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SICB 2023 Annual Meeting Abstracts

1511 Evelyn Abbott, Mikhail Matz

Gene body methylation and gene expression plasticity do not correlate in a reef-building coral

As coral reefs continue to decline, the relationship between epigenetics and response to environmental change warrants investigation. In invertebrates, epigenetic markers are almost entirely in the form of gene body methylation (GBM). Here, we tested whether environmentally-driven changes in GBM impact gene expression plasticity in a reef-building coral. In our experiment, coral fragments were subjected to either heat or control conditions over four weeks, in addition to daily temperature fluctuations due to the time of day. Near the end of the experiment, some heated corals were switched to the control condition to see if their expression would revert remain in the heated state, indicating reduced plasticity. When taking a transcriptome-wide approach, we found no significant correlation between treatment-driven GBM change and reduced plasticity. In regards to daily expression changes, we found evidence that some genes had reduced plasticity at the end of the experiment. However, this was unrelated to GBM change. Finally, to look for fine-scale signatures of reduced plasticity and GBM change we identified modules of co-regulated genes, one of which showed reduced plasticity following heat treatment. However, there was no significant correlation between gene membership in this module and plasticity in the heat and control groups, and only a negligible correlation in the switched group. We conclude from these results that although GBM can change over time, this has no bearing on gene.

488 David Adams, Michael Deutsch, Lorin Neuman-Lee, Matthew Gifford

Consequences of Anthropogenic Fire Suppression for Lizard Immunity

Maintenance of innate immunity is energetically costly. When resources are limited, organisms might trade-off between immunity and other important functions like growth and reproduction. Climate change is expected to introduce novel or intensified immune challenges, which may exacerbate life history trade-offs and reduce individual fitness, especially in already vulnerable populations. Eastern Collared Lizards (Crotaphytus collaris) are especially vulnerable to the compounded effects of human disturbances, climate change, and life history trade-offs. Crotaphytus collaris is a Species of Greatest Conservation Need (SGCN) in the state of Arkansas where naturally occurring populations are concentrated on xeric glade outcroppings. Due to anthropogenic fire suppression, many glades have been overrun by red cedar trees (Juniperus virginiana), which dramatically altered the habitat. Crotaphytus collaris on cedar-encroached glades have smaller body sizes and lower fecundity than C. collaris on non-degraded glades, which current modeling suggests is caused by energy limitations on cedar-encroached glades. We investigated immune function and sex steroid concentrations of C. collaris between glades with varying tree densities across the reproductive season. We predicted that immune function would be suppressed during the height of reproductive investment and that the degree of immune suppression would be highest on cedar-encroached glades where energy is thought to be most limited. Results of these analyses and their implications for ecoimmunology and conservation efforts will be discussed.

1292 Danielle Adams, Brad Boyce, Daniel Hooks, Benjamin Klitsner, Samantha Price, Richard Blob

Material properties of Cetartiodactyla skull and jaw bones

Reentering aquatic habitats involved drastic evolutionary changes in the physiology and morphology of whales and dolphins (Cetacea) compared to their terrestrial relatives (Artiodactyla). Bone material properties of the skull and lower jaw, including density and

Young's modulus (material stiffness), are critically important for understanding mechanical loadings associated with the evolution of feeding and sound reception in cetaceans. However, across vertebrate phylogeny there are questions concerning the extent of variation in the material properties of bone within and between vertebrate taxa. To evaluate bone material properties across cetaceans and their close terrestrial relatives, I sampled density and stiffness at five different locations across the skull and mandible. I developed a bone preparation and testing protocol to obtain density and stiffness measurements for each core. Bone mineral density was tested using microCT and nanoindentation was used to collect stiffness measurements on embedded and polished bones. Preliminary results from measurements of density and stiffness align with previously studies of vertebrate bone, but show variability across species and skull locations. For example, specimens of deer skull (Odocoileus virginianus) had more variation in stiffness across skull locations than other sampled taxa. These data contribute to a wider understanding of the evolution of bone material properties within and between vertebrate taxa and specifically, how this variation might contribute to functional specialization for different habitats and life habits within the cetartiodactyl lineage.

881 Fadeke Adeola, Simon Lailvaux, Michael Kasumovic

Antennae removal affects calling effort and lifespan in adult male Teleogryllus commodus crickets

Males of many animal species exhibit costly signals that are subject to sexual selection via female choice. In crickets, the energetic cost of such signals in particular drives trade-offs with other important life-history traits such as longevity, such that increased calling effort often results in decreased male lifespan. But despite the fitness benefits of enhanced calling, the factors affecting variation in calling effort in adult males are poorly understood. The removal of male antennae has been shown to affect courtship call structure in house crickets, and is also linked to variation in both mating behavior and whole-organism performance. We tested the hypothesis that antennae removal will affect calling effort in the black field cricket, Teleogryllus commodus, a model system for understanding life-history trade-offs. To understand the consequences for both energetic expenditure and longevity, we also measured metabolic rate and lifespan in addition to calling effort. Our data show antennae removal modifies the relationship between calling effort and longevity, such that antennaectomized males who call more than those with intact antennae also do not live as long, yet does not affect energetic expenditure. These data demonstrate that key life-history trade-offs can potentially be decoupled from energetic expenditure, and offer insight into the factors affecting signal expression in adult male insects.

1144 Monique Ades, Ulrike Muller

Using a vertebrate collection to examine bat species representation and bone conservation

Vertebrate collections are an important resource for natural history and conservation research. Increasingly, collections are analyzed for their legacy of science practices inferred from the collection and its metadata. Here we analyze the skeleton collection of our university, with a taxonomic focus on bats. Our university is situated in the San Joaquin Valley in California, in a biodiversity hotspot. Our research questions are: how well are native species represented and how complete are the disarticulated skeletons. We formulated two hypotheses: whereas native species are well represented, bat specimens are underrepresented compared with other small mammals due to their crepuscular lifestyle; bat skeletons are less complete due to their more delicate skeleton. Our collection of 3200 specimens contains mainly native species (166 of 181 species), and missing species are disproportionately large (large ungulates, carnivores, marine mammals). Bats are well represented in terms of species (14 of 19 native species), but not in terms of specimens (75 specimens). To assess the quality of the skeletons, we compared 15 disarticulated skeletons from 4 bat, 4 rodent, and 7 finch species. We found that the long bones of the upper limb were always present, but lower limbs were often incomplete in all three groups. In the future, we will add data on more species and analyze collections from other institutions to examine the robustness of our findings.

232 Peter Aerts, Falk Mielke, Charlotte Vanden-Hole, Merel Van-Gorp, Chris van-Ginneken

Early development of locomotion in the piglet model: does size matter?

Intra-uterine undernutrition in humans typically results in low birth weight (LBW) and delayed post-natal neuromotor maturation. Since intra-uterine growth retardation is common in domestic pigs, piglets are premised as models to study delayed motor development. Applied to the locomotor paradigm, however, questions emerge: (i) how to map the developmental time scale of the precocial model onto the altricial target species' and (ii) how to distinguish size from maturation effects? Gait data were collected at voluntary walking speed during early development (0hrs – 96hrs post-partum; PP) for LBW and normal (NBW) piglets. Dimensionless spatiotemporal gait characteristics (according to dynamic similarity) become invariant already after a few hours PP, suggesting rapid post-natal neuromotor maturation. Moreover, dimensionless gait data are largely identical for LBW and NBW siblings, indicating that primarily size effects explain absolute locomotor differences. This is further supported by (i) normalized force generating capacity of limb muscles being indifferent between LBW and NBW; (ii) identical normalized ground reaction forces for LBW and NBW (>24hrs PP) and (iii) predictive modeling based on limb joint kinematics unable to decern the majority of LBW from NBW piglets (< 1 0hrs PP). Dynamic similarity also predicts identical mechanical locomotor costs for LBW and NBW. Yet, up to 10hrs PP, energy stores differ between LBW and NBW, likely explaining the observed difference in vitality and vigor between these groups.

697 Rita Afagwu, Avery Russell

How flower longevity affects epiphytic microbial abundance and community composition

Floral longevity determines the time during which pollinators can visit and thus plays a vital role in plant reproductive ecology. Because floral tissue is metabolically expensive, flower longevity tends to be highly environmentally dependent. Flowers are often colonized by abundant and diverse epiphytic microbial communities that could potentially influence the metabolic costs of flower maintenance. Yet how these epiphytic microbial communities change as flowers age is not known, despite the potential importance of these processes for understanding and predicting flower microbial community assembly and function. In this study, we (1) investigated if floral bacterial communities changed in abundance and diversity as the flowers age, and (2) and whether shorter and longer-lived flowers accumulate microbes at different rates. We tagged buds of five plant species to determine flower age from anthesis. Opened flowers were washed to examine changes in epiphytic bacterial abundance (via plating) and community composition (via PCR). Preliminary data reveals that for shorter-lived flowers, floral bacteria increased in abundance rapidly, whereas, for longer-lived flowers, floral bacteria increased in abundance much more slowly. Analysis of community composition is ongoing. Our results suggest that shorter-lived flowers may tolerate more bacteria and/or longer-lived flowers may have more mechanisms to reduce bacterial colonization and growth. We discuss how changes in microbial communities associated with flower age could shape pollination success.

972 Paul Agnani, Vincent Careau

The fast and the curious: speed, endurance, activity and exploration in mice

Given that organismal performance (e.g., sprint speed, endurance) sets the "envelope" within which individuals express their behaviour, there are likely many co-adaptations between suites of performance and behavioural traits. On one hand, performance might "compensate" for behavioural traits that increase predation risk, such that bold and active individuals should be able to sprint faster and for longer. On the other hand, performance could be "co-specialized" with behaviour to reduce overall predation risk, such that shy and inactive individuals should be able to sprint faster and for longer. Here, we tested the compensation and co-specialisation hypotheses in 51 female white-footed mice (Peromyscus leucopus) while also sampling blood to assess corticosterone levels. We repeatedly measured multiple aspects of locomotor performance (sprint speed and swimming performance) and behaviour (exploration, voluntary wheel running, and home-cage activity) and estimated the among- and within-individual correlations between these traits. All of the six among-individual correlations between the behavioural and performance traits were negative, and three were significantly lower than 0. Sprint speed was negatively correlated with both voluntary wheel running and home-cage activity, such that mice that were faster sprinters travelled less distance on the wheel and in their home cage. By contrast, the within-individual correlation between sprint speed and voluntary wheel running was positive and significant, providing another striking example of the importance of partitioning the correlations when studying complex traits.

483 Sweta Agrawal, Chris Dallmann, Su-Yee Lee, John Tuthill

Neural architecture of leg mechanosensory circuits in Drosophila

Animals rely on mechanosensory neurons to detect both self-generated (proprioceptive) and external (exteroceptive) sensory information. How are proprioceptive and exteroceptive signals integrated within the nervous system and subsequently used to guide behavior?Here, we address this question by mapping the connectivity of central mechanosensory circuits that process proprioceptive and exteroceptive sensory signals.

We reconstructed the circuit wiring and synaptic connectivity of leg mechanosensory circuits in an electron microscopy volume of the Drosophila ventral nerve cord. We focused our analysis on the synaptic connectivity of the femoral chordotonal organ (FeCO), the largest mechanosensory organ in the fly leg. By tracing all second-order neurons pre- and post-synaptic to FeCO sensory neurons, we found that movement and position-tuned FeCO neurons are connected to leg motor neurons via a series of nested sensorimotor loops involving both direct (monosynaptic) and indirect (polysynaptic, via interneurons) feedback. Vibration-sensitive FeCO neurons do not synapse onto motor neurons, but instead connect to interneurons that integrate sensory information across multiple legs. We also found that each FeCO subtype receives distinct presynaptic input, suggesting that synaptic release from mechanosensory axons may be independently tuned. Overall, our results reveal parallel proprioceptive and exteroceptive pathways for processing leg mechanosensory information. This organization reflects the FeCO's role in sensing a broad range of internally- and externally-generated mechanosensory signals.

276 Jose Aguilar, Nathan Harry, Christina Zakas

Comparative Hox gene expression in the two larval types of the poecilogonous annelid S. benedictii

Hox genes are highly conserved developmental transcription factors that are foundational for patterning animal bodies. Their expression patterns during development are key regulators of cell identity across the Metazoa. Hox genes are usually located and arranged in a gene cluster displaying temporal and spatial collinearity, however they are prone to gains and losses and their expression could be modified in some invertebrate species. We use the poecilogonous annelid Streblospio benedictii that has two types of offspring (planktotrophic and lecithotrophic) with different morphologies and life-histories. We wanted to test whether Hox gene expression differs in spatial and temporal variation between the two larval types at different developmental stages (i.e., free swimming larvae and juveniles). We identified eleven Hox genes in the genome of this species and their location in chromosome seven. Differences in the expression patterns of these genes at the free-swimming larval stage between the two larval types were determined by using Hybridization Chain Reaction (HCR) with probes for the eleven genes. We compared if there are differences in spatial expression in the equivalent segments for the two larval types. By using two time points, we also compared if there are variations in the timing of Hox gene expression based on the developmental mode. Differences in the timing and distribution of Hox gene expression within a single species, reveals how body plan variations may arise in larval evolution.

843 Liz Aguilar, Elizabeth George, Sarah Wolf, Mary Woodruff, Aaron Buechlein, Doug Rusch, Kimberly Rosvall

Tracing inter-individual variation in behavior and neural gene expression of aggressive female birds

Individual differences serve as the raw material for evolutionary change; thus, studying naturally-occurring, continuous trait variation can inform our understanding of behavioral evolution. Aggressive behavior, for example, is often adaptive in the context of acquiring essential breeding resources, yet considerable among-individual behavioral differences can persist. To investigate the mechanisms underlying such behavioral variation, we studied free-living female tree swallows (Tachycineta bicolor), obligate secondary cavity-nesters in which higher aggression determines greater success when competing for nesting cavities. We phenotyped individuals using multiple 5-minute simulated territorial intrusions. Two to seven days after the last trial, we collected tissues from 10 stably high and 10 stably low aggression females. Using RNAseq, we explored patterns of gene activity in the hypothalamus and medial amygdala, brain regions mediating aggression. Despite a well-powered design and a breadth of behavioral variation, results showed very few differentially expressed genes between high and low aggression birds. Co-expression analyses, however, revealed more substantial differences among individuals, especially related to transcriptional networks enriched for behaviorally-relevant biological processes. This suggests individual differences may stem from subtle but coordinated shifts in neural gene activity. Our discussion will dive deeper into these results and highlight genes and pathways that do and do not differentiate individuals with markedly different behavior. In doing so, we shed light on gene regulatory variation that may be used during behavioral evolution in the wild.

