked to environmental temperature. In order to cope with heat-induced stress, ectotherms can employ a range of physiological responses. Many species are able to utilize phenotypic plasticity to maintain optimal physiological processes under differing thermal conditions. Reversible plasticity is a vital aspect of thermal plasticity, as it can decreases costs of a mismatched phenotype when climatic shifts are rapid and reversible. We studied the time course of heat tolerance plasticity in the slender anole (Anolis apletophallus). We exposed lizards to an acute warming event (3h at 32°C) and repeatedly measured heat tolerance over the course of four days and measured differential gene expression using a transcriptome-wide approach across multiple tissues. We found that heat tolerance is plastic at both the transcriptomic and phenotypic levels. Moreover, heat tolerance follows a circadian rhythm, increasing between morning and mid-day and then decreasing at night. The magnitude of this fluctuation is greater in heat stressed lizards and remains greater one day post-exposure. We leveraged our transcriptomic analyses to explore gene expression pathways that aid in the plastic response. Our work suggests that plasticity may play a role in the survival of tropical ectotherms in changing environments.

## The fecal fling: Spring-powered frass ejection in skipper caterpillars

*Jaimie Wyckoff, Pranav Khandelwal, Jake Socha, Jeffrey Olberding*

Every living thing creates waste that must be removed. Successful waste disposal includes not just removal from body tissues, but also relocation away from the organism to prevent disease or the attraction of other harmful species. This process can pose a challenge for relatively stationary species. Caterpillars in the family Hesperiidae build shelters from plant materials in which they hide while feeding. To avoid the accumulation of feces, these shelter-building caterpillars have evolved a mechanism to fling their feces at high velocity relocating the fecal matter far from the shelter. Here we examine fecal flinging in the fiery skipper (Hylephila phyleus) across a range of sizes (3 – 30 mm) representing five instars of development. We recorded highspeed video of fecal firing and calculated fecal takeoff velocity from caterpillars at each size. There was no effect of body size in velocity (average 0.6 m/s). Size-independent velocity suggests the use of a latch-mediated, spring actuated mechanism, which has not yet been described in this species. We recorded additional highspeed video under greater magnification to observe the details of fecal firing. From these observations, we propose a mechanism whereby the movement of the anus and digestive tract deform an elastic cuticular structure, the anal comb, storing potential energy. When released, the anal comb rapidly recoils against the fecal pellet, launching it away at high velocity.

## Anamniocentesis: development of a method to genotype oviparous embryos from perivitelline fluid

*Jennifer Wyffels, Kady Lyons, Lance Adams, Kevin Feldheim*

Zebra Sharks can reproduce parthenogenically and, thus, there is an outstanding conservation need to develop a method to screen egg cases to maintain genetic diversity amongst managed populations. The objective of this study was to determine if egg pervitelline fluid could be genetically screened to identify developing parthenotes before hatch. To demonstrate initial proof of concept, perivitelline fluid was aspirated and genetically tested from several categories of egg cases (wind, yolked but without embryo development and yolked with a developing embryo). Perivitelline fluid from negative controls (wind) failed to produce a genetic signal (i.e. no maternal signal carryover) and the majority (80%) of perivitelline fluid from egg cases with a developing embryo resulted in successful DNA amplification and genotyping. Secondarily, perivitelline fluid was collected from eggs with live embryos that were allowed continue development and underwent similar genetic testing procedures. Results showed similar rates of successful parthenogenetic identification albeit at weaker power (i.e. fewer amplified loci). Perivitelline fluid was further sampled from a variety of eggs across different developmental categories and analyzed via flow cytometry. Fluid from live eggs had fewer events gated as cells compared to moribund or recently deceased embryos where cell shedding was higher, which corroborate genetic testing results and suggests that embryo cell shedding is limited in this oviparous elasmobranch.

## Unprecedented rates of parthenogenesis in ex situ zebra sharks

*Jennifer Wyffels, Kady Lyons, David Portnoy, Christine Dudgeon, Kevin Feldheim*

Parthenogenesis is known to occur across elasmobranchs in both viviparous and oviparous species. Cases of parthenogenesis have been primarily documented by happenstance when husbandry staff discover neonates in exhibits where adult females are housed in single-sex populations; therefore, the true rate of captive parthenogenetic births is unknown. This study focused on the zebra shark (Stegostoma tigrinum), an oviparous species commonly housed in aquariums where this mode of reproduction has been documented to occur, to quantify baseline rates of parthenogenesis. Over the course of one year, all yolked egg from 13 females across 7 institutions were incubated for several weeks to allow for visual identification of embryos in early development at the time of dissection. Tissue samples were taken for microscopy and genetic confirmation of parthenogenesis through microsatellite genotyping. Parthenogenesis was detected in all females and across institutions, regardless of male presence or absence. There was one exception, a maturing female who laid only five eggs during her first year of laying where no embryos were identified either visually or through genetic testing of egg fluid. For institutions where all eggs were monitored for an entire year, the baseline rate of parthenogenesis was unexpectedly high, suggesting that this phenomenon occurs more often than previously recognized. The prevalence of this phenomenon may complicate conservation efforts aiming to release genetically-diverse offspring back into the wild.

## In situ anatomy of pectoral, body, and respiratory muscles in green (Chelonia mydas)and loggerhead (Caretta caretta) sea turtles

*Jeanette Wyneken, Maria Chadam, Michael Echols*

The relationships of the pectoral musculoskeletal anatomy and pulmonary of turtles is especially challenging to describe due to the shell. How turtles breathe in the absence of a diaphragm or intercostal muscles is thought to be through muscular contraction and relaxation of a muscular "sling" around the lungs. Yet marine turtles lack a complete muscular sling Recent combinations of imaging techniques including three-dimensional axial computed tomography imaging along with standard verification dissections and novel preservatives that maintain the pliability of the muscles and lungs increase the ways we can approach understanding the marine turtle ventilation system. Three-dimensional CT imaging was followed by dissection to verify interpretations of muscle organization were done. A novel combination of 10% buffered formalin and Scarlet Imaging Animal Preservation System (Prep and Preserve)® used to preserve green turtles (Chelonia mydas) resulted in pliable yet preserved soft tissues that remain flexible after more than for more than 300 days. The prolonged quality of the muscles and lungs allowed for testing of several hypotheses over time focused on understanding the relationships of the pectoral girdle muscles, carapace, and pulmonary carapacial mesentery.

## Estimating a multi-species sprinting performance landscape in an Anolis lizard community

*Larkin Wynn, James Stroud*

Identifying how morphology connects to performance at both intraspecific and interspecific scales is important to understand how ecological communities assemble and are structured. We use linear discriminant analysis to plot 800 individuals of five Anolis lizard species, representing four ecomorphs, in a multivariate morphological trait space. Species are expected to form distinct clusters in this multivariate trait space as their morphologies correspond to differences in structural habitat use. We then map sprinting performance onto this trait space to identify local performance peaks. We will explore trade-offs between limb length, claw shape and size, and adhesive toepad size in sprinting performance. This study explores how morphological diversity relates to performance and resource partitioning in a lizard community, providing insights into the factors promoting species coexistence.

## Hands off! A non-invasive method for collecting DNA from white sharks (Carcharodon carcharias)

*Lila Xenakis, Toby Daly-Engel, Megan Winton, Dylan Gore, Kieran Stein, Greg Skomal*

Elasmobranchs (sharks, skates, and rays) are ecologically important keystone predators, and many species are currently under threat. Genetic diversity is a known buffer against extinction risk, and understanding patterns in diversity can improve conservation measures. But sampling DNA from elasmobranchs remains both logistically difficult and invasive, especially large shark species that are among the most vulnerable. To address this issue, we developed and tested a non-invasive method of collecting DNA from elasmobranchs to enable both individual and population-level genetic testing. Using an extendable pole-mounted scouring pad, four white sharks (Carcharodon carcharias) were swabbed on the back, while tissue samples were taken using a conventional biopsy-tipped pole spear to compare sequencing quality between collection types. We amplified 800 bp of the D-loop portion of the mitochondrial control region and eight nuclear microsatellite loci in each sample, and found that the resulting sequences were consistently clean, and the readability did not differ between collection methods. With this new technique, researchers will be able to collect DNA from white sharks and other threatened species non-invasively via sponge swab, ensuring that the animal is less impacted without sacrificing DNA quality.