1430 Ashley Aguilar, Oscar Hernandez-Reyes, Megan Wise-de-Valdez

Mosquito species diversity at the San Antonio Zoo

Mosquito-borne diseases are threats to the safety of captive animals like those in zoological settings. For example, St. Louis Encephalitis and West Nile Viruses caused the deaths of male orcas in 1990 and 2007. Similarly, Eastern Equine Encephalitis caused the death of four wolf pups translocated from Mexico to a Michigan zoo in 2019, and avian malaria continues to be a threat to captive birds. To date, there are only six zoos in the U.S. that have partnered with vector ecologists to establish mosquito surveillance systems despite the unique assemblage of potential mosquito hosts and the potential vector-borne disease risks. Therefore, we initiated the first zoological mosquito surveillance study in Texas. Two types of mosquito traps were set weekly at 11 sites across the San Antonio Zoo for 15 weeks in the summer of 2022. Mosquitoes were identified to species and stored for later blood-meal analysis. Culex quinquefasciatus made up 66.9% of all mosquitoes collected, followed by Aedes albopictus with 31.4%, and Aedes aegypti with 1.4%. This abundance and species distribution is consistent with residential mosquito surveys in San Antonio despite the zoo having significantly more shade coverage and a variety of potential hosts. This similarity between the two areas indicates a potential for the circulation of endemic and exotic mosquito-borne diseases between the zoo and the human population in San Antonio.

746 Siavash Ahrar

SPIM-Flow: Integrated light-sheet and microfluidics to study hydrodynamics of Hydra

Selective plane illumination microscopy (SPIM), or light sheet, is a powerful three-dimensional imaging approach. Interfacing light sheet microscopes with modern fluidics have remained difficult. Thus, samples imaged via SPIM are typically housed in static environments. We present a light sheet microscope (SPIM-Flow) that can be readily integrated with fluidics and explore its studying the biomechanics of line PT-1 Hydra vulgaris (Hydra). Specifically, we used SPIM-Flow to study the hydrodynamics of a freely moving Hydra polyp in millimeter-sized chambers (4 mm wide, 1.5 mm height). First, we confirmed that animals health are not negatively impacted by the fluid chamber. To this aim we observed feeding and baseline behaviors (e.g., tentacle swaying, elongation, and bending). Moreover, SPIM enabled easy imaging of the freely moving animal and tracer beads (for fluid visualizations). Next, we investigated Hydra's response to flow. Results suggest that animals responded to established flow by bending and swaying their tentacles in the flow direction. We used a previously described video analysis software (Flow-Trace) to better visualize pathlines generated by (e.g., vortex generated by the tentacle sways) and around Hydra (e.g., due to flow). Next, we asked how much shear stress a Hydra can withstand before letting go from a surface. Our preliminary results suggest that Hydra can withstand flow rates as high as 50 ml/hour.

794 Hannah Aichelman, Alexa Huzar, Daniel Wuitchik, Kathryn Atherton, Nicola Kriefall, Sarah Davies

Do facultative coral hosts buffer their symbionts in response to thermal extremes?

Increasing temperatures are compromising the symbiotic relationship between coral hosts and their algal symbionts. Physiologically, both symbiotic partners exhibit various stress responses; however, evidence suggests that host transcriptomes respond more strongly to stress compared to their symbionts. This lack of transcriptional response by algae raises the question: are coral hosts regulating their symbiont's environment to buffer environmental stress? We capitalized on the facultative symbiosis between the coral Oculina arbuscula and its algal symbiont Breviolum psygmophilum to characterize transcriptomic responses of the symbiont in and out of symbiosis, and compare with the coral host's response. To understand the response of the symbiont and host in symbiosis, symbiotic fragments of O. arbuscula were exposed to three temperatures: 1) control (18°C), 2) heat (32°C), and 3) cold (6°C). This experimental design was replicated with B. psygmophilum cultured from O. arbuscula to characterize how symbiosis modulates the symbiont's response. At the end of both experiments, samples were prepared for gene expression profiling. When comparing gene expression of B. psygmophilum symbionts in and out of symbiosis, many more genes were differentially expressed in response to temperature in culture, and gene expression plasticity was greater in culture. Additionally, in symbiosis, there were more differentially expressed orthologs in the host compared to the symbiont. While analyses are ongoing, thus far, these two experiments support our host buffering hypothesis.

663 Ayi Ajavon, Lauren Simonitis

What's that smell? a whiff of gunnel olfactory morphology

Chemoreception is used to track predators, prey, or find conspecifics. Across the Zoarcoidei suborder, diet varies from herbivory to carnivory. Members of the Pholidae family are found along intertidal shorelines of the east Pacific ocean, and are able to breathe air during low tide. Because of these characteristics -and a knowledge gap of intertidal fish olfactory systems- we examined three species: Apodichthys flavidus, Pholis laeta, and Pholis ornata, all of which are carnivores. In our study we used contrast-enhanced microCT scans and dissections to: 1) characterize the morphology of olfactory systems; and 2) compare the olfactory morphology of two Pholis species to a member of the Apodichthys genus. We found that the two Pholis species have two lamellae per rosette and the average lamellae area scales with body length, while Apodichthys flavidus has up to four lamellae per rosette which do not scale with body length. Additionally, the rosette area of Apodichtys flavidus is significantly larger than both Pholis species. This study is the first to characterize the olfactory system of Pholids through use of microCT scanning. Further research on members of the Zoarcoidei subfamily would improve understanding on how diet may inform the level of reliance upon the olfactory system; improve our knowledge of how intertidal fishes interact with their extreme environments; and provide new information to sensory biology as a field of study.

1006 Kubra Akbas, Zhaoyuan Zhang, Cruz Donato, Elizabeth Archer, Maria Schiavone, Carlotta Mummolo, Eleni Gourgou

Transdisciplinary exploration of the aging-driven locomotive decline in humans and nematodes

Aging is variably experienced across species; however, certain manifestations, like the decline of locomotive performance, are broadly shared. To investigate evolutionarily conserved manifestations of aging, we consider humans and the nematode Caenorhabditis elegans, the latter being a highly informative model system in the biology of aging. We aim to unveil common expressions of aging in the locomotion of these species, which have a distant evolutionary relationship, but share key molecular mechanisms underlying aging. We use standard locomotion analysis tools (e.g., camera-based and video tracking) and we employ established and novel motor performance indices (MPIs). Our approach includes linear (e.g., speed, Froude number, asymmetry, gait parameters) and nonlinear MPIs (e.g., Lyapunov exponent, variability, Floquet multiplier). Here, we focus on linear MPIs, adjusted for each species, and we compare their trends as they change with age. We find unexpected similarities and differences between aging animals of the two species, in both humans and nematodes. Moreover, we identify methodological challenges in the comparative study of aging-driven locomotive decline, and we propose strategies to tackle them. Our transdisciplinary approach combines invertebrate neurobiology, robotics, and human locomotion analysis, providing a new path for the comparative study of locomotion in very different animals. Lastly, our work sets the stage for further investigation of the physiological mechanisms underpinning locomotive aging across species.

141 Valentina Alaasam, Jenny Ouyang

Habituation to Artificial Light at Night in Zebra Finches

Artificial light at night (ALAN) dramatically alters the nighttime environment and has become one of the most ubiquitous human-induced environmental stressors of our time. Laboratory studies show that ALAN exposure can induce immediate behavioral and physiological changes in animals, which, in some cases, can lead to severe health consequences. However, the capacity for animals to habituate to ALAN, i.e. the degree of flexibility & reversibility of their responses over long-term exposure, has yet to be tested. Furthermore, we do not know whether there is concordance between behavioral and physiological habituation. While behavioral responses may be flexible and reversible, physiological stress resulting from ALAN exposure or as biproduct of sleep debt, might accumulate over the long term. We conducted a 6-month long repeated measures experiment using the zebra finch (Taeniopygia guttata) to measure behavior (sleep-wake cycles) and physiological stress (blood oxidative status) resulting from ALAN exposure. As ALAN expands and intensifies on a global scale, understanding the capacity for organisms to habituate and the role of habituation in species persistence is of immediate priority.

1168 Amir Alayoubi, Laura Stein, Kim Hoke

Neuronal activation in fear, memory, and mesolimbic structures following model predator exposure

Anti-predator behaviors such as hiding, freezing, and fleeing vary across taxa, though the neural circuitry mediating these behaviors have been studied in relatively few taxa. The Trinidadian guppy displays unusual anti-predator behaviors (e.g., approaching predators for inspection), offering an opportunity to investigate the neural underpinnings of unique anti-predator behaviors. Here, we identify four brain regions in the Trinidadian guppy that are differentially activated after exposure to predatory stimuli. Guppies were third-generation lab-reared fish derived from natural populations with evolutionary history of high- and low-predation. We exposed guppies to either a model predator replica or control condition. Subsequently, we immunohistochemically labelled their brains for a marker of neuronal activation (phosphorylated ribosomal protein S6; PS6). Optimizing a novel, semi-automated cell quantification technique using the open-source software FIJI allowed us to accurately and efficiently quantify PS6 positive cells in three dimensions. We found little evidence for an interaction of brain region, predator exposure, and source population on neuronal activation. However, we did find four regions with moderate to strong evidence of differential neuronal activation. Regions include the central, ventral, dorsal, and lateral areas of the telencephalon, presumptive homologs of the basolateral amygdala, nucleus accumbens, and hippocampus of mammals, respectively. Altogether, our findings suggest neuronal activation in regions that innervate reward, memory, and fear circuits may mediate anti-predator behaviors.

90 Molly Albecker, Sarah McKay Strobel, Molly Womack

Predicting outcomes of developmental stress in tadpoles (frog larvae): Who is resilient to what?

For most organisms, the road through development is often bumpier than smooth. Stress experienced during development can have life-long negative impacts on individual phenotypes and, ultimately, evolutionary outcomes. For organisms with distinct life stages (complex life cycles), metamorphosis may provide a clean slate that erases the effects of developmental stress from previous stages. Alternatively, developmental stress may be carried over to later life stages affecting organismal performance and even population demography and persistence. We gathered decades of studies on anurans (frogs and toads) to examine how developmental stress affected larval growth and development rate. We determined whether developmental stress effects could be predicted by stressor type (e.g., density, temperature, salinity, food restriction) or phylogenetic history. We also determined whether effects on larval development resulted in carry-over effects post metamorphosis that impacted individual performance. We lay out future directions for comparative work to identify the mechanisms underlying developmental stress variation among clades and better predict how clades will be differentially impacted by future environmental stressors.

1640 Carrie Albertin

How to make a cephalopod: insights from the genome

Coleoid cephalopods (octopus, squid, and cuttlefish) have a highly derived body plan with a suite of morphological novelties, including their adaptive coloration system and sucker-lined arm crown. Other prominent coleoid features, including their elaborate, highly centralized nervous systems and complex camera eyes, are classic examples of convergent evolution with vertebrates. More striking in many ways than the disparities in the adult body plan is early development in cephalopods, which lacks any trace of the spiral cleavage program characteristic of non-cephalopod molluscs and other spiralians. Instead, cephalopod embryos undergo bilateral, meroblastic cleavage on top of a large yolk, morphologically resembling early embryogenesis in fish and constituting yet another example of convergence between these two distantly related groups. How this highly derived body plan and its novel developmental program relate to those of other animals has been obscure. To study the genetic basis underlying these innovations, we sequenced the genomes of emerging coleoid model systems, including the longfin inshore squid Doryteuthis pealeii and Octopus bimaculoides. These genomes reveal a conserved repertoire of transcription factors and signaling ligands that is broadly similar to that found in other invertebrate bilaterians, as well as suites of differentially expressed genes that are only identified in coleiod genomes. These results point to key roles of both ancient and novel genes in the evolution of the novel cephalopod developmental program.

455 Joseph Alexander, Madeleine Hagood, Marianne Porter

Mechanical Properties of Atlantic Stingray (Dasyatis sabina) Skin

Batoids are dorsoventrally flattened cartilaginous fishes. Their skin has a collagen fiber network where fiber angles are larger than those described in sharks, and like sharks, some batoid species have dermal denticles. Previous research showed batoid skin exhibited anisotropic behavior when tested along different axes of stress. We quantified the mechanical behavior (tensile strain at maximum load (%) and Young's modulus (MPa)) of batoid skin (Atlantic stingrays; Dasyatis sabina) containing dermal denticles across disc regions, surfaces, and between testing axes (longitudinal, parallel to body; hoop, perpendicular to body). Due to their dorsoventrally-compressed morphology, we hypothesized that skin in the hoop direction would have a greater strain, while skin in the longitudinal direction would be stiffer to facilitate undulating disc movements. We also hypothesized that dermal denticle density would vary by region (anterior and posterior) and surface (dorsal and ventral). We dissected disc skin from six stingrays, divided each into regions, and imaged them for denticle density analysis. To evaluate mechanical properties, regions were cut into 5 pieces (3 longitudinal, 2 hoop) for tensile testing in an Instron E1000 at 3 mm/s strain rate. We found that skin tested longitudinally was more extensible and skin from the outer disc was less stiff and extensible than skin from the inner disc (dorsal and ventral). We also found that denticle density (denticles/mm2) varied among disc regions and surfaces.

461 Camilo Alfonso, Jared Gladbach, Ignacio Moore

Annual survival and steroid hormones in birds

Steroids are regulatory hormones that can mediate the trade-offs between critical functions like survival and reproduction. For example, empirical evidence in birds has found that increasing levels of corticosterone can increase survival while decreasing reproductive fitness during environmental challenges. Other studies have found that testosterone can enhance reproductive efforts at the cost of survival in male vertebrates. However, such studies have generally focused on single species, and it is unclear if the relationships between steroids and survival are consistent across species. We performed a metanalysis to determine if species level variation in testosterone and corticosterone levels can explain annual survival rates in birds. We used publicly available databases for 573 records on testosterone and corticosterone levels and annual survival probability of 98 species of birds. We found a negative correlation between corticosterone and estimates of annual survival probability within the order Passeriformes. However, an analysis of all species did not support this relationship. Given variation between lab and field protocols, the negative relationship between corticosterone and annual survival probability in the order Passeriformes is probably even stronger than described and it is hard to make conclusions about the lack of a relationship in other groups of birds. In addition, steroid levels and survival rates might respond independently to ecological and evolutionary variables, making it difficult to find a unifying pattern among all birds.

209 Joshua Allen, Brett Hodinka, Tony Williams

Experimental manipulation of developmental plasticity and its consequences for juvenile performance

Large fat reserves in young birds may buffer against variable conditions during development but reduce flight performance after fledging. Some species therefore demonstrate facultative mass recession prior to fledging, potentially promoting carryover effects of improved flight performance into the post-fledging period. However, the significance of phenotypic plasticity in pre-fledging development, especially at the physiological level, in determining individual quality and fitness in post-fledging juveniles is critically understudied. Here, we manipulated perceived mass in European starlings (Sturnus vulgaris) by fitting nestlings with 4.0 g weighted backpacks six days before fledging. We measured subsequent somatic developmental trajectories (mass, wing length) and physiology (aerobic capacity, energy state, oxidative status), after which fledglings received nanotag radiotransmitters to track post-fledging performance (activity, activity-slope, dispersal). Weighted nestlings demonstrated greater mass recession than controls and reduced wing growth, coupled with increased dROMs. Furthermore, dROMs was negatively correlated with activity in controls, while hemoglobin was positively correlated with day of dispersal. Yet, significant weight treatment interactions uncoupled relationships between physiological condition and post-fledging performance as treated fledglings showed no difference in average activity or dispersal timing. Together, our data demonstrate the complexity of individual variation in developmental trajectories during the 'workload transition' at fledging and suggest that physiology (not just somatic development) may predict post-fledging performance.