## Squeezing in tight spaces: How does worm move faster in confined channel?

*Justin Xu, Prathyusha Kokkoorakunnel Ramankutty, Paulami Sarkar, Saad Bhamla*

Living organisms employ diverse strategies to navigate through highly confined environments. For example, semiaquatic worms such as Lumbriculus variegatus (California blackworms) use their flexible, slender bodies to move through tight channels in wet granular soil or through tangles made from conspecifics. Motivated by these natural strategies, in this study, we examine a single worm as it moves within an open capillary tube of varying diameters (1.5 mm - 0.2 mm), quantifying its behavioral dynamics, including speed and the time required to escape the channel. To better understand the mechanisms underlying these movements, we develop a computational model in which a single worm is represented as a self-propelling active polymer confined within a cylindrical open channel. Through simulations, we explore the escape dynamics of the active polymer as a function of confining radius, channel length, and polymer stiffness. Our findings demonstrate that flexible filaments escape quickly in strong confinements. Our study provides a foundation for developing bio-inspired robotic systems capable of efficient navigation in complex and confined spaces.

## Characterization of the Hippo signaling pathway in the colonial cnidarian *Hydractinia*

*Qingru Xu, Danielle de Jong, Christine Schnitzler*

The Hippo signaling pathway is a regulator of cell proliferation and tissue growth in mammals. It includes a kinase cascade that controls the cytoplasmic or nuclear localization of a transcription coactivator, Yorkie, thereby affecting downstream gene expression. Despite the conservation of pathway components in animals and unicellular relatives, functional data outside of traditional model organisms is limited and often inconclusive, leaving the ancestral function(s) of the pathway unresolved. The marine, colonial invertebrate Hydractinia has incredible regenerative abilities and displays indeterminate growth at the colony level, thanks to a pluripotent adult stem cell population. We are studying the Hippo pathway in Hydractinia by focusing on two biological processes, polyp head regeneration and juvenile colony growth. We observed expression of Hippo and Yorkie mRNA and Yorkie protein in budding polyps in juvenile colonies. We are using cell type-specific markers and the EdU cell proliferation assay in co-localization analyses with Hippo pathway components to determine the cell types that express these genes. Additionally, we found that pharmacologically inhibiting Yorkie with Verteporfin negatively affects rates of polyp head regeneration and colony growth. These results align with the pathway's established functions in cell proliferation and tissue growth. By providing data from a cnidarian species with versatile tissue and cell plasticity rarely seen in mammals, this project aims to shed light on the evolution of the functions of the Hippo pathway.

## Dimorphic niches explain sexual dimorphism in the morphology and integration of an orchid bee brain

*Denise Yamhure Ramirez, Santiago Ramirez*

Sexual dimorphism is pervasive across animals and is well-documented in visible phenotypic traits favored by sexual selection. Yet, the extent to which sexual dimorphism arises in more inconspicuous traits, as a response to ecological factors, is less studied. Here we explore sexual dimorphism in the brain of the orchid bee Euglossa dilemma, a species with dimorphic niches, where the sexes exhibit distinct ecology and behaviors. Using microtomography, we provide sex-specific brain atlases for this orchid bee, and comparatively study the morphology and developmental integration of brain regions. We show that males invest more in all primary visual processing sites, which are strongly integrated with the central complex, suggesting that males relay more on flight stability and the sky-compass navigation to meet the unique cognitive demands of their behavioral ecology (e.g. larger home ranges and courtship display). We also reveal that females have larger mushroom bodies with increased neuron numbers, and are uniquely integrated with the optic lobe, implying greater capabilities for visual associative memory. We suggest this is as an adaptation to their nest building and social behavior, for which an increased ability to learn visual landmarks is beneficial for central place foraging and traplining navigation. Our results, therefore, identify brain regions of sex-specific sensory adaptations and provide candidate sites to further understand the neuroethology of this pollinator.

## Sexual conflict, social networks, and the fitness consequences of female multiple mating

*Janice Yan, Reuven Dukas*

Sexual conflict is ubiquitous across the animal kingdom and often involves sexual harassment of females by males. An overlooked outcome of sexual conflict is its potential impact on social behaviour. Furthermore, female behavioural avoidance of harassment remains poorly understood. We therefore conducted several experiments using bed bugs (Cimex lectularius), one of the most well-known models of sexual conflict because they reproduce via traumatic insemination. First, we constructed social networks of freely interacting bed bugs and found no evidence of females avoiding males in realistic group conditions. However, when tested individually, females strongly preferred female rather than male social cues. Taken together, these findings suggest that the sexes may be in conflict over the social environment. Next, we found that females inseminated weekly lived longer and produced over 50% more lifetime offspring than females inseminated daily, thereby demonstrating high costs of polyandry in bed bugs. We then observed bed bug populations where we manipulated females' insemination recency and found that recently inseminated females did not avoid males more but were more frequently rejected by males, providing a clear example of male mate choice based on female sexual history. Finally, through detailed video-recordings, we found that females plastically increase avoidance of males after receiving three consecutive inseminations. Overall, our results provide novel insights into the selective pressures that shape sexual and social behaviours in both sexes.

## Linking ovarian development and mating strategies in jumping spiders

*Lin Yan, Damian Elias*

Mating strategies in animals vary widely from systems where animals compete for access to mates (intrasexual selection) to systems where choosers select amongst potential mates (intersexual selection). The physiological patterns underlying this diversity are unknown in most species. We utilized the occurrence of both mechanisms in jumping spiders to ask whether ovarian development in females affects the mating strategies adopted. Evidence suggests that, in members of the genus Phidippus, males compete for access to immature females by mate guarding, while in members of the genus Habronattus, males produce complex courtship signals that choosy mature females use to select appropriate mates. To test the hypothesis that variation in ovarian development correlates with mating strategies, we paired Phidippus otiosus and Habronattus formosus females at various ages with males and recorded behavioral interactions. We performed micro-CT to visualize the ovarian development. If ovarian development is associated with variation in mating strategies, P. otiosus females should be receptive earlier and have more developed oocytes than H. formosus females. Behaviorally, P. otiosus females are receptive in the first few days after maturation, while H. formosus females are receptive 2-3 weeks after maturing. However, ovarian development shows the opposite pattern, with H. formosus females having faster-developing ovaries than P. otiosus. We discuss the complex physiological processes underlying this variation in mating strategies and the evolution of mating systems in jumping spiders and other animals.

## Respiratory Encoding by Vagal Sensory Neurons in Larval Zebrafish

*TingTing Yan, Luis Hernandez-Nunez*

Dysautonomia, a common disorder that affects over 70 million people worldwide, occurs when the autonomic nervous system (ANS) fails to regulate itself.

This dysregulation can lead, for example, to orthostatic hypertension, a common symptom in patients with neurodegenerative diseases such as Parkinson's, Alzheimer's, or Autism, where blood pressure abruptly fluctuates when shifting from sitting to standing. There is limited research on how the nervous system locally controls blood flow in various organs in response to increased cardiac output. Our study aims to uncover the neural circuitry involved in respiratory blood flow detection using zebrafish as a model organism. We hypothesize that vascular tone in the gills and other physical parameters relevant to respiration are represented in Vagal Sensory Neurons (VSNs). To visualize VSN activity and blood flow simultaneously, we established a transgenic zebrafish line expressing a calcium indicator in VSNs and a red fluorophore in erythrocytes. The cardiac output of the zebrafish was increased through the presentation of visual threat. Calcium activity, blood flow, and heart rate changes were recorded before and after stimulation. Understanding the mechanism of sensory regulation of respiration will shine light on future therapeutics of autonomic nervous system dysregulation.