788 Jonathan Allen

Cloning, polyembryony and asexual reproduction in echinoderms

The recruitment of new individuals into marine ecosystems is a critical determinant of community structure, yet much of our understanding of the ecology of marine invertebrate embryos and larvae remains rudimentary. One fundamental assumption of most life histories, that one egg yields one offspring, has been demonstrated to be false under a number of conditions and in a number of taxa. In this talk, our understanding of the production of multiple offspring from a single egg, referred to as polyembryony or cloning, will be reviewed for echinoderms. New insights into the mechanisms, induction and frequency of cloning will be provided for asteroids, echinoids and ophiuroids. Examples of zygotic cloning will be given for several species of echinoids including Dendraster excentricus, Echinarachnius parma and Eucidaris tribuloides. Examples of larval cloning will be given for three keystone asteroid species (Acanthaster sp., Asterias forbesi and Pisaster ochraceus) and one ophiuroid (Ophiopholis aculeata). Preliminary data will also be presented on the ecological consequences of cloning for each of these species, focused on the potential costs of clone production on larval size, development time and survival to metamorphosis.

1242 Kelsey Allen, Rocio Gonzalez-Olvera, Jennifer Hoy

A binocular perception deficit characterizes prey pursuit in developing mice

The house mouse is a powerful model to investigate the genetic and neural circuit mechanisms underlying mammalian visual system development. However, comparatively few researchers study the development of mouse vision in the context of their natural visual ecology, which is necessary to discover fundamental mechanisms underlying the relationship between developmental changes and evolutionary processes (evo-devo). To advance our understanding of mammalian visual system development and evolution, we employed the natural and complex visual processing required of mice to successfully capture live insects and pursue moving visual objects. This approach led us to discover that weanling mice (postnatal day 21, P21) have robust binocular visual field processing deficits and that activity in the superior colliculus (SC) is significantly enhanced, relative to adult mice, where information from the nasal visual field is processed. This provides the first description of a difference in visual perception associated with a specific developmental difference in early visual area activity within the mouse. Ongoing extracellular electrophysiological experiments in the awake-behaving mouse are poised to reveal important differences in the encoding of salient visual stimuli at key stages of mouse development. Overall, we are working to understand how developmental differences, relative to the function of specific visual circuits that are genetically tractable in the mouse SC and conserved across mammalian species, relate to recently discovered developmental differences in either prey detection or pursuit.

1737 Angelique Allen, Judit Pungor, Cristopher Niell

2-photon calcium imaging of neural responses to polarized light stimuli

Polarization vision is found in a number of species across the animal kingdom, particularly in invertebrates. In cephalopods the photoreceptor anatomy that supports the detection of light polarization, and the behavioral ability to distinguish between different polarizations of light have been demonstrated, though how neural circuits in the cephalopod brain process polarization information is unknown. In some aquatic invertebrate species, such as the fiddler crab, polarization processing occurs separately but in parallel to luminance. In others, such as the crayfish, polarization is processed using the same channel as luminance. In order to determine how neurons in the optic lobe of Octopus bimaculoides encode polarization information, we performed 2-photon calcium imaging of neural responses to visual stimuli that varied in either luminance or polarization angle. Initial preliminary results on large-scale organization of neural activity suggest responses to polarization stimuli are retinotopically organized, and that there are distinct though overlapping spatial patterns of activation to luminance and polarization stimuli. These results provide a basis for future studies to quantify neural coding of polarization at the level of individual neurons.

1118 Meagan Allira, Kristin Dyer, Lauren Lock, Juliana Nunes-Batista, Guang-Sheng Lei, Ryan Relich, Daniel Becker

Identifying seasonality of viral shedding in Mexican free-tailed bats (Tadarida brasiliensis)

Most pathogens of zoonotic concern exhibit pronounced seasonality in their natural hosts, and seasonal pulses of infection can indicate periods of high risk of cross-species transmission. Long-distance migration is one ecological process that could affect both transmission and immunity but has received little attention in relation to epidemiology in bats. Because bats have been widely studied in the context of zoonotic viruses, migration could have important consequences for human health. In western Oklahoma, we sampled Mexican free-tailed bats (Tadarida brasiliensis), a species well-recognized for long-distance migration, at a large maternity roost at monthly intervals over one year between spring arrival and fall migration. We collected oral and rectal swabs, extracted nucleic acids, and used PCR/RT-PCR to characterize infection status and genetic diversity of herpesviruses and coronaviruses. We then used generalized additive models to identify seasonal patterns in both viruses to test whether infection prevalence was greatest upon spring arrival, during reproductive periods, or during preparation for fall migration. With both viral families being found in saliva, and herpesviruses being a truly latent virus family whereas coronaviruses rely on waning immunity for reinfection, we hypothesize that the presence of herpesviruses could predict coronavirus shedding in saliva samples. Ongoing analyses will also incorporate immunological changes and provide novel insights into the complex seasonality of virus shedding in a migratory bat species.

465 Karla Alujevic, Leah Bakewell, Jelena Bujan, Christian Cox, Luke Frishkoff, Eric Gangloff, Guillermo Garcia-Costoya, Matthew Gifford, Akhila Gopal, Samir Gulati, Alyssa Head, Monica Miles, Ciara Pettit, Charles Watson, Kelly Wuthrich, Michael Logan

Thermal ecology in 3D: new methods for quantifying thermal environments of terrestrial ectotherms

Predicting ecological responses to rapid environmental change has become one of the greatest challenges of modern biology. Two major hurdles in forecasting these responses are: (1) accurately quantifying thermal environments organisms experience in their habitats and (2) overcoming mismatch between the size of the organism and the resolution at which environmental data are collected. This is especially important for ectotherms that experience thermal environments at small spatial scales, often occupying habitat that is only several square meters in area. Recent technological advancements with 3D-printing and infrared drone photogrammetry offer unique benefits for quantification of thermal microclimates across relevant spatial scales. In thermal ecology, operative temperature models (OTMs) are integral for estimating the temperatures available to ectotherms within their habitats. 3D-printing offers the prospect of robust, easily replicated, morphologically accurate, and cost-effective OTMs. Infrared images from drone transects, stitched together using photogrammetry, can be used to quantify the 3D spatial structure of thermal environments across large areas at fine resolution. Here, we develop these methods using a range of lizard species distributed across different habitats within the continental US. We provide a framework for integrating drone thermal imaging with 3D-printed OTMs to quantify thermal landscapes in space and time and in unprecedented detail. Utilizing these technological advancements allows for accurate and spatially explicit forecasting of ectotherm responses to climate warming, habitat conversion, and other environmental changes.

706 Yareli Alvarez, Leslie Babonis

Dueling anemones: Inducible defense structures as a model for the evolution of cell type plasticity

Sea anemones can reproduce by asexual fission creating colonies of genetically identical individuals. Some species of sea anemones, such as Metridium senile, respond aggressively to encroaching members of different colonies by transforming preexisting feeding tentacles into specialized fighting tentacles that are equipped with a special type of stinging cell not found in any other tissue. Because of this unique suite of cnidocytes, fights result in retreat of the encroaching individual or in necrosis and potentially, death. Inducible defensive structures have evolved independently in cnidarians multiple times, suggesting plastic control of stinging cell identity may be an ancestral feature of this group. To understand how cell fate plasticity is controlled, we induced fighting responses in pairs of non-identical M. senile adults and collected samples of both feeding tentacles and fighting tentacles at multiple time points after induction. We use microscopy to characterize the morphology of stinging cells in tentacles transitioning from feeding to defensive structures and comparative transcriptomics to identify the regulatory pathways driving stinging cell plasticity. Together, our results elucidate the mechanism by which environmental cues can be transduced into novel traits and serve as a model for understanding cell fate plasticity more broadly.

1770 Estephannie Alvarez, Sydney Yoon, Jhoselyn Pineda, Ashlie Barillas, Christopher Harrod, Yoonjeong Choi, Alexia Anous, Malik Alhadi, Tyrone Hayes

Effects of Estrogen and TAML on Sex Differentiation in Xenopus laevis

Ethinyl estradiol (EE2) is a synthetic estrogen commonly used in oral contraceptives. EE2 is released in urine and can be found in ground, surface, and wastewater. EE2 contamination in waterways can feminize male wildlife or otherwise interfere with reproduction. For example, EE2 induces ovarian development in genetically male African clawed frogs, Xenopus laevis. The catalysts, Tetra-amido macrocyclic ligands (TAMLs), can degrade EE2 and can potentially be used to rid the aquatic environment of EE2. However, before introducing TAML as a water treatment strategy, we must identify potential adverse effects of TAML, itself. We examined genetic male X. laevis from two lines that differ in their sensitivity to estrogen. Animals were exposed to either TAML (1.3 mg/L, 13 μg/L, 0.13 μg/L), estradiol (E2, 3μg/L), EE2 (E2, 3μg/L), or ethanol solvent control. Gonads were examined using gross morphology and histology to determine the sex ratio after exposure throughout larval development. The frog lines varied in their response/sensitivity to E2 as expected, however, EE2 was nearly 100% effective at inducing ovaries in both frog lines. TAML did not affect the sex differentiation of the gonads in either population. These data suggest that TAML may be safely used without effects on sex differentiation in frogs. Future studies will examine whether TAML protects against the effects of EE2.

118 Aurora Alvarez-Buylla, Jonathan Long, Lauren O'Connell

Adaptations to deadly diets: a poison frog plasma protein mediates alkaloid transport

Alkaloids are important bioactive molecules throughout the natural world, and in poison frogs they serve as a diet-derived source of chemical defenses against predation. Despite the importance of alkaloids in poison frog physiology and the proposed roles of plasma proteins as mediators of inter-organ alkaloid trafficking, the responsible alkaloid-binding proteins have not been identified. We use chemical approaches to show that one major plasma protein is responsible for alkaloid trafficking in poison frogs. Proteomic and biochemical studies establish this plasma protein to be liver-derived pumiliotoxin-binding globulin (PBG/SERPINA1). In addition to alkaloid binding activity, PBG sequesters and regulates the bioavailability of "free" plasma alkaloids in a pH-dependent manner. Furthermore, the alkaloid binding specificity of PBG differs across independent origins of toxicity in the poison frog clade. Unexpectedly, PBG is not related to known plasma "sponge" proteins like albumin or saxiphilin, but instead exhibits structural homology to mammalian hormone carriers. These data define a novel mechanism of chemical defense transport in poison frogs that may have evolved from plasma hormone transport activity.

1656 Patricia Álvarez-Campos, Helena García-Castro, David Salamanca-Diaz, Bria Metzger, Elena Emili, Vincent Mason, Nathan Kenny, B. Duygu Özpolat, Jordi Solana

Single-cell transcriptomics reveal specific gut regions in a freshwater annelid

Many organisms have specialized digestive tract regions that serve different functions as the food is digested and the nutrients are absorbed. Annelids (segmented worms) are also thought to have a regionalized digestive tract based on histological and anatomical analyses, however, no specific molecular markers have been identified to date. Using single cell RNA sequencing (scRNA-seq), it has become possible to identify molecular markers for different and often elusive cell types that were not easy to distinguish via histological or bulk RNA sequencing techniques. We have generated the first single cell atlas of the fresh water annelid Pristina leidyi, using ACME dissociation with the cell barcoding protocol SPLiT-seq. We identified several gut-associated cell clusters with specific molecular markers. We then visualized the localization of these markers using Hybridization Chain Reaction (a multiplexed fluorescent in situ hybridization method), and found that Pristina leidyi has a complex gut organization with approximately 10 regions or cell types along the entire anterior-posterior axis of the body. Some of these regions are as specific as only in 2 segments, always at the same location, with very defined borders where marker expressions at the transition segment do not overlap. Revealing the complexity of the digestive track in this deceptively simple looking worm opens new avenues of investigation.

72 Beau Alward

Genetic dissection of the hormonal control of social status in a cichlid fish

Social behavior is shaped by the social environment. However, it is unclear how the brain converts social cues into behavioral responses. To discover these mechanisms, my lab uses the African cichlid Astatotilapia burtoni. A. burtoni males stratify along a social hierarchy, wherein dominant (DOM) individuals maintain territories and court females while non-dominant (ND) males do not. These behavioral differences correlate with profound differences in physiology, brain, and behavior. A. burtoni social status is in flux, as ND males can ascend to DOM status when given the opportunity, and DOM males can descend to ND social status when in the presence of larger DOM males. My research program aims to identify mechanisms controlling social status in A. burtoni using naturalistic, high-throughput behavioral paradigms combined with techniques such as CRISPR-Cas9 gene editing. Given the importance of steroid hormones in regulating social behaviors across vertebrates, we recently used CRISPR/Cas9 to generate mutant A. burtoni lacking two key steroid receptors, androgen receptor alpha (AR?) or AR beta (AR?). Multiple DOM traits were controlled by either AR in a modular manner, suggesting social status is controlled by independent androgen-driven mechanisms. Insights from these results are guiding our current studies on identifying novel genes and neural systems that control flexible social behavior. Our findings have important implications for understanding the mechanisms of social behavior, especially in species whose behavior relies on social experience.

306 Stephanie Amaya, Daniela Becerril, Paula Gonzalez, Yuichiro Suzuki

The hormonal regulation of temperature-dependent color changes in Manduca sexta larvae

Genetic accommodation is an evolutionary 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 as a result of a change in temperature. RNA-seq on the brain/corpora allata complex revealed several changes in genes associated with juvenile hormone (JH) and ecdysteroid signaling. Our findings demonstrate that JH levels fluctuate in response to temperature, while the evolution of ecdysone levels underlie the process of genetic assimilation of the black larval coloration. Thus, changes in different hormones underlie distinct dimensions of genetic accommodation.

1564 Ali Amer, Eric Gangloff, Dustin Reichard, Anna Schill, Wyatt Mcqueen

The relationship between corticosterone and triglycerides across contexts in the common wall lizard

An animal's hormonal phenotype is plastic and modulates the response to varying environmental conditions. For example, corticosterone (CORT), the primary glucocorticoid in ectothermic vertebrates, plays a complex role in regulating resource allocation, energy balance, and recovery from acute and chronic stressors. Triglycerides, the most energy dense of all macromolecules, provide a measure of energy availability, but circulating levels of both CORT and triglycerides are seldom measured in ectotherms. Here, we investigated the relationships among CORT, triglyceride levels, and body condition under captive and free-living conditions in common wall lizards (Podarcis muralis), an extremely versatile species that thrives in urban environments, including outside its native range such as Cincinnati, Ohio, USA. By measuring these biomarkers in plasma samples collected from captive and free-living individuals from introduced populations, we tested how different environmental conditions and energetic status might affect their relationship. We hypothesized that in lizards with poor body condition, there is a negative correlation between CORT and triglyceride levels as lipid reserves are burnt for energy replenishment regardless of environment. However, for lizards in good condition, we predicted a positive correlation as CORT upregulation encourages foraging behaviors, thereby increasing food intake and triglyceride levels. Our work provides insight into how physiological systems related to energy consumption and distribution are regulated in response to different internal and external conditions.