## Illumination mediates a switch in both active sensing and control in weakly electric fish

*Yu Yang, Huanying Yeh, Debojyoti Biswas, Noah Cowan*

Animals integrate multiple sensory inputs to explore environments and execute locomotor behaviors. During these behaviors, the nervous system internally reweights streams of information, putting more emphasis on those with the least uncertainty, e.g. in a Bayesian framework (Knill 2007). However, sensory uncertainty also modulates active sensing behavior: animals produce more vigorous active sensing movements as sensory uncertainty increases (Stamper et al., 2012; Biswas et al., 2023). To better understand the link between active sensing and multisensory reweighting, we studied how the weakly electric glass knifefish Eigenmannia virescens alters its movement dynamics in response to parametric manipulations of illumination. We hypothesized a concomitant switch in active sensing behavior and multisensory reweighting. To test this, we varied illumination levels from 0.1 to 210 lx as fish tracked a moving refuge. We discovered that in a neighborhood of a critical threshold (3.5-18 lx), small changes in illumination led to dramatic changes in both active sensing and multisensory control. Specifically, slight decreases in illumination led to steep increases in fish head and tail movements and refuge tracking phase lag. Outside this threshold, large changes in illumination only caused mild variations in behavior. A control-theoretic sensory reweighting model that dynamically increases the weight of vision over electrosense based on increased illumination corroborated these observations. Our findings enhance our understanding of active sensing, multisensory reweighting, and locomotor control.

## Replicated tests for urban thermal adapation in the green anole lizard Anolis carolinensis

*Shannan Yates, Alex Gunderson*

The growth of the global human population is driving urbanization, introducing new selective pressures on organisms in these habitats. Therefore, cities offer a unique opportunity to study adaptation to rapid environmental change. Due to the Urban Heat Island effect, cities are generally warmer than rural surrounding habitats and urban organisms are predicted to be more heat tolerant than their rural counterparts. Understanding how urbanization drives the evolution of thermal traits can thus help us to predict how biodiversity will be affected by the rapid warming associated with climate change. In this study, I tested for divergence in thermal traits between urban and rural populations of the green anoles (Anolis carolinensis) in two different cities: New Orleans and Baton Rouge, Louisiana. I tested for differences in three traits: preferred temperatures, cold tolerance, and heat tolerance after animals were acclimated to common garden laboratory conditions for 10-14 days. I predicted that preferred temperatures and heat tolerance would be higher in urban lizards but lower cold tolerance. Contrary to my predictions, none of the traits differed between rural and urban sites (T-tests; all $P > 0.05$; Fig. 1).. I theorize that behavioural thermoregulation is buffering urban green anoles from the effects of the urban heat island effect, reducing divergent selection on thermal traits between urban and rural lizards.

## Biologically !nspired Design: Methods and Practice

*Jeannette Yen*

Biologically Inspired Design takes superlatives of Nature and translates into designs and engineering processes. Design rules are found using phylogenetic and convergent evolutionary analyses to find common patterns for deep bio inspired designs. To invent a new bio inspired design requires identifying key patterns and abstracting that to an application. Some tricks of the trade that promoted interdisciplinary learning and engagement include: cognitive dissonance, functional matrices, pattern abstraction, identification of key levers.

Consideration of performance, creativity, and scalability are applied to test credibility vs. readiness of designs. This course gives new value to Nature.

Learning Objectives: Identify good examples from Nature that are ripe for design; Understand how Nature works; Apply principles from Nature to human-centered products and processes; and Build a bio-inspired design: scaling, materials, challenges.

## Systems Virology: integrating experimental data to bring virus genomes to life

*John Yin*

The life cycle of a virus relies on its encounter with a host cell. After adsorbing to the cell surface, the genome of the virus enters the cell and diverts cell resources toward the expression of virus genes, the replication of virus genomes, the packaging of genomes into particles, and the release of progeny particles into the extracellular environment. One may write mathematical statements—coupled ordinary differential equations–to describe such processes. Further, the behavior of the equations may be constrained by incorporating biochemical and biophysical data from experiments, and they can be solved by computer. In short, the resulting computational model incorporates and integrates experimental data on molecular-level processes to predict the average timing and release of virus progeny from an infected cell. Such predictions, which are correlates of virus fitness, can be tested in the lab and refined. Moreover, these models can be used to explore fundamental questions and societal needs, which include: how viruses exploit the material and energy resources of their hosts, how mutations in different genes interact in their effects on virus fitness, and how anti-viral strategies might be designed to resist virus escape.

## Frequency impact on swimming mechanics of robotically-controlled jellyfish

*Noa Yoder, John Dabiri*

Jellyfish such as Aurelia aurita exhibit low cost of transport compared to other swimming organisms. Their relatively simple morphology allows for in-depth study of their naturally-occurring locomotion, yet natural swimming is a subset of the full, physically-realizable performance envelope. Robotic control can expand the range of accessible swimming regimes, giving us a better understanding of their physiological limits which can help inform bioinspired designs. This study uses robotic control to explore the relationship between the contraction frequency of the jellyfish bell muscle and jellyfish swimming speeds. Experiments were conducted using a previously-developed method of stimulating the jellyfish muscles with electric pulses from a microcontroller. Varying the frequency of stimulation allowed us to vary contraction frequency, and speeds were visually recorded as the jellyfish swam downward in a 2.1m tall vertical tank. At frequencies below 0.4Hz the jellyfish contractions did not generate sufficient thrust to counteract the buoyancy of the microcontroller. At frequencies above 0.8Hz the jellyfish muscles were not able to respond quickly enough to stimulation. For an intermediate range, however, jellyfish speeds did not vary with frequency, indicating that frequency variation does not appear to be a method of control for swimming speeds. New models for jellyfish swimming that incorporate the hydrodynamic effect of vortex formation and background flow were developed and compared with these results to seek an explanation for the observed phenomenon.

## Urbanization effects on stress and auditory-visual processing in House Sparrows (*Passer domesticus*)

*Emma Yonker, Natalie Leake-Jara, Madeline Tinskey, Kelly Ronald*

Urban expansion introduces various anthropogenic challenges for wildlife, such as habitat fragmentation, novel predators, and pollution. These challenges may disrupt animal communication and contribute to increased stress levels. This study explores the physiological consequences of urban stressors on house sparrows (Passer domesticus). Specifically, we examine how urbanization affects the anti-stress hormone (i.e., corticosterone, CORT) levels and its relationship to auditory and visual processing. Sparrows were collected from rural, suburban, and urban areas around Holland, MI. Blood samples were analyzed for baseline and elevated CORT levels to assess stress responses. Auditory processing was evaluated using auditory brainstem responses, which assess the ability to detect sounds at varying frequencies and intensities. Visual processing was assessed through electroretinogram tests, which indicate motion detection ability by measuring flicker fusion frequency—the threshold at which individual light flashes can no longer be distinguished. We predicted that (1) urban birds would show higher chronic CORT levels than rural birds and (2) differences in sensory processing may be due to differing CORT concentrations in urban versus rural birds. Our results will contribute to an understanding of animal communication in a growing urban environment and the overall impact of anthropogenic disturbances on wildlife. Ultimately, this will provide insights into conservation strategies aimed at reducing the effects of human activity.