1644 Haley Amplo, Ariel Camp, Brooke Flammang

Exploring the Range of Motion of Antennarius commerson using XROMM

Frogfish (Family Antennariidae) are a group of cryptic, primarily benthic fishes that are known for their utilization of multiple modes of locomotion. Frogfish use their pectoral fins to "walk" along substrate or station hold in their environment, as well as during jet propulsion and swimming. However, they must reorient their pectoral fins to transition between each form of locomotion, switching from a planted position to an extended position to a streamline position. Frogfish use their unique ball-and-socket shoulder joint and pectoral fin morphology, which includes three elongate radials articulating with cartilaginous elements between them and the scapula and coracoid, to accomplish fin reorientation. Here, we explore the range of motion (RoM) seen in frogfish while reorienting their fins by using X-Ray Reconstruction of Moving Morphology (XROMM). XROMM was performed ex vivo on two specimens of Antennarius commerson, with the specimen puppeteered through full RoM positions seen in living frogfish. Biplanar x-ray videos were analyzed in XMALab and digital bone models of the left-side cleithrum and radials from postmortem ?-CT scans were animated within Maya software. RoM was defined by exploring the maximum excursion along the x-, y-, and z-axes from both Radial 1 and the scapular socket and Radial 3 and the coracoid socket. We found that frogfish are capable of extreme long-axis rotation, more so than what was found in either flexion-extension or abduction-adduction.

66 Andrew Anderson, Suzy Renn

A proposed hypothesis for predicting regulation of sex-biased traits using evolutionary history

The evolution of mechanistic pathways that govern sexually dimorphic traits is an active research area. With the expectation that sex-steroids associated with one sex should regulate dimorphic traits for that sex, times where these situations do not occur merit some explanation. Over evolutionary time a trait that may have been favorable for one sex, and hence dimorphic, may now become favorable in the opposite sex leading to renewed monomorphism or even a reversed sexual dimorphism. The traits resulting from these evolutionary events are termed "cross-sexual transfers". Here we present a hypothesis, the Ancestral Modulation Hypothesis (AMH), that the evolutionary history can predict the mechanistic patterns observed in trait formation. The AMH lays out two mechanistic patterns, spanning multiple levels of regulation (Signal–hormone titers, local synthesis, and expression of receptors; Architecture—regulatory elements and transcriptional patterns) that would indicate whether cross-sexual transfer can explain the currently observed trait or if the trait emerged de novo. The purpose of the AMH is to identify the mechanistic pattern through an integrated approach, and to predict expected mechanisms based on evolutionary history or vice versa. A secondary purpose of the AMH is to provide a broad framework for describing and discussing mechanistic patterns and the evolution of sex-biased regulation. We present this idea for discussion and evaluation for possible refinement or revision based on current and future research.

247 Grace Anderson, Sam Afshari, Jesus Vega, Nathan Koehler, Lauren Johnson, Brittney Ivanov, Michele Johnson

Does Testosterone Change Fiber Type in Muscles Underlying Lizard Social Behaviors?

Testosterone regulates a variety of sexual and social behaviors in animals, but we do not yet know whether different muscles underlying these behaviors respond to testosterone in similar ways. The muscles involved in reproduction in male Anolis lizards offer an excellent model in which to explore this question. Two sets of sexually dimorphic muscles control behaviors regulated by testosterone and are likely targets of physiological change. These are the retractor penis magnus (RPM), which retracts each hemipene during copulation, and the ceratohyoid muscle (CH), which controls the dewlap, an extendable throat fan that signals aggression or sexual motivation in anoles. Adult males of two species (A. carolinensis and A. sagrei) were divided into three treatments (low testosterone, high testosterone, and control). High testosterone dramatically increased the area of the RPM through increased fiber size, but did not alter the size of the CH. Here, we categorize muscle fiber types using succinate dehydrogenase (SDH) and Myosin ATPase. Darker SDH stain indicates increased oxidative potential in a muscle fiber, while a darker myosin ATPase stain indicates greater muscle contraction velocity. If testosterone directly affects muscle fiber type, through binding androgen receptor (AR) and changing gene expression, we predict little difference between fiber type composition between species with the same testosterone treatments. This study will contribute to our understanding of hormonal influence of behavior and physiology in vertebrates.

329 Rindy Anderson, Charlie Daria, Morgan Slevin

Effects of anthropogenic noise on cognition and growth in the zebra finch (Taeniopygia guttata)

Anthropogenic noise has deleterious effects on wildlife in urban environments. In humans, anthropogenic noise exposure during childhood can have long-term effects on cognitive processes in adulthood. Here we tested if urban noise impacts avian cognitive performance by testing adult zebra finches (Taeniopygia guttata) on several cognition tasks in the presence or absence of urban noise playback. We also tested if urban noise impacts growth and cognitive development by testing adult zebra finches on cognition tasks after exposing them to urban noise, pink noise, or no noise during their first 90 days of life. We found that urban noise exposure marginally reduced cognitive performance during tests of a novel motor skill, but did not reduce performance during tests of color association learning or spatial memory tasks. We found that urban noise exposure during development marginally affected cognitive performance in adulthood on a color association task. While urban noise exposure during development did not affect adult body size, treated males and females developed less bright bill coloration, and redder bills, respectively, than untreated birds. Our results suggest that urban noise exposure may affect morphological traits, such as bill color, that influence social interactions and mate choice. Future studies should examine how noise exposure affects other cognitive behaviors, such as social behavior, and how social behavior in turn might exacerbate or mitigate negative effects of noise.

554 Philip Anderson, Kehan Pan, Bradley Scott, Abby Weber, Bingyang Zhang

A Thorny Landscape: The Diversity of Biological Puncture Systems

Vipers inject venom into prey using fangs, mantis shrimp harpoon fish with spear-like appendages, and cacti disperse clones via spines attached to passing mammals. These are a few examples of the diversity of biological puncture tools. Although disparate in materials, kinematics and scale, all three systems must adhere to the same set of physical laws that govern puncture. While the interplay between morphology, material, and puncture performance has been experimentally demonstrated in individual systems, these patterns have not been unified into a general framework. We take a step towards this goal by combining energetics modeling with theoretical simulations and experimental data to create performance landscapes for puncture tool morphology. Here, performance is a combination of structural properties and puncture efficiency. The relative importance of these components is weighted to create combined landscapes for various puncture scenarios that are populated with measurements from 100+ species, including vertebrates, invertebrates and plants. Regions of morphospace occupied by the biological tools generally align with specific performance scenarios: Shark teeth plot in high performance regions when puncture and hydrodynamics are weighted more heavily than structural resistance. Other tools, such as snake fangs and wasp ovipositors cluster in high performance regions when performance components are weighted more evenly. These landscapes are a first step towards creating a physics-based framework for studying the evolution of disparate puncture systems across phyla.

587 Susan Anderson, Andrew Russell, Andrea Liebl

Epigenetic Response and Variable Developmental Environments in a Cooperative Breeding System

Epigenetic regulation influences behavioral phenotypes throughout life. Variable developmental environments, such as temperature, diet, sociality, and other ecological pressures, can induce an epigenetic response altering an individual's gene expression without changing the underlying genetic sequence; this may allow flexibility in coping with unpredictability in future environments. One specific environmental trait that can influence developmental epigenetic signals is parental care. Although previous studies focusing on the effect of parental care on epigenetic signals have used biparental systems; however, cooperatively breeding systems, where adults in addition to the breeding pair help raise offspring, demonstrate more variation in parental care than biparental systems and therefore are likely to have a greater influence on epigenetic signals. Here, we use chestnut-crowned babblers (Pomatostomus ruficeps), a cooperatively breeding passerine from the Australian Outback, to analyze how variable developmental social environment influences the establishment of epigenetic signals. Specifically, DNA from blood samples taken at hatching and fledging was used to assess how epigenetic signals change dependent on helper number and provisioning effort of adults. We hypothesize that variation in adult helper number will predict overall levels of methylation throughout the genome as well as methylation of particular genes (e.g. parental or dispersal genes). This research aims to add to the growing body of ecological epigenetics work in understanding the evolution of altruism and how variation within social systems develops.

940 Kyra Anderson, J. Andres Marquez, Erik Sperling, Murray Duncan

Using the metabolic index to predict changes in habitat of red urchin (Mesocentrotus franciscanus)

Red urchins (Mesocentrotus franciscanus) play an important role as herbivores in kelp forest ecosystems and are a valuable economic resource. Occurring between 0-90 m depths along the northeastern Pacific Coast, red urchins experience heterogenous dissolved oxygen and temperature conditions throughout their range. As oceans warm, the metabolic oxygen demands of marine ectotherms (like red urchins) increase while the global inventory of oceanic dissolved O2 systematically decreases. Here, we aim to better understand the ecophysiological impacts of predicted ocean warming and deoxygenation on the viable aerobic habitat of red urchins. To do this, we conducted respirometry experiments to determine standard metabolic rate (SMR) and the critical pO2 below which SMR can no longer be maintained (Pcrit) of red urchins from Friday Harbor, WA. We performed these experiments across 5 temperatures between 6-22°C to determine the effects of temperature on Pcrit and SMR. Then, we use the metabolic index to map changes in the predicted aerobic habitat of red urchins using a high-resolution forecast of temperature and oxygen conditions on the northeastern pacific coast in 2100. We hypothesize that the viable aerobic habitat of the red urchin will decline as the northeastern pacific waters warm and lose oxygen. In the future, we will collect similar respirometry data on red urchins from northern and southern California to better understand how hypoxia tolerance varies across latitudinal gradients.

1027 Aha Anderson, Martha Munoz, Nathalie Alomar

Differences in Critical Temperature Minimum across the Plethodontidae Family

Lungless salamanders (Plethodontidae) are a diverse family of amphibians. They are especially diverse in Southern Appalachia, where there are dozens of distinct species, some widely distributed and others mountain endemics. The physiological traits for this clade can provide insight into how this rich lineage has evolved. One physiological trait with potential to vary across the family is the critical temperature minimum, or CTMin, which is the low temperature at which an ectotherm loses motor control. CTMin data from individuals across seventeen Plethodontidae species was combined with phylogenetic data to analyze the evolutionary history of the trait.The primary genus studied was the Plethodon, particularly the glutinosus clade, but data from two other genera, Desmognathus and Eurycea, were collected. The three lowest CTMin values were found in the Plethodon genus; P. chlorobryonis, P. teyahalee, and P. cheoah. Of the clades within the Plethodontidae family, the glutinosus clade within the Plethodon genus exhibited the most diverse CTMin values. The variety within the clade is likely due to diversity in habitat between species, with lower CTMin values likely being linked to lower average temperatures in their microhabitats. A future direction would be to compare evaporative water loss rates with CTMin data.

1427 H Luke Anderson, Jairo Cabo, Jordan Karubian

Linking resource ecology and sexual selection in a lek-mating manakin

Lek mating systems are often characterized by high levels of male reproductive skew, and theory predicts that female mate choice in these systems is primarily driven by indirect genetic benefits. However, this gene-centric perspective overlooks the potential importance of ecological factors in shaping individual variation in male trait expression and fitness. We hypothesized that heterogeneity in resource availability among males at a lek would influence male display rate and female visitation in the frugivorous white-bearded manakin (Manacus manacus). Males of this species perform energetically costly courtship displays at individually defended courts within larger leks. Here, we present data from a single lek in the Chocó region of northwestern Ecuador, where we longitudinally monitored fruit availability and display activity at male display courts. We also assessed resource availability at the level of male home ranges, using radio telemetry to monitor male space use while concurrently conducting fruit surveys. We found considerable variation in the amount of fruit available to different males, and individual-level variation in fruit availability strongly predicted levels of display activity. Importantly, male display rate strongly predicted rates of female visitation. These results indicate an important link between resource availability and male display performance in a lek mating system, suggesting that ecological variables may play an underappreciated role in shaping variation in individual mating outcomes at leks.

1496 Audrey Anderson, Emily Wilkins, Marie Strader, Katherine Buckley

Parental identity influences developmental plasticity of the purple sea urchin innate immune system

Anthropogenic climate change is the increasing the occurrence of marine heat wave events, which threaten the health and survivability of many marine invertebrates. Strongylocentrotus purpuratus, an ecologically important omnivore, face increased incidences of marine heatwaves, which could compromise their ability to combat infectious disease. The sensitivity of early life-history stages and whether developmental environments can influence the development of the immune system remains unknown. To assess the role of developmental temperature on the innate immune system, we spawned 3 pairs of adult S. purpuratus conditioned at ambient conditions (14°C) to produce offspring. Fertilized eggs from each cross developed in ambient (14°C) and elevated (18°C) water temperatures through the development of the pluteus stage (6 days post fertilization), where pigment cells, an essential component of the innate immune response, are clearly visible. Samples were collected at the 64-cell stage and the pluteus stage for morphological analysis. We found that S. purpuratus embryos developed in elevated temperatures were larger at the 64-cell stage, while the pluteus stage had greater numbers of larval pigment cells than those raised in ambient conditions. However, these results varied significant when accounting for cross identity, indicating an important role of genotype in structuring how the immune system develops in response to differences in the environment. The results emphasize the complex dynamics influencing how marine invertebrates acclimate to elevated environmental temperatures.

1527 Jeffery Anderson-Jr, Joshua Pulliam, Jerry Wong, Ignacio Moore, Ulmar Grafe, Salwa Khalid, Jake Socha

How does height influence perch-related locomotor behaviors in arboreal snakes?

Arboreal colubrids inhabit a wide array of forest types, elevations, and locales. When traversing gaps within tree canopies, snakes of the subfamily Ahaetuliinae have been observed to employ a range of locomotor behaviors including cantilevering, lunging, jumping, and gliding. These behaviors entail a risk of falling, with injury potential increasing with height. Does arboreal height influence the locomotor behavior of snakes when on a perch? In this study, we examined the behavior of two species of Ahaetuliinae (Dendrelaphis pictus and Ahaetulla prasina) and an outgroup species (Lycodon capucinus) at low ($h = 1.5$ m) and high ($h = 5.0$ m) heights. At each height, we examined behavior in the presence or absence of a nearby target, an artificial tree branch spaced at a distance of 85% SVL (snout-vent length). In each trial, snakes were observed for a set duration (10 minutes) while given periodic stimuli to induce movement. Preliminary results suggest that height does not influence behavioral choice in Dendrelaphis, but does so in both Ahaetulla and Lycodon. Specifically, Dendrelaphis are more prone to perform dynamic behaviors (jumping, lunging, and volitional dropping) compared to Ahaetulla and Lycodon. These results suggest that dynamic behaviors like jumping may have evolved prior to gliding in Chrysopelea, the sister taxon to Dendrelaphis. This research was supported in part by the National Science Foundation under grant numbers 1922516 and 2027523.