## Gene expression, embryogenesis, and ecology in frogs

*Becca Young*

Frogs have an impressive diversity of reproductive modes. In addition to the ancestral aquatically-reproducing species, frogs have evolved complex adaptations including direct development, terrestrial nesting behaviors, parental care, and even the concealing of embryos in body cavities. Challenges of these diverse developmental environments have been linked to variation in egg properties (e.g., egg size and yolk abundance) and embryo architecture. Notably, embryogenesis differs in overall rate and relative timing between small-egged, fast-developing aquatic species (e.g., Xenopus spp.) and large-egged, slow-developing terrestrial species (e.g., poison frogs and rain frogs). Here, we ask how genes and gene expression and co-expression during embryogenesis change in the semi-terrestrially developing poison frog (Epipedobates machalilla) relative to canonical patterns described in Xenopus. Further, we leverage existing ecological and life history data to identify phylogenetic correlates of reproductive ecology across frogs.

## Beware the company you keep: social distancing and site fidelity in the maritime earwig

*Carter Young, Vikram Iyengar*

The spatial distribution of individuals in a group provides insight into how natural and sexual selection shape the behavior of social species. In the maritime earwig Anisolabis maritima, males possess asymmetrical forceps used in nonlethal intrasexual combat, whereas females frequently kill conspecifics while defending nests from cannibalism. In our study, we observed the spatial distribution of maritime earwigs maintained at an equal sex ratio to determine 1) if the sex or size of earwigs affected their nearest-neighbor distances and 2) if sex or size affects site fidelity to a shelter. We found no relationship between sex or size and the distances to either same-sex or opposite-sex neighbors. Additionally, only one-third of the earwigs in this study showed site fidelity; size and sex did not affect the frequency of this behavior. While no site fidelity is unsurprising in a scavenging insect inhabiting a dynamic intertidal environment, we did not expect sex and size to have no effect on nearest-neighbor distance. These results suggest that A. maritima aggregate based on the recognition of multiple conspecifics, forming a social network, instead of only orienting towards the nearest mate or rival. We are currently conducting social network analyses on our image datasets to fully explain the effects of sex and body size on the social structure of maritime earwigs.

## Visualization of tiny, springy deformations of an ultrafast trap-jaw ant's propulsive head

*Melody Young, Clare Cook, Justin Jorge, Roarke Horstmeyer, Sheila Patek*

Tiny biological springs integrated with latches can propel extremely fast movements with high power density (power/mass). Exemplifying these spring-latch systems, trap-jaw ants (Odontomachus brunneus) slowly store and rapidly release elastic potential energy in their head capsules. The elastic mechanism propels each mandible at 49,100 rad/s using a mere 24.2 $\mu$J - reflecting an extraordinary power density of 396,000 W/kg spring-loading muscle. Previous studies of the elastic mechanism were limited to single-plane, global displacements of the ant head. To determine how trap-jaw ants distribute tiny displacements across their head capsule to achieve high power density, new optical technology was needed to simultaneously resolve tiny local displacements across a wide field of view. We developed an ultra-high-speed fourier light-field microscope capable of resolving displacement fields across three-dimensional geometries at high resolution and frame rates. We recorded the real-time deformation of the recoiling head capsule during the spring propulsion phase of mandible strikes (100,000 frames/s; 29 individual ants; ∼10-15 strikes/ant). The side of the ant head recoiled an average $33.3 \pm 11.4$ µm medio-laterally within 0.12 ms, offering the first real-time and fully resolved measurements of the head recoil that torques the mandibles. This new dataset and optical system offer new insights into the magnitude, timeline, and distribution of displacements of the small elastic structures which are foundational to high power density, ultrafast, spring-propelled movements.

## Growth and sex differences in biological aging in *Danio rerio*

*Noor Yousuf, Peggy Biga*

Sex-specific aging can be found in many species in the animal kingdom, and observable in behavior, phenotype, and genotype. Recently there has emerged the use of building epigenetic clocks to accurately predict the biological ages of animals in which chronological age is not always known. Most epigenetic clocks are mammalian-based and few have been developed for fish species. This study examines the methylome of zebrafish, Danio rerio, to validate an established epigenetic clock and test for sex-specific differences in epigenetic regulation using reduced representation bisulfite sequencing, ATAC sequencing, and RNA sequencing. The clock made and formatted to examine sex differences will then be utilized to create a new clock for the green swordtail, Xiphophorus multilineatus.

Zebrafish is a model organism commonly used to examine early development and neurological diseases, but they lack clear genetic and sexual dimorphism and lab-reared zebrafish no longer have sex chromosomes. This causes zebrafish to be an ineffectual model for age- and growth-related sex-specific models, but the developed aging methylation clock can be used to identify sex and potential sex-specific biological aging in the zebrafish. Additionally, the zebrafish aging methylation clock will be used to develop a similar clock for the green swordtail, which exhibits sexually dimorphic growth and aging, with unique male-specific growth and aging morphotypes.

## Examining the relationship between spatial preferences, age, and group size in highly social cichlid

*Andrew Yuan, Veronica Britton, Erika Moore, Tessa Solomon-Lane*

Spatial preferences play an important role in understanding social behavior both at the individual and group level. How an organism interacts with, and is influenced by, its environment results in varied social experiences arising over time. We aim to understand how features of the social environment – specifically fish age, body size, and group size – impact individual spatial preferences. Due to their highly social characteristics, the African cichlid fish, Burton's Mouthbrooder (Astatotilapia burtoni), was used as the model species. Fish were divided into treatment groups, ranging from one to eight fish, and from a couple weeks to months old, and placed into identical environments. Each aquarium contained a square, clay "fortress" (8 × 8 cm, with an open center) positioned in the center. A camera system using Raspberry Pis was set up to record fish activity and behavior. The softwares TRex and SLEAP were employed to score the recorded behavior. Social and spatial behavior differed across treatment groups, including in how much spatial preferences of individual fish overlapped with other group members, as well as, specific aquarium regions. We also tested for effects of group density and fish ages on defined territorial boundaries and aggression. This research can improve our understanding of spatial preferences, with broader implications for social network dynamics and reciprocal interactions between individuals and their environments over short and long periods of time.

## How do mudskippers and mudskipper-inspired robots taxi?

*Kai Lauren Yung, Daehyun Choi, Nami Ha, Halley Wallace, Kenny Zhang, Saad Bhamla*

Mudskippers (Oxudercinae) are known for their adapted pectoral fins modified for terrestrial locomotion which also allow them to "skip" on water. Mudskippers also move using submerged swimming and taxiing movement where the eyes remain above water. We study how Periophthalmus darwini uses its pectoral and pelvic fins in conjunction with its caudal fins to power the taxiing behavior that precedes water hopping. Though this taxiing bears some similarities to flying fish, it is distinct where flying fish fully submerge preceding "flight" and have different fin structures which cannot be used on land. To uncover how mudskipper's terrestrially adapted fins can contribute to airborne hopping, we have built a robotic model to simulate biological mudskipper's locomotion. We use 3D printing and laser-cutting of plastic materials to build the body and fins, and use two counter-rotating motor driven propellers to simulate caudal fin propulsion. The fins move using a motor and string to pull the fins outward and an elastic string that rapidly resets the fins inward. The robot aims to reproduce the speed (10 body lengths per second) and angle control of biological mudskipper fins. This robot's speedy control and locomotion at the interface breaches a new area for air-water robotics with potential applications for submarines maintaining visuals like mudskippers taxiing, or torpedoes that can move in and out of water with precise angular control.