58 Rodrigo Andrade-Luna, Fletcher Levy, Chris Law

Evaluating Mandible Size and Shape Using Rensch's Rule, in the Family Felidae

Sexual dimorphism, differences between the sexes within the same species, vary in how evident they may appear. According to Rensch's Rule, in species in which males are the larger of the two sexes, sexual dimorphism increases with species' body size. The inverse

is true if females are the larger sex. In this study, we test if mandible size and shape follow Rensch's Rule in the carnivoran family Felidae. Felids provide a good model system due to the variation in diet, body size, and habitat range they exhibit. We 3D scanned 79 mandibles across 15 species and used geometric morphometrics to quantify sexual dimorphism in mandibular size and shape. We found that mandibular size did not exhibit a significant relationship with either sexual size dimorphism or sexual shape dimorphism, indicating that felids do not follow Rensch's rule. Different influences may explain our findings, but differences in diets and/or sociality could be explored as potential explanations. An increased sample size of specimens may also be warranted. Against expectations, the tested mandibular size proxy did not go against or align with Rensch's Rule.

179 Tim Andries, Sam Van-Wassenbergh, Wendt Müller

Relationships between feeding performance, kinematics, and skill in a granivorous songbird

More efficient capture, manipulation and swallowing of food can reduce the time spent foraging or increase food intake, both of which are beneficial for survival. Feeding performance is therefore generally regarded to be under strong natural selection. In granivorous songbirds, feeding is a complex process as seeds need to be dehusked before they can be consumed, making the feeding act a biomechanically challenging endeavor. However, most research has focused on feeding performance in relation to beak morphology, while the influence of beak kinematics and skill remains largely unknown. In this study, we investigated at the individual level how feeding performance relates to both feeding kinematics and skill in the Canary (Serinus canaria). High-speed videos during feeding were recorded and subjected to automated tracking of beak tip movements to compute kinematic properties (beak tip speed and acceleration) and quantify skill (seed handling tactics) and performance (seed processing time and success rate). Better skills, by accurate positioning of the seed for being split in half, had a positive impact on feeding performance compared to more random positioning and crushing the husk into multiple, scattering fragments. Surprisingly, individual variation in kinematical variables did not significantly affect performance in our population. Our data suggests that seed positioning precision, and hence the control of coordinated beak and tongue movement, is critical to minimize feeding durations in songbirds.

358 Vinicius Anelli, Priscila Rothier, Anthony Herrel, Tiana Kohlsdorf

Head shape variation in fossorial lizards reflects distinct burrowing substrates

Fossoriality evolved multiple times in Squamata frequently in association with body elongation and limb reduction. Explanations for snakelike forms rely on energetic and biomechanical benefits for burrowing through the substrate. However, modifications in head shape have also been described, as most fossorial lizards are head-first burrowers and use their heads to perforate the soil. Here, we focused on morphological evolution of head shape in Gymnophthalmidae, a lizard family comprising at least two independent snakelike fossorial lineages. We first evaluated if head shape evolved in association with different burrowing substrates among fossorial lineages using outline-based morphometrics and phylogenetic comparative analyses. Secondly, we tested the resistance imposed by distinct substrates on different skull morphologies during head-first burrowing using 3D-printed models of gymnophthalmid skulls. Our results indicate that sand and leaf-litter burrowers exhibit distinct adaptations to fossoriality. Sand-swimmers evolved wedge-shaped snouts, while leaf-litter dwellers are characterized by compact heads. Differences in head shape influence locomotion through subterraneous environments, as burrowing forces vary depending on the substrate, skull shape and burrowing orientation. Overall, our results suggest that evolution of distinct head shapes in fossorial lizards reflects subtle environmental differences associated with the occupation of subterraneous microhabitats.

391 Vinicius Anelli, Anthony Herrel, Ana Carolina Carnaval, Tiana Kohlsdorf

Phenotype-environment associations in the morphological evolution of neotropical lizards

Characterization of current patterns of biodiversity and their underlying ecological and evolutionary processes provides a reliable conceptual framework for future projections concerning the effects of environmental changes on biological lineages. Species richness is frequently claimed as an essential proxy for biodiversity patterns, but other components of diversity, such as morphological variation, must not be relegated. Phenotype determines functional properties that influence individual performance, ultimately affecting fitness and the establishment of biological lineages – including its perpetuation facing environmental changes. Here, we aimed to characterize the role of phenotype-environment associations in the evolution of morphological diversity in extant neotropical lizard lineages. We assembled an ecomorphological database comprising linear morphological measurements, microhabitat use characterization and geoclimatic data for neotropical lizard species available at herpetological collections. We then implemented phylogenetic comparative method and corroborated the hypothesis that shape is more strongly associated with habitat than climate in lizards. Our results also suggest that climatic parameters, such as temperature and precipitation, exhibit habitat-specific correlations with morphological diversity. Overall, our study contributes to a framework for future projections concerning the effects of environmental change on the diversity of life forms in the neotropics.

1671 Dave Angelini, Devin O'Brien, Ye Jin Lee, Qifan Wen

Testing the canalization of scaling in bumblebee mouthparts

Allometric scaling of anatomical traits is wide-spread among organisms. Extremes in static allometry often reflect histories of intense selection, such as in sexually competitive weapons. Extreme allometric structures have been shown to have greater static scaling coefficients than other traits and to have increased variance among individuals. We wished to explore this pattern more widely, wondering if certain traits might be subject to different evolutionary forces leading to negative allometries and reduced variance. Bumble bees (Hymenoptera: Apidae: Bombus) show an incredible degree of size variation within and between individuals and species. While this variation may allow individuals to specialize in foraging on different flowers suited to their morphology, species differ in their degree of specialization, and individuals may be required to exploit similar floral resources regardless of their size. Therefore, we wished to test a hypothesis that more specialist bumble bee species will display lower allometric scaling of mouthparts and lower variance compared to reference traits. Using forage data from the literature to characterize floral specialization, we quantified mouthpart morphology as multiple linear measurements from approximately 300 individuals of 9 species. Reference traits included leg morphology as multiple linear measurements and forewing and hindwing shapes quantified using geometric morphometrics. We find extensive variation in scaling among species. Mouthpart shapes correlates with forage plant diversity rather than phylogenetic signal.

283 Laura Antizzo, Donald Mykles, Talia Head

Characterization of protein kinase C in the molting gland of two decapod crustaceans

Ecdysis, the act of shedding the exoskeleton, is an important growth event of decapod crustaceans. The molt cycle is a unidirectional process consisting of the stages: intermolt, premolt, ecdysis, and postmolt. Molt-inhibiting hormone is synthesized within the X-organ of the eyestalk ganglia and inhibits the Y-organ (YO). The synthesis of ecdysteroid molting hormones by the YO are necessary for transition through the molt cycle. The activation of protein kinase C (PKC) is hypothesized to stimulate ecdysteroid synthesis through activation of the mechanistic target of rapamycin (mTOR). However, the extracellular ligand and downstream events of PKC activation are not fully understood. We have identified four candidate sequences of PKC isoforms in the YO transcriptome of Gecarcinus lateralis and Carcinus maenas. PKC isoforms are classified based upon their second messenger requirements. Of the three PKC subfamilies – conventional, novel, and atypical – both G. lateralis and C. maenas transcriptomes contain conventional, two novel, and one atypical transcript. In G. lateralis the isoforms appear to have differential expression across the molt stages. Expression of the conventional and novel PKC isoforms increase during premolt stages. The atypical isoforms appear to have comparatively low expression across all molt stages. Distribution of each PKC isoform across various tissues was identified using end-point PCR for both G. lateralis and C. maenas. Funding is provided by NSF (IOS-1922701).

1525 Gabriel Antoniak, Enric Xargay, Joaquin Gabaldon, Kira Barton, Bogdan-Ioan Popa, Alex Shorter

Estimating Whole-Body Kinematics and Kinetics of Swimming Bottlenose Dolphins

Cetaceans are efficient swimmers, with estimated propulsive efficiencies exceeding those of mechanical propellers. However, experiments to verify these efficiencies have been limited because swimming kinematics and kinetics are difficult to measure due to the inherent challenges of the marine environment. We apply a data science approach to estimate the whole-body swimming kinematics of bottlenose dolphins (Tursiops truncatus) from inertial measurement unit (IMU) data coming from a biologging tag. The estimated whole-body kinematics, along with center-of-mass-corrected tag data and individual-specific morphology, are subsequently used to drive a hydromechanical model of dol-

phin swimming. This model segments the dolphin body into 4 linked bodies, each with their own geometry and hydromechanical parameters, while the fluke is treated as a flexible plate with both spanwise and chordwise stiffness. This modeling approach allows us to estimate the forces at the fluke, the forces that must be generated inside the dolphin body to move the fluke through the water, as well as the overall propulsive efficiency. We apply this method to kinematic data collected from a tag placed anterior to the dorsal fin of bottlenose dolphins at Dolphin Quest Oahu. Our model predictions are broadly in line with existing literature. This approach enables the estimation of swimming kinematics and kinetics for individual dolphins in both managed and wild settings, greatly expanding our ability to investigate dolphin swimming biomechanics using biologging tags.

1332 Josephine Antwi, Dianne Baker

Identification of Fungal Strains on Spotted Lanternfly (Lycorma delicatula)

The spotted lanternfly (SLF) was discovered in Pennsylvania in 2014 and has since spread to multiple eastern states. In 2018, a common entomopathogenic fungus, Beauveria bassiana, was identified as causing localized population collapse of SLF in Pennsylvania. In the current study, we isolated pure fungal strains from dead SLF samples collected from Pennsylvania. We used four approaches to identify two of these fungal strains. In the first approach, we used PCR to amplify the Internal Transcribed Spacer (ITS) region for fungi. DNA sequencing with subsequent comparison to the National Center for Biotechnology Information database indicate that both fungal strains belong to B. bassiana, the entomopathogenetic fungus previously found on dead SLF. Beauveria bassiana is known to secrete toxic compounds to facilitate the fungal invasion process in insects. To confirm the identity of B. bassiana, we used qRT-PCR to amplify genes encoding the toxic compounds, beauvericin and bassianolide. In the third approach, we used Scanning Electron Microscopy for morphological identification. Images from both fungal strains were identical to published images of B. bassiana. Lastly, to confirm the pathogenicity of the fungal strains, we conducted a lab bioassay using the cotton aphid (Aphis gossypii). Three days after treatment, we found higher mortality on aphids treated with fungi than aphids in the control group. Our study suggests that B. bassiana could be responsible for the mortality of SLF analyzed here.

895 Simon Anuszczyk, John Dabiri

Enhanced Swimming and Hydrodynamic Efficiency of Robotically controlled Aurelia aurita

We study the performance envelope of Aurelia aurita jellyfish with embedded microelectronic swim controllers that manipulate the frequency of body contractions during swimming. Jellyfish have the lowest cost of transport of all metazoans and live in a wide range of ocean temperature, salinity, pH, and depth, due to their evolutionary success and adaptability. Cnidarian's single cell layer muscles impose biological velocity limits which are seldom seen during normal swimming behavior. Manipulating the frequency of body contractions will allow us to approach these limits and better understand the role of swimming mechanics in the observed evolutionary success. Previous work has demonstrated enhanced jellyfish vertical swimming speeds of 2.8 times baseline speeds without swim controllers. Indirect measurements suggest that this enhanced swimming can be achieved without proportional increases in energy consumption. Here, we examine this question using direct measurements of the hydrodynamic efficiency of robotically controlled Aurelia aurita associated with enhanced swimming speeds. Using PIV, we measure the kinetic energy of water set in motion by the animals to determine hydrodynamic efficiency. This will help to determine if these enhanced speeds are energetically feasible for wild jellyfish. This work also demonstrates a system to study the latent enhanced swimming exhibited by robotically controlled jellyfish.

1025 Md Zafar Anwar, Bret Tobalske, Suyash Agrawal, Haoxiang Luo, Bo Cheng

Decision making and control in hummingbird's escape maneuver in response to light removal

Hummingbirds excel in aerial agility and flight stability, unparalleled to most natural and manmade fliers. Yet, their control of these amazing maneuvers is not well understood. In this work, we tried to understand their maneuvers and get insights into hummingbirds' decision-making and flight control, by startling two calliope hummingbirds to elicit escape flight and removing the visible light at varied timing. We found that the hummingbird's escape maneuver comprises different flight modules starting from evasion, reorientation, nose-down dive, forward flight, and nose-up to hover. Hummingbirds rapidly switch across these modules as many 5 times in less than 200 ms to execute escape maneuvers even in the absence of vision. Hummingbird's trajectory of initial modules during head saccades i.e. evasion and reorientation were unaffected by the light conditions. We found the existence of a visual input window that affects the decision to nose-down dive to forward flight or nose-up pitch to hover after reorientation. We then related the wing motion pattern repeatability to the relative degree of feedback and feedforward control during different modules of maneuver. The bird's dynamic was found to be rate commanded as the body angular rate, on the wingbeat cycle, varied proportionally with the change in wing motion. Hence reducing the computational demand on flight control.

1036 Md Zafar Anwar, Bret Tobalske, Suyash Agrawal, Haoxiang Luo, Bo Cheng

Kinematics and dynamics analysis of hummingbirds hovering under external torque

Hummingbirds' flight is amongst the most advanced compared to other natural and man-made fliers. To better understand and replicate their feat in flapping robots, in this work, we report the kinematics and dynamics of the hummingbird's flight in the presence of external torque. We conducted experiments on one male and one female Calliope hummingbird, where we glued a permanent magnet ($\sim$10% of their body mass) on their back. While feeding from the feeder they had to hover under a varying magnetic field between two electromagnets exerting torque along the body roll axis, which is unstable and their most sensitive degree of freedom. Various torque profiles were applied by varying the current through electromagnets: Constant, Impulse, and sinusoidal (2 Hz, 5 Hz, and 10 Hz). With an external impulse, the body is perturbed by about 30 deg and the hummingbird was able to recover to its original posture to within 5 degrees in less than 50 ms after the removal of external torque. We also extracted the flight dynamics by replicating the flight kinematics from 3D reconstructions of high-speed recording in a rigid body simulation to find the wing actuation torques applied by the hummingbird as well as the resulting aerodynamic torques (quasi-steady model).

934 Kate Appleman, Katarina Lettner, Andrew Behrmann, Pirooz Eghtesady, Lucas Kirschman

Measuring the Efficacy of Left Atrial Appendage Tissue to Function as an Aortic Valve

Left ventricular outflow tract obstruction (LVOTO) is a congenital heart defect that impedes blood flow from the left ventricle to the aorta. The aorta is the main artery that delivers blood to the body from the heart. The focus of this study is on the LVOTO, a deformity commonly associated with aortic stenosis (AS). AS occurs when the aortic valve (AV) does not open properly. This condition could lead to aortic insufficiency (AI), a condition in which the function of the AV is compromised and causes backflow. The AV is typically replaced when the conditions of AS and AI are present. Current AV replacement procedures use either a mechanical valve or an animal tissue valve. However, this study investigates the use of left atrial appendage (LAA) tissue as a substitute material for the AV replacement. The aim of this study is to further the understanding of the efficacy of the neo-LAA valve to withstand increased pressurization conditions. The current results reinforce the idea that LAA tissue could be a good alternative material for reconstruction of the LVOT. Therefore, the results could potentially lead us to the betterment of surgical procedures used to correct LVOTO.