## Does fish passage select for American eel size?

*Miriam Yushavaiev, Amanda Horung, Rita Mehta, Andrea Ward*

Anguilla rostrata (American eels) are catadromous fish transitioning from marine to freshwater habitats during their early life stages. During their transition American eels are known to emerge from water and traverse land which can happen during that initial upstream migration. Although elvers have been known to climb the walls of dams during their upstream migration, dams characterized by fast flows and slippery vertical surfaces are obstacles to their successful migrations. In this study, we monitored migratory patterns of eels utilizing fish-passages, man-made structures to aid in fish migration, in local Long Island waterways (Rockville Centre, NY) to understand their effectiveness. Additionally, we tested fish-passage preference by eels of varying sizes to develop more effective passages to allow eels to traverse dams in their migration routes. We hypothesized that fish-passage type would impact preference in young eels. To monitor the fish-passages, passive eel traps ("mops") were deployed, to see whether particular eel sizes were more successful in traversing the fish-passage. To test the preference for certain fish-passages, eels were collected from local dams and tested moving up 3 different ladder types overlaid with various substrates. Based on our previous studies, we predicted that eels would prefer to traverse the passage with the non-compliant substrate. Results from this study will help local managers in building new fish-passages that are effective in facilitating migration of an economically and ecologically important species.

## Lions and Tigers and Bears, oh my: a new data-driven ecological and behavior categorization scheme

*Hartrich Zack, Alexa Wimberly, Graham Slater*

A fundamental problem in functional morphology is quantifying ecological variation. Mammalian locomotor ecology usually is divided into univariate categories (e.g., fossorial, arboreal). Their simplicity and inconsistency erase the nuance of animal behavior and obscure ecological signal, causing difficulties in recovering relationships between ecology and morphology. We propose a multivariate categorization scheme ranking substrates based on importance, and scoring behaviors done on each substrate, using Carnivora as an example. Using the literature, we determined the importance of four substrates (terrestrial, aquatic, subterranean, arboreal) for each species and ranked substrates from unimportant to vital. We also determined whether five vital behaviors (foraging/eating, resting, denning, predation avoidance, travel) occur on each substrate, creating species behavior scores. Using these rankings, we performed polychoric and tetrachoric PCAs and cluster analyses to assess our schemes and to compare them to each other and univariate categorizations. In both PCAs, there is a clear gradient from the most arboreal taxa to the most aquatic and subterranean taxa, suggesting that our methods capture the continuum of locomotor ecology. Cluster analyses recovered far more groups than typical of univariate schemes. Furthermore, clusters do not align well with previous schemes in the literature; the substrate ranking and behavior scoring clusters do not align with each other. Substrate importance and behavior location capture different aspects of locomotor ecology, and our methods provide more nuance than univariate schemes.

## eDNA metabarcoding to assess native freshwater mussel biodiversity in North America

*Emily Zavacki, Omera Matoo*

Biodiversity loss is one of the biggest challenges facing humanity today. Described as one of the most imperiled fauna in the US, freshwater mussels are experiencing precipitous declines with extinction rates of 50% by the end of century. In addition to river warming, intensive agricultural land use and frequent droughts in the Great Plains states (including Nebraska and South Dakota) has further exacerbated mussel populations decline. Because the current distribution of mussels is poorly understood in these states, it is difficult to identify potential source brood to maintain genetic diversity in state hatcheries, locate waterways for reintroduction, or even assess declines of historically common species. However, conventional field surveys are time-consuming, disruptive, and require taxonomic expertise. To address this, we will use environmental DNA (eDNA) metabarcoding approach. eDNA metabarcoding is a molecular systematics approach that will allow simultaneous detection of multiple mussel species, via analyses of water samples, using high-throughput DNA sequencing with two widely used phylogenetic taxonomic markers - cytochrome c oxidase subunit I (COI) and NADH dehydrogenase subunit 1 (ND1). These results, when complemented with tactile surveys, will inform (1) mussel biodiversity across large spatial scales, (2) rare and federally listed species; (3) out-of-range and/or invasive species; and (4) estimates of community relative abundances of mussels. Overall, this study generates critical insights for evolutionary potential, long-term sustainability, and policymaking for freshwater mussels.

## Do ant colonies collectively learn to improve pavement construction?

*Haolin Zeng, Jonathan Bowles, Takao Sasaki*

Individual social insect workers can learn complex behaviors from their nestmates, but the potential for collective learning to improve task performance at the colony level remains underexplored. Recent studies suggest that red imported fire ants (Solenopsis invicta) demonstrate tool use when traversing sticky surfaces to reach a food source, paving a path using nearby movable objects. We investigated whether ants could improve the efficiency of path construction with experience. We coated a petri dish with Vaseline, which is aversive to fire ants, provided glitter by the dish, and placed food at its center. This setup was then presented to a food-deprived colony fragment composed of approximately

2,500 worker ants. Ants used glitter to cover the Vaseline and create a path across the dish, initiating from the periphery and gradually reaching the food at the center. The paving trial was repeated over the following week. With each trial, the paths became increasingly narrow and more coherent, and each ant contributed more effectively to the construction. Our results demonstrate, for the first time, that social insects collectively learn and improve task efficiency in a form of tool use.

## Ballistic rapting by tongues in salamanders and chameleons

*Yu Zeng, Christopher Anderson, Stephen Deban*

Chameleons (Chamaeleonidae) and many lungless salamanders (Plethodontidae) can quickly project their tongues to capture distant prey. Both ballistic tongue systems feature a tubular accelerator muscle coupled with tapered skeletal elements and slender, elongated retractor muscles, but the biomechanical principles and evolutionary mechanism remain enigmatic. Here, we studied the dynamics of entire tongue projection-retraction cycles. In both groups, the tongue projection movement is characterized by an initial acceleration phase and a subsequent deceleration phase, allowing the tongue pad to collide with the prey at a limited ideal range of velocity and deceleration. When colliding with the prey, the tongue pad experiences the greatest deceleration and reaches zero speed, after which an elastic restoring force from the retractor system initiates the retraction movement. We show this rapid adhesion and recoiling (termed 'rapting') is modulated through the timing of eccentric contraction of the retractor muscles. With a mathematical model, we show that the biomechanical coupling between a linear accelerator (i.e. the projector system) and a muscular tether (i.e. the retractor system) modulates the dynamics of the ballistic projection-retraction cycle. Our results help to explain not only the convergence in design and performance of ballistic tongues in salamanders and chameleons but also how selection for capturing distant prey and small body size may underlie the evolution of ballistic tongue systems.

## Movement alters ecological dynamics in heterogeneous environments

*Bo Zhang, Jamaal Jacobs*

Understanding mechanisms of coexistence is a central topic in ecology. Mathematical analysis of models of competition between two identical species moving at different rates of symmetric diffusion in heterogeneous environments show that the slower mover excludes the faster one. The models have not been tested empirically and lack inclusions of a component of directed movement toward favorable areas. To address these gaps, we extended previous theory by explicitly including exploitable resource dynamics and directed movement. We tested the mathematical results experimentally using laboratory populations of the nematode worm, Caenorhabditis elegans. Our results not only support the previous theory that the species diffusing at a slower rate prevails in heterogeneous environments but also reveal that moderate levels of a directed movement component on top of the diffusive movement allow species to coexist. Additionally, we have expanded our work to test the outcomes of different movement strategies in a various of fragmented and toxincant environments. Our theoretical and empirical results found that species with a relatively low motility rate maintained a moderate growth rate and high population abundance in fragmentation. Alternatively, fragmentation harmed fast-moving populations through a decrease in the populations' growth rate by creating mismatch between the population distribution and the resource distribution. Our study will advance our knowledge of understanding habitat fragmentation's impacts and potential mitigations, which is a pressing concern in biodiversity conservation.

## Why Click? The adaptive value of the click beetle's clicking mechanism

*Liyuan Zhang, Teagan Mathur, Aimy Wissa, Justin Yim, Marianne Alleyne*

Click beetles (Coleoptera: Elateridae) are capable of jumping without using their legs due to a special morphological structure that lies between their mesothorax and prothorax. This feature enables it to rapidly convert stored elastic potential energy into kinetic energy. Previously our group's research described the morphological features of the latch-mediated spring actuated system, and the dynamics of the jump, but it is still unknown why this mechanism evolved in, and only in this group of beetles.

Some hypotheses propose that the clicking mechanism helps click beetles to get out of constraint spaces. To test these hypotheses, we designed and manufactured a test station that constrained beetles in various ways. Through careful observation and examination of the beetles' clicking reaction in the test station, we are closing in on how clicking benefits the beetles' ability to escape from predators and avoid undesirable orientations. When fully constrained, click beetles do not use the clicking mechanism to get out of tight spaces, but when partially constrained the mechanism will help them escape.

The innovative experimental approach provides further insights into the design and construction of legless robotic mechanisms that are capable of locomotion across diverse terrains and can escape from constraints regardless of body orientation.

## Defining relative joint stiffness in multi-articular muscle-tendon driven systems

*Margaret Zhang, Talia Moore*

Joint stiffness significantly affects system compliance during movement. Even for planar joints, such as the knee, stiffness is evaluated in multiple axes, presented in a 6 by 6 matrix that defines the relationship between stress and strain of bending movements in multiple directions. This method, combined with serial dissection, determines the contribution of different tissue types to joint stiffness. Empirically measuring joint stiffness in multi-articular muscle-tendon driven structures is even more complex because a joint's stiffness profile depends on all joints' configurations. Mammal tails are particularly challenging because muscles connect to tendons that span 5-30 multiaxial joints, and removing tendons causes joint dislocation. We seek to establish standardized methods to empirically characterize tail joint stiffness in a way that incorporates overall tail configuration, demonstrated on a Jaculus jaculus.

First, we built a customized rig to precisely control tail configuration while measuring joint angle as force is applied. In lieu of serial dissection, we measured individual joint stiffness with tendons loaded (connected to muscle) and unloaded (disconnected from muscle) to isolate passive connective tissue contributions. We introduce a new compliance matrix function that defines a joint's stiffness profile dependending on the configuration of the whole tail. Future work aims to add this function-based definition of stiffness to the OpenSim modeling environment. These methods will facilitate more precise biomechanical examinations of tail performance and evolution.

## Fish swimming in a shear layer: the dynamics of energy conservation

*Yangfan Zhang, Robin Thandiackal, Connor White, Yu Pan, George Lauder*

We hypothesize that fish locomotor gaits can enable energy saving by allowing animals to alter their locomotor kinematics in response to dynamic changes in a flow field. To examine fish's responses to dynamic conditions, we studied brook trout (Salvelinus fontinalis, 250g, 24cm long) interacting with an experimentally generated shear layer in a flow tank and swim-tunnel respirometer. With a free-stream flow of ∼1.5 BL s-1 (50% of their sustained maximum swimming speed), trout can stay nearly stationary along the shear layer, tilting their body at a small angle of attack, despite encountering near free-stream flow at their head. The flow between the shear layer and the anterior region of the trout (measured by particle image velocimetry) generated thrust and balanced fluid drag on the posterior body region (revealed by force measurement and computational fluid dynamic analyses). Trout exhibited almost no undulatory motion despite the moving fluid. Direct measurement of aerobic and nonaerobic energetic costs showed that trout swimming in a shear layer had a 74% lower locomotor energy (reaching a level approaching the resting metabolic rate) compared to trout swimming in the free stream. We conclude that since shear layers are common in natural streams and ocean flows, the use of a velocity gradient to harness energy from moving fluid can be a fundamental mechanism to achieve energy saving by vertebrates moving through fluids.

## Cross-specific analysis of fluid flow and beating kinematics in swimming ctenophores

*Mohammadreza Zharfa, David Peterman, Adrian Herrera-Amaya, Margaret Byron*

Metachronal coordination—in which several closely spaced appendages actuate at a phase lag from their neighbors, producing a metachronal wave—is used by a large number of organisms to facilitate feeding, locomotion, and other functional behaviors. In the context of swimming, this strategy appears across a wide range of lengthscales (from microns to centimeters) and diverse taxa (including ctenophores, crustaceans, and polychaetes). However, the relevant dynamical and morphological parameter space is very large, including stroke amplitude, beat frequency, phase lag, appendage spacing, appendage kinematics, total number of appendages, and many other variables. It is not clear how shifts in any of these often-interdependent properties affect the overall efficacy and performance of metachronal systems. Here, we compare the overall beating kinematics and flows generated by three species of ctenophores (Beroe cucumis, Pleurobrachia bachei, and Bolinopsis microptera), which locomote across a range of fluid Reynolds numbers (approximately $10<Re<2\ 00$). We find that at similar Reynolds numbers, Beroe produces more coherent fluid flow than Pleurobrachia. We also note other key differences in the fluid flow around the metachronally coordinated propulsors (ctenes) for each species, as well as differences in morphology (ctene spacing) and propulsor kinematics (spatiotemporal asymmetry). Our results emphasize the importance of subtle differences in morphology in driving fluid flow, and lay the groundwork for future systemic investigation of the parameter space of metachronal swimming.

## Muscular hydrostats mechanics under gravitational loading

*Bokun Zheng, Noel Naughton*

Muscular hydrostats, such as the arms of octopuses or trunks of elephants, are soft, boneless structures actuated via architecturally complex arrangements of muscle groups. Octopus arms are well adapted for underwater operation, where the arm's similar density of water enables effectively weightless operation. Outside of the water, however, octopus arms struggle to counteract the increased gravitational load. In contrast, elephant trunks, while operating according to the same biomechanical principles, are well adapted for operation in this higher gravitational load environment. This study analyzes muscular hydrostat mechanics under gravitational loads by considering the muscular hydrostat as an elastic beam and considering self-buckling criteria due to gravity. We investigate how the interplay of geometric and material properties defines stable operational envelopes for muscular hydrostat structures. Additionally, we explore the ability of muscular hydrostats to expand these stable envelopes through their ability to self-stiffen by activating specific muscle groups. We identify fundamental biomechanical functional limits of muscular hydrostat structures for stable operation across different mediums and compare these limits to observed octopus arm and elephant trunk physiology. The findings of this study not only enhance our understanding of natural muscular hydrostats but also have implications for the design of soft robotic arms. By elucidating the mechanical principles governing these structures' performance in various gravitational conditions, we pave the way for more efficient and adaptable soft robotic systems.

## Development of the cardiac sympathetic system and contractility control in larval zebrafish

*Marissa Zheng, Gracie Wang, Calista Adler, Areni Markarian, Luis Hernandez-Nunez*

The sympathetic nervous system plays a key role in fight-or-flight responses by adjusting the function of viscera to the metabolic requirements of vigorous behaviors. Studying the neural circuits that coordinate organ modulation in response to environmental changes has remained elusive given the limitations of mammalian models that require anesthesia and invasive procedures to access the sympathetic ganglia. Therefore, we leveraged the optical and genetic advantages of zebrafish, a model that has traditionally been used to study brain and behavior, to functionally study the sympathetic circuits for cardiac control in unanesthetized, intact, behaving animals. Using optogenetic activation of the anterior sympathetic ganglion, we determined the functional progression of sympathetic innervation of the heart. Calcium imaging in sympathetic neurons revealed a large diversity of temporal activity patterns, with more than ten groups of neurons with distinct dynamics. Additionally, we are also using optogenetic activation to investigate the onset of contractility control. Our results establish the key stages for functional development of the cardiac sympathetic system and set the stage to expand the use of zebrafish in studying the neural circuits that control the heart.