633 Jessica Arbour

good.fibes: an R approach for semi-automated detection of muscle fibers from diceCT scans

Contrast-enhanced CT scanning approaches like diceCT (iodine-based contrast scanning) have provided revolutionary tools for the digitization of morphology and non-destructive sampling of specimens. One particularly useful property of diceCT in the study of animal biomechanics is the ability to visualize muscle fibers, as length and orientation of fibers are important determinants of muscle force production. However, techniques for isolating and quantifying muscle fiber attributes from such scans are limited, with some available only through expensive proprietary software. Here we present an R-language based approach (good.fibes) for the semi-automated tracking and measurement of muscle fibers from diceCT scans. This stepwise algorithm uses texture analysis of voxel grayscale values to detect fiber tracks, requires only a stack of images of the muscle as input, and is designed to minimize memory usage. We also present functions for quality checking, merging redundant or incomplete fibers and 3D visualization of fiber tracks. We examined the performance of this approach using two datasets with known fiber lengths – an ant, Monomorium pharaonic, mandibular muscle dataset and a bat, Rousettus aegyptiacus, cranial muscle dataset. We find that good.fibes accurately estimated the length and configuration of the muscle fibers, and that variation in fiber lengths was similar to approaches like Amira's XTracing and the ImageXD. We hope that this open-source approach will expand the diceCT toolkit and improve access for morphologists/biomechanics researchers.

280 Jamal Ardister, Brian Feeny

Modeling of Undulatory Swimming Motion Using Velocity Constraints

This research pursues a low-order model of undulatory fish swimming. Current approximations neglect the deformation of the surrounding water, analogous to a "landfish" on a rigid substrate. The model consists of three rigid bodies: a head (lead body), midbody, and tail. The midbody has imposed angular oscillation (in lieu of neuromuscular activation) relative to the head. Velocity (nonholonomic) constraints emulate the effects of dorsal and caudal "fins" on the landfish. The head is constrained to move in the direction it is pointing. The midbody is linked to the head and tail by pins and springs. The tail is also constrained to move in the direction that it is pointing. We apply nonholonomic Lagrange equations to produce the equations of motion, consisting of two second-order dynamic equations and two first-order nonholonomic constraint equations, representing a sixth-order forced dynamical system. We analyze the behavior of these equations of motion. Simulations were conducted using Matlab. Over a range of parameter values, examples of robust, smooth fish-like swimming were found, in which the head oscillates slightly about a mean path as the landfish "swims". Parameters are observed to affect how well the velocity builds from rest. Ongoing studies include systematic simulations for uncovering classes of behavior, small-parameter perturbation analyses for revealing roles of parameters in regular motion.

1040 Adrien Arias, Elizabeth Mendoza, Manny Azizi

Alligators use elastic energy storage in ankle extensors during steady state walking

Most cursorial animals save metabolic energy during locomotion by using elastic energy storage to reduce muscular work. The distal free tendons of legged animals studied so far (e.g. turkeys, goats, rats) are morphologically well-suited for storing elastic strain energy, but alligators have relatively shorter distal free tendons. It remains unclear whether alligators and other sprawling animals are capable of using elastic energy storage during locomotion or whether the lack of long, compliant tendons imposes additional work requirements on muscle fibers in vivo. Through a combination of in situ muscle preparations, joint-level analyses, and in vivo muscle function measurements during walking, we show that 1) the lateral gastrocnemius (LG) of alligators is capable of storing significant elastic energy in its tendon during supramaximal contractions, 2) surprisingly, LG develops force mostly isometrically while the ankle joint performs negative and positive mechanical work during ground contact, and 3) in vivo operating lengths of LG fall on the ascending limb of its force-length curve. Together these results show that LG's external free tendon stores and releases elastic strain energy at the ankle while LG muscle fibers contract isometrically— even at the low locomotor speeds used during alligator walking.

1209 Timothy Arlowe, Russell Main, Worapat Sawatwong

In Vivo Tibial Bone Strains During Locomotion in the Green Iguana (Iguana iguana)

Mechanical loading models are used to study adaptive skeletal mechanobiology mechanisms. Most studies have used rodent models, thus there is a knowledge gap for how these mechanisms differ among vertebrate groups. To narrow this gap, we evaluated the in vivo bone strain environment of the green iguana tibia during treadmill locomotion. We examined subadult green iguanas ($n = 3$) over a range of speeds (0.45- 1.34 m/s) to determine peak strains. Bone strains were measured using single element($n = 2$-3) and rosette strain gauges($n = 1$), which were surgically attached to the tibial anterior, posterior, and medial surfaces. At 0.45m/s the peak strains were 384 $\mu\varepsilon$ (48 to 633 $\mu\varepsilon$), -186 $\mu\varepsilon$ (-108 to -264 $\mu\varepsilon$) and 221 $\mu\varepsilon$ (82 to 445 $\mu\varepsilon$) at the anterior, posterior, and medial surfaces, respectively. At 1.34 m/s, peak strains observed were 1105 $\mu\varepsilon$ (100 to 1444 $\mu\varepsilon$), -560 $\mu\varepsilon$ (-368 to -752 $\mu\varepsilon$) and 316 $\mu\varepsilon$ (149 to 504 $\mu\varepsilon$), respectively. Peak principal tensile and compressive strains on the medial surface were 140 $\mu\varepsilon$ and -69 $\mu\varepsilon$ at 0.45m/s and 178 $\mu\varepsilon$ and -94 $\mu\varepsilon$ at 1.34 m/s. Our objective moving forward is to evaluate in vivo strains during axial compression loading and to apply a loading protocol from in vivo strains to induce a bone adaptive response.

786 Roxanne Armfield

Snakes: The Rulebreakers of Tetrapod Morphology

Snakes are able to bypass many of the functional and morphological constraints encountered within Tetrapoda by being released from bite-force related selection pressures. This has produced a level of functional separation between cranial units unseen in other vertebrates, and has facilitated a high level of cranial disparity across modern snake taxa. Unravelling the mechanisms and drivers behind these novel changes presents a challenge as, currently, our 'standard investigative toolkit' is insufficient to answer these questions alone, and poses its own challenges: the snake fossil record is scarce and lacks diagnostic cranial material; conflicting phylogenetic topologies present contrasting evolutionary scenarios for character acquisition; and our understanding of the functional morphology of extant taxa is limited. Modelling alethinophidian snake anatomy as an integrated system allows us to ascertain what morphological constraints are present when remodelling the skull. Using DiceCT techniques to capture musculoskeletal relationships in situ, as well as soft tissue data from ligaments and cartilages. Our preliminary results suggest that the arrangement of fibrous connective tissue within major snake clades is highly variable, and may be able to compensate for larger-scale changes in skeletal element morphology. Whilst the examination of soft tissue anatomy appears to increase morphological disparity between taxa, we additionally ask whether these changes translate to functional differences at the organismal level, and test whether alethinophidian cranial anatomy represents a many-to-one system.

711 Eric Arredondo, Alison Bell, Tina Barbasch, Chad Brock, Alexis Heckley

Quantifying territorial aggression among three-spined male stickleback in the wild

In territorial animals, successful territory defense is critical for fitness. While variation in territorial aggression among individuals has been documented in a number of species, the underlying genetic basis of this variation in the wild is often unknown. In this study, we take advantage of an experiment which introduced three-spined stickleback from eight different source lake populations into Loon Lake in Alaska. The potential cross-population genetic admixture of the F2 generation of stickleback in Loon Lake provides an opportunity for genetic mapping studies. Here, we determine whether data on territorial aggression in the field could be used for quantitative trait locus (QTL) mapping. Nesting males were identified via snorkeling and were measured for their behavioral response to a simulated territorial intrusion in the field on two occasions, 24 hours apart, to assess repeatability. For each male, we also recorded body size, nuptial color, parasite load, nest microhabitat, clutch size, and embryonic development stage to identify potentially important covariates. There was extensive individual variation in territorial aggression among individual males, with some indication that the variation is repeatable and correlated with other male traits and nest microhabitat. These findings suggest that data collected on natural variation in behavior in the field could be used for future genetic mapping studies.

998 Madeline Arrmstrong, Andrew Mahon, Kenneth Halaynch

A morphological and molecular investigation of Ammothea (Pycnogonida, Chelicerata) specimens from An

Ammotheidae (Pycnogonida, Chelicerata) is one of the most abundant pycnogonid Families in the Southern Ocean with Ammothea being the most represented genus in collections from this region. A high level of morphological plasticity both within and between species in Ammothea and a lack of genetic information has led to confusion in the interrelationships of this genus. This is further complicated by conflicting historical reports citing inaccurate collection locations and changing of the genus descriptions which has led to the history of this genus to be convoluted. Thus, a reevaluation of the genus using both morphological and molecular approaches is warranted to investigate within and between species variation. For this study, we analyzed approximately 420 specimens from the genus Ammothea collected on three research cruises in the Southern Ocean including the Western Antarctic Peninsula, the Bellingshausen, Amundson, northern Weddell, and Ross Seas regions. Based on morphology, we identified 19 of the roughly 30 Antarctic and sub-Antarctic species for this study. We also present 14 novel Ammothea mitochondrial genomes, greatly increasing our genetic references for this group, allowing us to investigate intrageneric differences and relationships. The addition of these data, both morphological and molecular, greatly improves our understanding of this dominant genus of charismatic sea spiders.

557 Kaja Arusha, Krystle Boadi, Sabrina Ellah, Daniela Kim, Carolyn Bauer

Does sibling presence mitigate impacts of fostering on degu HPA-axis development?

This study examined how the presence of siblings affects endocrine stress response development in cross-fostered offspring of a social rodent, Octodon degus. We hypothesized that remaining with siblings mitigates the stress of fostering. Pups were either not cross-fostered (controls), cross-fostered at postnatal day 8 without siblings (single cross-foster), or cross-fostered at postnatal day 8 with the rest of their birth litter (complete cross-foster). One day after fostering and later at weaning, cortisol was measured at baseline and stress-induced levels, and dexamethasone was used to assess negative feedback efficacy. We predicted that stress response reactivity would be highest in single cross-fostered pups, lowest in controls, and moderate in complete cross-fostered pups. Specifically, we predicted that single cross-fostered pups would have higher stress-induced cortisol levels and weaker negative feedback than their complete cross-fostered counterparts. This investigation will contribute to our understanding of how family instability impacts postnatal stress response development.

326 OLAYINKA ASHIRU, OLUWAFEMI AMUSA, Sifau Mutiu, Adebayo Ogunkanmi, Bola Oboh

Genetic Diversity and Population Structure of Treculia africana (Decn) from Southern Nigeria

Treculia africana Decn. (African breadfruit) is an important economic and socio-cultural fruit crop with high medicinal value. The tree has important sociocultural ties with the indigenous people of Eastern Nigeria. This tree is native to Nigeria and West Africa, where it also serves as a source of supplemental food and a nutritionally balanced diet. The genetic resources of this tree are being eroded because of widespread habitat destruction. However, information about genetic diversity and population structure, and morphological variation, is limited for the species. In this study, the aim is to determine the genetic diversity and population structure of T. afriana in Nigeria. In this study, we investigated the genetic diversity and population structure of the Nigerian collection using rbcL markers. DNA isolation and purification were one and a polymerase chain reaction was done to amplify the gene region and sequencing. Observed heterozygosity varied from 0.16 to 0.86, with an average of 0.58. Partial sequencing of chloroplast genes of the 38 plants generated mixed patterns. Pairwise FST (0.00 and 0.50) values revealed weak genetic differentiation between the populations but strong differentiation within the populations. These findings have shown that there is a high genetic diversity present in wild collections of T. africana. These results agree with previous reports that T. afrciana is native to the Southern Nigerian ecological region, and provides sufficient diversity for genetic exploration and genetic improvement efforts.

1562 Andrea Aspbury, Caitlin Gabor, Spencer Levings

Role of urbanization on life history traits, cognition, physiology, and morphology of Gambusia

Freshwater biomes contain 40% of the Earth's biodiversity and are disproportionately affected by rapid rises in extinction rates resulting from anthropogenic change. Change in land use on aquatic ecosystems is associated with "urban stream syndrome" (altered hydrology, elevated concentrations of nutrients and contaminants, reduced biotic richness, and the dominance/presence of more tolerant species). Urbanization of stream environments can alter physiology, morphology, behavior, cognition, and life history traits, and may promote tolerance of altered conditions. In two consecutive years we sampled Gambusia affinis from six streams varying in the amount of land development, and measured multiple phenotypic traits. The population from the most urbanized population had a stronger relationship between fecundity & female size than fish from the other populations. Across all populations, there was a strong relationship between female size and reproductive allocation, although degree of development was not a significant factor. Morphology and behavioral measures of G. affinis also varied across populations but the amount of development was not a significant factor. The cognitive performance of G. affinis was lowest at intermediate development levels. The stress hormone response profile also varied with urbanization. Together these results indicate that some phenotypic traits respond more directly to urbanization and land development than others, but other factors not measured here also play a role in allowing for tolerant species to persist in the face of the urban stream syndrome.

1206 Darene Assadia, Sean Polidori, Delbert Green

Plasticity in Sensory Perception: Role of Visual and Olfactory Systems in Monarch Butterflies

Animals rely on sensory perception to detect and respond to different resources that are crucial for survival. Foraging is primarily mediated by vision and olfaction in most insects, and in diurnals like butterflies, vision is considered to be their primary sensory modality. In Monarch butterflies, Danaus plexippus, perceptual range towards blooming plants has been estimated during observational studies, but the variation and plasticity of sensory perception within summer and fall generations has not been explored. Fall monarch survival depends on fueling their southward migration, so locating nectar sources in unfamiliar landscapes is vital. In contrast, summer monarchs forage at local scales in their breeding grounds. Therefore, comparing the sensory capabilities of summer versus fall generations reveals how senses are altered under the migratory syndrome, thus revealing any migration induced sensory trade-offs. We use a flight arena in a controlled indoor space to study visual and olfactory perception of migratory and non-migratory monarch generations. Using blooming Lantana camara plants, we get insight into how monarchs locate nectar sources, and the role of different sensory modalities in doing so. The results of this study may help to inform predictions about the effects of anthropogenic pollution on foraging monarchs.

468 Braulio Assis, Alexis Sullivan, Stephanie Marciniak, Christina Bergey, Tracy Langkilde, George Perry

70 years of invasion: genetic adaptation of fence lizards in response to the invasive fire ant

Invasive species can impose novel selective pressures on native fauna. The red imported fire ant is a successful invader of the Southern United States following its introduction in Port Mobile, AL in the 1930s. In these invaded populations, fire ants have established a bidirectional relationship with the native eastern fence lizard, playing the roles of novel predator and novel prey. Inconsistent with rules of latitudinal gradients, lizards from populations exposed to fire ants have relatively longer hind limbs, which in turn facilitate removal of swarming ants in combination with twitching behavior. We conducted a genome-wide association study (GWAS) using whole-genome sequences and phenotypic data from 386 fence lizards from Alabama (AL; invaded by fire ants). These data are complemented with 40 genomes from fire ant-naïve populations in Tennessee (TN) and Arkansas (AR). Based on 16.5M SNPs, we observe highest average FST values for AL vs. TN (0.249) and AL vs. AR (0.273) populations, with a lower average FST between TN and AR (0.239) despite separation by a major geographic barrier, the Mississippi River. Preliminary analyses also point towards a trend of higher genetic diversity and effective population size in AL. With ongoing GWAS and integrative evolutionary genomic analyses, we expect to better understand the process of how local fauna adapts to major invasive species.