## Navigating captivity: Motile life of dinoflagellate symbionts in an acoel worm

*Grace Zhong, Manu Prakash*

Biological individuality has long intrigued philosophers and scientists. Symbiosis offers a unique lens to this concept. Motility is an important aspect of agency, and in symbiosis with multicellular hosts, inhibition of symbiont motility and host-controlled symbiont mobility are common in order for the host to achieve community goals such as prescribed symbiont distribution. We introduce acoel worms hosting symbiotic dinoflagellates - without a gut and flat in morphology - as an ideal platform to probe symbiont motility inside host tissue. We established cultures of two acoel species - Waminoa sp. and Heterochaerus australis - both hosting dinoflagellate symbionts. By using tracking microscopy and quantitatively analyzing motility patterns of symbionts within host tissue, we discover and characterize impressive motility ($\sim 1\mu$m/s) of dinoflagellate symbionts ($\sim 10\mu$m in size) in Waminoa sp.. The observed motility of the many symbionts inside the worm is decoupled from the motion of the worm. We find that this impressive motility occurs over long distances along membranous host networks, and that host microtubule and actin may play a role in guiding symbiont motility. We use electron microscopy and perturbation experiments to further probe the roles of potential symbiont motility mechanisms and host tissue structure in the observed motility behavior. Our findings raise intriguing questions about the interplays of motility mechanisms and tissue environment, and contribute to our understanding of agency in symbiosis.

## Impact of schooling on flow-generated noise in fish: fin synchronization and spatial patterns

*Ji Zhou, Jung-Hee Seo, Rajat Mittal*

This study investigates how schooling behavior in fish influences the generation of hydrodynamic noise during swimming, focusing on the impact of fin synchronization and spatial arrangement. Using high-fidelity computational simulations, we model both the fluid dynamics and the far-field acoustic emissions resulting from pressure fluctuations on schooling carangiform swimmers. We examine how the number of fish in the school, the phase relationships of their fin movements, and their spatial distribution affect noise production. Our findings demonstrate that phase synchronization of fin movements is a critical factor in determining the acoustic output of the group. For smaller schools, optimal coordination of fin movements among individuals can significantly reduce the overall noise emitted into the far-field. Additionally, the spatial configuration of the school also plays a key role in influencing noise levels. In larger schools, substantial noise reductions occur even with uncoordinated fin movements, highlighting the acoustic collective benefits of fish schooling. These results offer new insights into the ecological significance of fish schooling behaviors and suggest applications for designing bioinspired underwater vehicles that minimize noise pollution.

## Soleus muscle passive force and swelling in cold temperatures

*Ruiyang Zhu, Samantha Falcone, Richard Marsh, Thomas Roberts*

Isolated skeletal muscles swell when placed in low solute solutions, as osmotic pressure drives water into cells and interstitial spaces. Previous work has shown that this increase in muscle volume is associated with an increase in passive muscle force, and it has been proposed that this increase in force results from the interaction of intramuscular fluid and collagenous extracellular matrix. To further evaluate the mechanism behind muscle swelling and passive force increase, we exposed the soleus muscle of mice to isotonic and hypotonic solutions at cold temperatures (10°C) and physiological temperature (37°C). Passive force was measured as the soleus was stretched passively in 8 increments of 0.25 mm to a total of 2 mm past its original length. Preliminary results show muscle passive forces increase from isotonic to hypotonic conditions at cold temperature. In addition, results showing that the soleus muscle swells in colder temperatures under hypotonic conditions suggest that volume regulation mechanisms are not disrupted by cooler temperatures within 27°C of physiological temperature. However, further work utilizing a broader range of temperatures is necessary to fully understand the effect of temperature on muscle passive force and its underlying volume regulation mechanisms.

## Undertaking behaviors in the common eastern bumblebee *Bombus impatiens*

*Stephanie Zhu, Micaela Romero, Z Yan Wang*

Encountering a dead conspecific is a common occurrence for socially-living animals. Research in honeybees, ants, and termites demonstrates that social insects are capable of diverse behavioral strategies to manage the corpses of nestmates, including removal, burial, cannibalism, and avoidance. These behaviors, collectively known as undertaking, are essential for maintaining colony fitness in these advanced eusocial insect species. In comparison, almost nothing is known about undertaking behaviors in the bumblebee, a social insect that has been characterized as being "primitively eusocial." Unlike advanced eusocial insects, bumblebees exhibit smaller colony sizes, more flexible division of labor, and annual rather than perennial life cycles. Understanding undertaking behaviors in bumblebees is important given their unique intermediate position on the spectrum of sociality. Here we investigate behavioral responses to dead conspecifics in the common eastern bumblebee, Bombus impatiens, with deep learning methods. We identify major behavioral motifs of bumblebee undertaking, including corpse removal, antennation, and mandible contact, as well as less frequent interactions with corpses, such as aggression. Our results inform the evolution of this unique behavioral adaptation and its importance in the transition to advanced eusociality. Future goals of this study include exploring the plasticity and specialization of bumblebee undertaking and identifying the underlying neural mechanisms.

## Response to sudden wing damage in flying flies reveals the robustness of flapping-wing flight

*Yue Zhu, Lingsheng Meng, Wael Salem, Jean-Michel Mongeau*

Biological systems are robust and adaptive to change. For instance, flapping-wing flight in insects, despite its energetic cost, exhibits exceptional resilience compared to conventional fixed-wing aircraft and drones. In particular, how resilience to wing damage in flapping-wing flight arises from passive mechanics and sensory feedback remains elusive. To tease out their contribution, we developed a yaw-free paradigm enabling laser-based ablation of a single wing in flight and reconstructed 3D wing kinematics. Following unilateral wing damage, flies (Drosophila) instantaneously rotated toward the damaged wing and increased wingbeat frequency while the damaged wing instantly led the intact wing. Most flies recovered yaw stability within 500 ms. Surprisingly, the time to recover stability was independent of wing area loss. The residual phase between the intact and damaged wing in a yaw-fixed (open-loop) and yaw-free (closed-loop) paradigm was similar. Further, the intact and damaged wing phase difference was proportional to the amount of damage in both paradigms. 3D wing kinematics changed instantaneously after damage and were sensitive to the amount of damage. Using a control theoretic framework, we show that flies with more wing damage are less robust about yaw. Taken together, these results implicate wing-thorax mechanics and sensory feedback in regulating wing kinematics immediately following damage. Mechanisms of wing damage compensation in flies could inspire smart mechanics and control algorithms for flapping-wing robots.

## Implications of range-edge populations in conserving the critically imperiled *Aconitum reclinatum*

*Diamanda Zizis, Melody Sain, Chris Martine, Scott Schuette*

Range-edge populations often exhibit unique genotypes compared to core populations due to their tolerance of greater variation in environmental conditions. However, range-edge populations can also suffer the effects of inbreeding if they are isolated from other populations. Aconitum reclinatum (Ranunculaceae) is a critically imperiled plant species found in five states of the Appalachian region of the United States: Pennsylvania, West Virginia, Virginia, North Carolina, and Tennessee. This plant is adapted to cool, moist environments but faces threats from increasing wetland disturbance and logging over its range. The species health of A. reclinatum has previously been found to be lowest in its northern and southern range-edge populations, in Pennsylvania and Tennessee respectively. Comprehensive knowledge of A. reclinatum population structure remains limited. To address this, we collaborated with Natural Heritage programs in the five states within its range to sample populations across the species distribution and generate a genotyping-by-sequencing data set of single-nucleotide polymorphisms (SNPs). This dataset will be used to calculate population statistics and infer population health. Particular attention will be focused on range-edge populations, which have historically been under-researched despite their importance for conservation. The findings will contribute to conservation strategies aimed at protecting A. reclinatum, including identifying genotypes that may enhance species resilience to a rapidly changing environment.