759 Oghenevwogaga Atake, Brian Eames

Homologizing vertebrate mineralized tissues: how do chondrichthyans make bone-like tissues?

Bone is an evolutionary novelty of vertebrates, and most ancestral and modern vertebrates have bone in their internal supporting skeleton (endoskeleton). Chondrichthyans (sharks, skates, and relatives) or osteichthyans (bony fishes and tetrapods) are the two main clades to which all living jawed vertebrates belong. The endoskeleton of modern chondrichthyans is routinely described as lacking bone. However, sub-perichondral mineralized tissues in neural arches and tesserae of sharks and skates show morphological, histological, and molecular features consistent with vertebrate perichondral bone. If bone-like tissue and perichondral bone are homologous, then they must share a developmental program derived from the last common ancestor of chondrichthyans and osteichthyans. Cartilage maturation, the main driver of perichondral bone formation, is charcterized by several features including hypertrophy (increase in cell size) and col10 expression. To test the hypothesis that "bone-like" tissues and perichondral bone are homologous, we assessed whether the developmental program of bone-like tissues corresponds to that of perichondral bone. Using histology dyes and immunohistochemistry, we show that histological and molecular features of cartilage maturation occur prior to the formation of bone-like tissues in the little skate. These data suggest that cartilaginous fishes make bone-like tissues using a developmental program that is homologous to that of perichondral bone. Data from this study may provide a line of evidence to challenge the consensus that modern sharks and relatives don't make bone.

337 Jorge Audino, Kyle McElroy, José Amoroso-Rodriguez-Marian, Jeanne Serb

Uncovering opsin expression and diversity among bivalve visual systems

Eyes provide a tractable system to study how molecular and morphological traits can jointly result in new functions. For instance, visual adaptations frequently result from a specific opsin palette combined with different optical components and properties. However, our understanding is limited by eye anatomy and opsin expression data which are missing for many invertebrate visual systems. Bivalve mollusks display a remarkable diversity of photoreceptor organs, including five main types, ranging from simple pigmented cups to complex mirror eyes. While eyes have independently evolved in the group with many subsequent losses, the evolution of the photopigments remains largely unexplored in bivalves. One long-standing question is whether the diversity and evolution of opsins correspond to the morphological evolution of those visual systems. To gain insights into this question, we sequenced transcriptomic data from eyes and mantle tissue for eight species of pteriomorphian bivalves, sampling from all five orders. We recovered opsins belonging to six major opsin groups. Rhabdomeric opsins (coupled to Gq proteins) are the main visual opsins expressed in all eye types. Retinochrome was also found in all samples. Interestingly, scallops' eyes express 12 opsins while compound eyes express at least five, both including different xenopsins. In contrast, eyespots express three opsins. The increasing knowledge of opsin diversity and anatomical patterns should illuminate the complex evolution of such intriguing visual systems.

1502 Jennifer Austiff

Development and evolution of a carnivorous larval stomach in the frog, Lepidobatrachus laevis

Frogs typically have a biphasic life history in which larvae and adults occupy separate dietary niches. Typical tadpoles filter-feed on a herbivorous or omnivorous diet. During metamorphosis, they cease feeding and develop an adult stomach which is suited to a bulk-feeding, carnivorous diet. However, Lepidobatrachus laevis tadpoles feed on bulky prey immediately after hatching, do not stop feeding during metamorphosis, nor do they undergo a significant dietary change after metamorphosis. Lepidobatrachus laevis tadpoles have an-adult like stomach and feeding habits, collapsing the dietary gap between life history phases of tadpole and adult frog. Only minor changes in stomach morphology occur across larval development and metamorphosis, and the stomach does not completely remodel during metamorphosis as with most frogs. This study investigates the genetic underpinnings of stomach development in L. laevis by comparing their development to that of a frog with typical tadpole feeding and stomach metamorphosis, Xenopus tropicalis. This study will investigate gene expression between embryonic and adult stomach development within each species and differential gene expression between L. laevis and X. tropicalis embryonic stomach development as well as metamorphic stomach development. Additionally, this study will investigate if any pathways exclusive to developing the adult stomach of X. tropicalis are expressed during the embryonic development of L. laevis's adult-like larval stomach. This analysis will provide greater understanding of the evolution of heterochronic shifts in development and life history evolution.

1804 Prachee Avasthi, David Matus, David Mets, Austin Patton, Ryan York

Dissecting the evolution of behavior in non-neural eukaryotes

Before the rise of nervous systems, evolution had already imbued organisms with a multitude of behaviors. In fact, the vast array of unicellular eukaryotes ('protists') may possess the greatest behavioral diversity of any taxonomic group. At least 200,000 protist species exist. Some are photosynthetic. Some hunt bacterial prey. Some live in the microbial world, others are the size of grapefruit. The vast majority have not been characterized, much less subjected to laboratory study. In this talk, I will share our efforts toward developing protists into model taxa for the evolutionary and genetic dissection of behavior. We have developed novel imaging platforms that allow us to measure - and perturb - the movement of dozens to hundreds of organisms simultaneously. Using these data, we can construct quantitative maps of behavior (via the TREBLE framework) that allow comparisons of the movements of diverse species. In parallel, we have developed cheap and genome-free sequencing methods for measuring intra- and interspecific genetic variation among protists. We have used these genotyping tools, in combination with our high-throughput phenotyping platforms, to probe the genetic bases of high-dimensional behavioral traits in the algal genus Chlamydomonas. In conjunction, we are generating frameworks for tracking these patterns of behavioral evolution over macroevolutionary scales. This work intends to provide open and broadly-available tools for dissecting the full breadth of eukaryotic behaviors and to facilitate mechanistic research in this understudied clade.

272 Tess Avery, Diego Vaz, Molly Gabler-Smith, George Lauder

Denticle Multiverse 2: 3D imaging and analysis of dermal denticles on the Portuguese Dogfish

Placoid scales, or dermal denticles, are structures that cover elasmobranch skin. Multiple methods are available for studying denticles including histology, scanning electron microscopy (SEM), and gel-based surface profilometry. Each of these methods provide unique information, but they lack complete three-dimensional (3D) data and the ability to see the basal root of the denticle. One technique that helps fill this gap is micro-CT imaging, which enables 3D visualization of denticles including details of the basal root. Micro-CT provides a dataset of unique measurements including volume and surface area, as well as traditional two-dimensional length and width measurements. We micro-CT scanned skin samples from multiple locations on an ontogenetic-series of preserved specimens of the Portuguese Dogfish (Centroscymnus coelolepis). Using 3D models generated from these data, we assessed denticle scaling throughout ontogeny. Results showed negative allometry for denticle volume and surface area with respect to body length. Using a principal component analysis (PCA), we visualized how much each variable influenced the change in denticle morphology over ontogeny. The PCA plots were also used to group denticles into "morphotypes" based on shared shape. Incorporating micro-CT scanning, along with other imaging techniques, could allow for deeper insights into the morphology of sensorial organs such as the 3D structure of modified denticles associated with pit organs. The denticle multiverse is vast!

974 Corrine Avidan, Elizabeth Brainerd

Pharyngeal jaw suction feeding in channel catfish

The external flows used by suction feeding fish to draw food into the mouth are well described, however intraoral waterflows, which bring food to the esophagus entrance, remain understudied. As water flows through the mouth, it eventually curves away from the esophagus and toward the gills. How is water, and the food suspended in the water, redirected toward the pharyngeal jaws and esophagus? To better understand how fish are able manipulate flow and redirect food, we combine stereoscopic high-speed X-ray videos to quantify skeletal motion (XROMM) with buccal and esophageal pressure transducers, radio-opaque flow tracers, and tracked food particles to show internal waterflow within the buccopharyngeal cavity of channel catfish (Ictalurus punctatus). We found that food is redirected toward the esophagus through rapid opening of the pharyngeal jaws. This rapid opening creates a decrease in pressure and water flow similar to external suction flows in order to redirect the food toward the esophagus. We also observed the start of deglutition by capturing the moment of esophageal tightening using the esophageal pressure transducer. These results suggest a novel role for the pharyngeal jaws in producing intraoral suction to bring food into the entrance of the esophagus. By providing a more complete picture of the feeding process, this novel combination of techniques will open a new area of investigation to fully understand how aquatic vertebrates feed.

588 Salih Elnour Salih Awouda, Angela Clemens, John Long, Candido Diaz

The Glue of Moth-Catching Spiders: Biochemical Properties of Spread Droplets

Orb-weaving spiders catch almost every kind of flying insect, except one: moths. Spiders in the sub-family Cyrtarachninae capture moths, and they appear to do so, in part, by making a glue that is very different from that of orb-weaving outgroups. Given the importance of glue in capturing moths, we sought to understand the biochemical properties of moth-specialist aggregate glue droplets. We used Raman Spectroscopy to analyze the spatial distribution of the chemical composition of the glue droplets that have been spread out flat, as they would be during capture of moths. We analyzed moth-specialist species Cyrtarachne yunoharuensis and Mastophora hutchinsoni and two generalist species, Argiope aurantia and Leucauge venusta. Samples were then reanalyzed after being washed in Nanopure water, a process that separated water soluble components – salts and small proteins – from insoluble components, the larger glycoproteins. We predict that there is a distribution of glycoprotein in the core of the glue droplets and salts towards the edges for moth-specialist species, as opposed to the homogeneous distribution of components previously found in generalist glues. This distribution of components, we hypothesize, allows for a rapid drying of the glue as it spreads into moth wings, gluing down scales before they are able to be shed and the prey escapes. This research is supported by the National Science Foundation, project #2031962 to CD and JL.

1225 Heather Axen, Rebecca Bachtel, Ioulia Bespalova

Thermal plasticity in wild Drosophila pseudoobscura across Colorado's front range

The ability to cope with substantial fluctuations in environmental variables is a main determinant of ability to persist in the face of climate change. Adaptation to thermally variable local environments may select for increased ability to flexibly respond via phenotypic plasticity to temperature fluctuations due to climate change. The climate variability hypothesis (CVH) predicts organisms from habitats with extreme temperature variation, both annually and over shorter periods, will express increased ability to cope with thermal stressors compared to those from less variable habitats. We evaluate support for the CVH by investigating thermal tolerance in wild caught Drosophila pseudoobscura collected across an elevational gradient in the eastern slope of Colorado's Rocky Mountains. Using elevation as a proxy for thermal variability, isolines from low, medium, and high elevations (1706, 2,600, and 3200m, respectively) were reared in cool, ideal, and warm temperatures (15, 20, and 25°C); and each population at each developmental temperature was evaluated for survivorship, critical thermal maximum and minimum. Low elevation lines had lowest survivorship with increasing temperatures, and under cold stress high elevation flies were least negatively impacted by increasing temperatures, supporting the CVH. In contrast, under heat stress the medium elevation flies showed the lowest tolerance, but the highest plasticity. This work illustrates the importance of local adaptation to the future of species under climate change associate stress.

332 Emin Aydin, Ismail Uyanik

Flow Speed Affects the Smooth Pursuit Tracking and Active Sensing Movements of Weakly Electric Fish

Refuge tracking behavior in weakly electric fish has become popular in the literature since it allows analyzing the free behavioral response of the fish in a single linear dimension. However, these analyses are mostly conducted in stationary setups with no water flow. Our goal is to examine the effects of flow speed on the smooth-pursuit tracking response and the active sensing movements of the weakly electric fish during refuge tracking behavior. To achieve this, we built a flow tunnel to control the flow speed to study refuge tracking behavior in Apteronotus albifrons and Eigenmannia virescens. We use a cylindrical refuge without flooring to allow video recordings from below. The refuge is attached to a linear actuator that moves longitudinally to provide visual and electrosensory stimulation for the fish. We experimented with $N = 10$ fish using a sum-of-sines type stimulus, sweeping the 0-2 Hz range. The experiments were repeated with various flow speeds (0-20 cm/s), illumination (0-300 lux), and refuge structures (with and without windows). We recorded the kinematic response of the fish under each sensory condition. We segregated the active sensing movements from the smooth-pursuit in the frequency domain. The smooth-pursuit tracking performance of the fish deteriorated as the flow speed was increased. In accordance, fish increased the number of active sensing movements with increasing flow speed.

978 Rebecca Bachtel, Theo Modla, Anna Schumacher, Ioulia Bespalova, Heather Axen

Species survey and assessment of endosymbionts in wild-caught Drosophilidae from Rhode Island

Understanding species distributions of hosts and the distributions of their common, physiological impactful endosymbionts, is fundamentally important for evaluating community dynamics, susceptibility to invasion, resilience to climate stressors, and evolutionary processes. While fly species in the family Drosophilidae are commonly considered model organisms in research, little attention has been given to wild populations and their ecology. The presence of physiologically important bacterial endosymbionts such as Wolbachia and Spiroplasma, affects wild populations both beneficially and detrimentally, depending on host species and pressure from stressors such as parasites, parasitoids, and temperature. In this study we survey biodiversity of Drosophilidae around Narragansett Bay in Rhode Island and assess endosymbiont presence through amplification of partial fragments of COI/COII (Drosophila) and surface protein genes wsp (Wolbachia) and p18 (Spiroplasma). We identified 13 unique Drosophilidae species. Across all species collected, 0.23 were positive for Wolbachia; Spiroplasma results were inconclusive, but further testing is underway to assess prevalence. The species with the highest frequency of Wolbachia was Drosophila melanogaster, with 0.45 infected. These results represent a first step in better understanding the ecology of these organisms in Rhode Island.

1052 Hosain Bagheri, Paige Caine, Michael Goodisman, Daniel Goldman

Detecting Subtle Subterranean Movement Via Laser Speckle Spectroscopy

A diversity of animals, vertebrate and invertebrate, live all or a portion of their lives underground. Thus, it becomes advantageous to have methods for evaluating their individual and collective subterranean behaviors. While techniques exist for detecting underground structures and movements via the transmission and reception of acoustic and electromagnetic waves, their sensitivity and accuracy are contingent upon the number and locations of receivers in the medium. The laser speckle spectroscopy method introduces a noninvasive alternative, while providing high sensitivity in capturing events of movement. We focus a HeNe laser upon a water saturated medium (10% by mass) composed of 3 mm glass particles and use a digital camera to capture the backscatter speckle patterns, which shift upon millisecond events of, in principle, sub-micron movements. One potential application is exploring the mechanical movements of trapped and buried insects, such as ants, which has previously (Spangler, Science, 1967) been linked to collective rescue behavior by nestmates. By burying an ant at different life stages (i.e., larvae, pupae, and adult) 1 to 5 cm under a saturated medium, we capture their spontaneous movements using this method. As the ant's developmental stage progresses, the frequency and duration of movement increases. Since ants sense medium vibration through their body via their subgenual organs, we hypothesize that mechanical cues produced by buried ants could potentially aid collective rescue by nestmates.