## 3D Architecture and Evolution of Snake Palatal Musculature

*Christopher Zobek, Alec Wilken, Casey Holliday*

Cranial kinesis is common across several major clades of tetrapods, where it plays a role in diverse behaviors such as feeding, signaling, and movement. The highest degree of kineticism among tetrapod skulls emerged in snakes, which use a complex “walk” of the medial palate to swallow prey. The “pterygoid walk” is powered by palatal muscles which are critical to understanding the functional evolution of the snake feeding system but are difficult to visualize and measure via gross dissection. To study the evolution and mechanics of these muscles across snake diversity, we used DiceCT and 3D fiber tracking software to model the fascicle architecture of the palatal muscles across six species. Currently our sample consists of a lizard outgroup and five snake species, with three major palatal muscles (mPPT, mLPT, and mRPT) modeled in each. Fiber models were used to calculate quantitative data on fiber orientations and pennation angles, and muscle mapping was used to calculate force orientations for each muscle.We found that both fiber orientations and force orientations of our sample shift rostrally as their palates became more independent of the surrounding bones and become more specialized for swallowing. Additional work will broaden the sample of the snake diversity and include more muscles to fully clarify the evolution of the soft tissues powering palatal kinesis.

## Parasite-inspired tissue attachment mechanisms

*Rachel Zoll, Gabriel Maquignaz, Michael Karpelson, Elio Challita, James Weaver, Robert Wood*

Parasites have evolved to survive in a wide range of habitats and are capable of anchoring into substrates with diverse moduli and surface textures. These parasites also span many length scales, and can survive across an equally broad range of highly turbulent or viscous environments. Since many of these species exhibit high host- or tissue-type specificity, their anchoring modifications offer a rich bio-inspired, and application-specific design space for the development of their engineered analogues. Drawing inspiration from one such example, we designed, manufactured, and tested a synthetic analogue of the mechanical anchoring system of Taenia sp., a tapeworm capable of latching onto the intestinal lining of its host. Using a sub-millimeter-scale manufacturing approach, we replicated the morphology of the tapeworm attachment organ and the rotational motion of the associated hook-like elements, which are capable of penetrating tissue with minimal physical damage. Our proof-of-concept work demonstrates the feasibility of replicating a parasitic tissue attachment mechanism in both form and function. This design approach could help further inform our understanding of parasite biomechanics and associated attachment site pathologies.

## Incorporation of heavy metals into crab shell and their impact on postecdysial mineralization

*Enmin Zou*

Heavy metals, such as cadmium (Cd), lead (Pb) and zinc (Zn), have been frequently found in crustacean exoskeletons. However, it has remained unknown as to in which phase of the molting cycle these metals are deposited to the exoskeleton and what effects these metals have on shell properties. These scientific questions were addressed under the hypothesis that divalent heavy metal ions would be incorporated into the exoskeleton during postecdysial mineralization through their ionic mimicry to calcium ions and thereby impede exoskeletal mineralization primarily accounted for by calcification. The blue crab, Callinectes sapidus, was used as the model crustacean for these endeavors. Newly molted blue crabs ($<$ 24 hr postecdysis) were twice injected with cadmium in cadmium chloride, lead in lead acetate or zinc in zinc chloride at days 0 and 2. At day 3 (cadmium) or day 4 (lead and zinc), all the survivors were sacrificed for collection of carapaces, soft tissues and hemolymph. The results of metal analyses revealed that cadmium is deposited to the exoskeleton during postecdysial mineralization and appears to adversely impact the organic matrix in the exoskeleton of Callinectes sapidus while lead suppresses exoskeletal calcification. Zinc was found deposited to the exoskeleton during postecdysial mineralization and inhibits exoskeletal calcification. Future investigations should be directed towards the elucidation of epidermal transporters that mediate the deposition of heavy metals to the exoskeleton.

## Linking form to complex function in the octopus arm muscular hydrostat

*Letizia Zullo, Beatrice Pistolato, Janina Röckner*

Dynamic interactions between animals' nervous system, body, and environment is crucial to their adaptive behaviors and is currently a topic of growing interest in field of AI and bio-robotics.

Despite not being vertebrates, octopuses are fascinating creatures to study the evolution of adaptive behaviors since they are swiftly moving, able to learn novel tasks and competing with skeletal animals in the same ecological niche.

Most of octopuses' complex tasks are performed using their flexible arms, containing the greatest concentration of neurons in any part of their body. Arms are capable of both independent motions, brought on by interactions between the arm and its surroundings, and complex motions controlled by the central brain. This is because the limbs of octopuses serve both as end-effectors of motor commands and sensory organs. The arms, with their vast array of mechanical and chemical receptors, sense their surroundings and play a first step in the action-related "decision-making" process.

The octopus arms as a whole can thus be seen as a 'reservoir' of possibilities where motions may arise at the limb level through the co-option of central command, muscle properties, and sensorial inputs. We think that this animal model can foster the shift from biological research on muscle hydrostats to soft-robotics applications, which are now booming in a number of disciplines including surgery and human health

## Mosquito visual tracking and predictions with Bayesian dynamical systems inference

*Christopher Zuo, Chenyi Fei, Soohwan Kim, Alexander Cohen, David Hu, Jörn Dunkel*

2023 saw nine cases of non-travel-related mosquito-borne malaria in the United States. In sub-Saharan Africa, malaria kills 600,000 people every year, most of them children under 5; approximately one child every minute. Despite years of research in into mosquito host seeking, a quantitative understanding of their behavior remains elusive. Here, we perform 3D infrared tracking of the Aedes aegypti mosquitoes in an environmental chamber at the Center for Disease Control and use Bayesian dynamical systems inference methods to learn quantitative models for their behavior in response to sensory cues. We focus on their host selection criteria based on visual cues by providing mosquitoes with a pair of different-sized black spheres to simulate different-sized hosts. We find that mosquitoes are more attracted to larger spheres, but less than expected according to our mathematical model of their visual system. Quantitative models of mosquito behavior learned from 3D tracking experiments may provide important insight into mosquito host selection and inspire the design of more effective mosquito traps.

## Genetic signatures of a very isolated Clark's anemonefish population

*Jann Zwahlen, Manon Mercader, Saori Miura, Marcela Herrera Sarrias, Hiroki Takamiyagi, James Reimer, Vincent Laudet*

Remote archipelagos offer a great opportunity to study isolated populations and their evolutionary history. The remote Ogasawara islands in Japan not only host many endemic species, but also distinct populations of widespread ones, such as the Clark's anemonefish Amphiprion clarkii. While A. clarkii usually has two colour morphs, an orange morph associated with Entacmaea and Heteractis host anemones, and a black morph in Stichodactyla, Ogasawara is home to only the black morph. However, black Ogasawara A. clarkii live in Entacmaea host anemones, usually associated with the orange phenotype. This is particularly interesting, since we showed that the pigmentation of typical A. clarkii is plastic and changes if they are moved to a different host. Therefore, Ogasawara A. clarkii show differences in the pigmentation plasticity compared to other populations. Using whole genome resequencing data to understand the genetic positioning of Ogasawara A. clarkii in comparison to A. clarkii from mainland Japan we find that these two populations are indeed strongly separated based on single-nucleotide polymorphisms (SNP). Furthermore, by including A. clarkii populations from throughout the Indo-Pacific, we will show the population genetic positioning of Ogasawara A. clarkii on a global scale and whether the Ogasawara A. clarkii should still be part of A. clarkii or assigned its own species, as was initially proposed a century ago (A. snyderii). Remote archipelagos offer a great opportunity to study isolated populations and their evolutionary history. The remote Ogasawara islands in Japan not only host many endemic species, but also distinct populations of widespread ones, such as the Clark's anemonefish Amphiprion clarkii. While A. clarkii usually has two colour morphs, an orange morph associated with Entacmaea and Heteractis host anemones, and a black morph in Stichodactyla.