1598 Hosain Bagheri, Salaheddin Ahmadi, Robin Koshy Mathews, Benjamin Bethke, Rebecca Fisher, Hamid Marvi

Electromyographic Study of Arm Muscle Functions in Octopus bimaculoides

The octopus arm is a muscular hydrostat that enables the octopus to explore its environment, capture prey, and achieve locomotion. The arm features transverse, longitudinal, and oblique muscles that allow the arm to shorten, elongate, bend, and twist. The previously reported orientation of these muscle fibers has been used to hypothesize which muscle groups activate to achieve specific movements. Through localized electromyography (EMG) recordings of the longitudinal and transverse muscles of Octopus bimaculoides, we have quantitatively confirmed the roles of these muscle layers. Six 50 micron diameter bipolar hook electrodes were inserted into a freshly amputated arm. This included four probes in the oral, aboral, and lateral longitudinal muscle regions and one in the transverse muscle for EMG recording using an electrophysiology data acquisition system. One probe was inserted into the axial nerve cord to electrically stimulate the arm through a signal generator. Experiments were conducted with the arm submerged and suspended in a water container with surrounding cameras for recording, all housed by a Faraday cage. The findings of this study can be used to inspire the soft robotics community to engineer solutions by designing robots primarily composed of soft materials, for applications such as minimally invasive surgery, wearable prosthetics, handling fragile objects, and search-and-rescue operations.

1029 Elizabeth Bliss Bagnato-Conlin, Young Kwon, Darcy Kelley

Phonotactic response to male advertisement calls in Xenopus females

Across vertebrate species, vocalizations are integral to social communication. Animals call to coordinate across social contexts including courtship, rivalry, and alarm signaling. In diverging populations, co-evolution of courtship signals and preferential responses to these signals can present a reproductive barrier, leading to speciation. Across 29 species of Xenopus, males generate unique advertisement calls during courtship, differing in tempo across species and pitch across species-groups. Phonotactic behavior to male calls has only been studied in X. laevis South Africa where females show preference towards their conspecific's calls when presented with calls from another species-group. It is unknown whether females maintain preference when exposed to calls of more closely-related species, and whether females of other species show similar preferential responses. To investigate this, we designed a 2-choice playback experiment where we broadcasted X. laevis and X. petersii male advertisement calls and a white-noise control to sexually receptive females of these two sister species. We calculated the proportion of time spent near a broadcasting speaker as a proxy for preference for the call. Female X. laevis exhibited significant preference for X. laevis calls even when presented with calls of its closest-related extant species. Surprisingly, X. petersii females showed no preference for their conspecific's call. Thus, female preference to advertisement calls does not seem to have evolved in parallel with male advertisement calls in Xenopus.

1602 David Baier, Morgan Turner, Erin Trammell, Inthavha Singharaj, Rudich Sasha, Ryan Carney

XROMM analysis of the distal forelimb of Alligator mississippiensis during the high walk

Crocodilians, given their relatively basal phylogenetic position within archosauria, provide a unique window for interpreting several locomotor evolutionary events. The origin of upright posture and return to "semi-erect" posture, bipedalism and return to quadrupedalism, and multiple origins of wings all involve major modifications of forelimb mechanics. We used XROMM to reconstruct distal forelimb joint motion of Alligator mississippiensis performing high walks on a treadmill. We measured elbow, forearm, radiale, and metacarpal movements. The humeroulnar (elbow) joint flexed during mid-stance and early swing, but also adducted and medially rotated through stance and rapidly abducted and laterally rotated during the stance-to-swing transition. The radius translated and rotated relative to the ulna within the forearm. The elongate radiale primarily aligned with the radius during stance and then flexed strongly during the stance-to-swing transition and underwent abduction/adduction and long axis rotation movements that appeared to correspond to loading and unloading of the limb. The five metacarpals were mobile throughout the stride cycle: spreading and dorsiflexing with respect to the wrist throughout much of early and mid-stance, and collapsing and plantarflexing at end-stance and swing. Future work will explore the rapid movements at the stance-to-swing transition which suggest possible elastic recoil from soft tissues. Additionally, we will compare differences between forelimb and hindlimb kinematics.

193 Leigh Bailey, Kimberly Rosvall, Alexandra Bentz

Effects of the maternal social environment on mechanisms of embryonic programming in songbirds

Females breeding in competitive environments often allocate more testosterone to offspring prenatally, leading to potentially adaptive changes in their developmental trajectory. However, the mechanisms by which this occurs are still unknown. Previous work suggests that maternally derived testosterone can have lasting effects on offspring gene expression via DNA methylation (i.e., stable changes in gene expression that do not alter DNA sequence). Here, we manipulated the breeding density of a highly territorial songbird (tree swallows) and, focused on their developing offspring, we measured genome-wide expression of neural mRNA and global methylation across development. Females breeding at high density experienced significantly higher rates of aggressive interactions and their eggs are predicted to have higher testosterone concentrations, which should correlate with the socially sensitive biological processes identified in our molecular analyses. However, because maternally derived testosterone is metabolized over the first 12 hours of development, we are additionally measuring concentrations of its primary metabolite, etiocholanolone. We predict etiocholanolone, while previously considered inactive, may directly correlate with socially sensitive processes or provide a more soluble pathway for embryonic steroid uptake. prior to conversion to a more metabolically active androgen. This work will provide insights into the mechanisms by which maternal social experiences are encoded into developing offspring.

464 Penelope Baker, Julie Butler, Lauren O'Connell

Parent Recognition and Preference in Poison Frog Tadpoles

Many neonates rely on their parents for their nutritional needs. Mimetic Poison Frog (Ranitomeya imitator) tadpoles indicate hunger and induce feeding by begging for food using body vibrations directed at a caregiver. Begging is energetically costly and increases predation risk, so tadpoles must decide with each visitor to their nursery if they should beg for food. Whether tadpoles recognize their parents or display begging to any potential caregiver, related or not, is unknown. We tested the hypothesis that tadpoles can distinguish their parents from other adults by exposing tadpoles to related and unrelated males and females and measured begging time and time near the stimulus. We found that tadpoles beg more to their biological mom than un-related female caregivers, but do not distinguish their biological fathers from other males. Next, we investigated how the quality of parental investment impacts begging, parental preference, and boldness. While less parental care leads to more begging, only tadpoles raised by "good" parents exhibit a preference for their mom. Interestingly, tadpoles with more invested parents were more active around a novel non-social stimulus. Together, our data indicate that the quality of parental investment drives parent recognition and preference, and high parental investment produces bolder tadpoles. These experiments fill an important gap in our understanding of the life-or-death decisions tadpoles make about begging with each visitor to their nursery.

1574 Zachary Baker, Doug Fudge, Andrew Lowe, Dakota Piorkowski

The Biomechanics of Hagfish Eggs

Hagfish eggs possess mucus-covered clusters of hooked filaments at each pole. Each egg is around 2 cm long with filaments that extend 200-400 μm out from the egg tips. Filaments are 20 μm wide at the stalk and terminate at 60 μm wide structures that resemble mushroom caps. These so-called "anchor filaments" are believed to join hagfish eggs, but the timing and biomechanics of egg-egg attachment are not well understood. For example, some freshly laid eggs possess a dome of elastic mucus that prevents attachment to other eggs. In this study, we measured the force required to separate pairs of attached hagfish eggs and found that the average attachment force in seawater was 0.2 N ± 0.02 N, with similar force values for subsequent separations. The material properties of anchor filaments were explored by conducting tensile tests on individual filaments to failure. These tests reveal that anchor filaments can stretch to strains of about 0.3 before they break and possess a Young's modulus similar to that of collagen bundles. Videomicroscopy of filament interactions during cap engagement and separation revealed both bending and torsion of the caps and filaments. Ongoing work is exploring the function of the hooks in the wild and the ontogeny of filament and cap formation.

1586 Dianne Baker, Kyle Schultz, Katherine Crowder

Impacts of Research Experiences and Academic Supports on Student Retention, Success, and Identity

The Jepson Scholars Program was designed to improve retention, graduation, and career or post-graduate placement, for students majoring in natural sciences at the University of Mary Washington (UMW), a public, predominantly undergraduate institution. Funded by NSF S-STEM, the program provided financial and academic support to two cohorts of 10 academically talented, low-income students planning to major in biology, chemistry, physics, or earth/environmental science. Our goal was to increase student success through a combination of established best practices and an innovative early research experience. Prior to matriculation, Scholars participated in a 5-week mentored research program. Then, in their first academic year, Scholars enrolled in STEM-themed first-year seminars and common sections of introductory courses, and participated in peer-assisted study sessions. Scholars also participated in a 10-week summer research program at UMW after their second or third year. A mixed methods approach was used to track the growth and perspectives of the Scholars, focusing on academic performance, research experiences, scientific identity, and career aspirations. Cohort 1 Scholars graduated in 2021-22, and the cohort met all academic and career benchmarks. Notably, 95% of Scholars across both cohorts also conducted research during one or more academic years, greatly exceeding participation by non-Scholars at UMW (39%). Exit surveys indicate that program features, and particularly the pre-matriculation research, promoted students' identities as scientists and success as science majors starting postgraduate careers.

561 Leah Bakewell, Kelly Wuthrich, Noah Gripshover, Anabarbara Gonzalez, Maria Alcivar, Claire Williams, John David Curlis, Stephen Greiman, Samir Gulati, Renata Pirani, Noa Ratia, Daniel Romero, W. Owen McMillan, Michael Logan, Christian Cox

Parasite diversity and abundance in an assemblage of Anolis lizards in Panama

Our understanding of biodiversity assembly in communities is biased towards free-living macro-organisms. However, most organisms are accompanied by a suite of symbionts that can include mutualists and parasites. While the dynamics of biodiversity within communities (i.e. which taxa are present or absent in a community and why) are relatively well-studied, relationships between the diversity of symbionts and the diversity of hosts within a community remain understudied. In particular, it is important to understand the shared and unique aspects of parasite communities among hosts within diverse communities, such as those that live in the lowland tropics. We assessed parasite burden across seven species of Anolis lizards coexisting at a single site in Panama by identifying and counting ectoparasites and dissecting the body wall, lungs, liver, and digestive tract of each lizard in order to identify any endoparasites. The ectoparasites collected from these anoles included trombiculid mites and ticks, and the endoparasites included cestodes, nematodes, and trematodes. While each host species we analyzed had some combination of the endo- and ecto-parasites listed, we found differences in the abundance and composition of parasites within and across each species. Overall, the quantification of the diversity and abundance of parasites of these tropical anoles could help explain how parasite diversity is related to host diversity within biological communities.

29 Deon Bakkes, Anne Ropiquet, Lidia Chitimia-Dobler, Dikeledi Matloa, Dmitry Apanaskevich, Ivan Horak, Ben Mans, Conrad Matthee

Adaptive Radiation and Speciation in Rhipicephalus ticks

Rhipicephalus are a species-diverse genus of ticks, mainly distributed in the Afrotropics with some species in the Palearctic and Oriental regions. Current taxonomic consensus comprise nine informal species groups/lineages based on immature morphology. We integrate biogeographic, ecological and molecular lines of evidence to better understand Rhipicephalus evolution. Phylogenetic analysis based on four genes (12S, 16S, 28S-D2 and COI) recovered five distinct clades with nine descendant clades generally congruent with current taxonomy. Historical biogeography is inferred from molecular divergence times, ancestral distribution areas, host-use and climate niches of four phylogenetically significant bioclimatic variables (isothermality, annual, seasonal and diurnal temperature range). Novel hosts enabled host-linked dispersal events into new environments, and ticks exploited new hosts through nested predator-prey connections in food webs. Diversification was further induced by climate niche partitioning along gradients in temperature range during off-host periods. Ancestral climate niche estimates corroborated dispersal events by indicating hypothetical ancestors moved into environments with different annual and seasonal temperature ranges along latitudinal gradients. Host size for immature and adult life stages was important for dispersal and subsequent diversification rates. Clades that utilise large, mobile hosts (ungulates and carnivores) early in development have wider geographic ranges but slower diversification rates, and those utilising small, less mobile hosts (rodents, lagomorphs and afroinsectivores) early in development have smaller ranges but higher diversification rates.

1439 Annika Baldwin, Paul Johnson, Jeffrey Garner, Ellen Strong, Nathan Whelan

Molecular ecology, conservation, and taxonomy of the freshwater snail Elimia melanoides

Freshwater gastropods have experienced substantial declines in North America due to environmental changes from water pollution and river impoundment. For example, 32% of gastropods originally found in the Mobile River Basin are presumed to be extinct, and 79% of species in the family Pleuroceridae are imperiled. Given the importance of pleurocerids to many freshwater ecosystems in eastern North America, their decline

risks the health of many rivers and streams. One pleurocerid species presumably lost from over 70% of its historic range is Elimia melanoides. Little is known about the molecular ecology of E. melanoides, and our current taxonomic concept of the species may not reflect true species diversity. Using 3-RAD library prep and Illumina sequencing, we assessed landscape genetic patterns and the systematics of the species to determine the number of separate species within what has been previously assigned to E. melanoides. Our data suggest the current concept of E. melanoides contains two distantly related species with similar outward appearance. Thus, the current range of E. melanoides is more restricted than previously thought. We found high population structure and limited admixture within each species, indicating that the extirpation of any one population would result in the loss of unique evolutionary potential. Our data also indicate convergence in shell morphology between the two species, rendering the shells of limited use for species circumscription and identification.

1608 William Ballentine, Kelly Dorgan, Allison Penko

Biostabilization of marine sands by microalgae and meiofauna

Microalgae (e.g. diatoms) in sediments secrete a complex, matrix of carbohydrates and proteins known as extracellular polymeric substances (EPS) that adhere sediment grains together and bind the surface of marine sands into a cohesive layer. EPS increases the critical shear stress required to dislodge and initiate mobilization of sediment grains, yet its effects are generally neglected in models of sediment transport, erodibility, and bed morphology. Meiofauna (a size class of animals less than 1mm) consume both EPS and diatoms, affecting the production and concentration of EPS and the growth rate of diatoms. To investigate the relationship between biomats and the shear stress required to initiate motion of marine sands, we cultured living EPS biomats using the diatom Cylindrotheca sp. for seven- and fourteen-day periods in individual microcosms. To investigate the effect of meiofauna on this relationship, EPS mats were grown in both faunaless microcosms, and microcosms inoculated with either small or large populations of meiofauna. Microcosms were placed in an open channel flow tunnel and exposed to unidirectional flow of varying magnitudes while sediment motion and mat winnowing were recorded and tracked using high resolution cameras. Quantifying the biostablizing potential of microalgal EPS mats and meiofaunal grazing on marine sediments increases our understanding of the effects small-scale biological interactions have on broad scale physical processes like erosion and can ultimately improve models of sediment transport.

609 Colin Bamford, Jack Nix, Paul Swiney, Tyson Hedrick, Vrishank Raghav

Mitigation Response of a Red-Tailed Hawk to Vertical Gusts

Here we study the biomechanical and aerodynamic response of a red-tailed hawk to vertical gusts. One major obstacle to stable unmanned aerial vehicle (UAV) or small aircraft flight is extreme gusts acting on the vehicle's airframe. Small vehicles struggle to fly through significant gusts, hampering their transport or defense applications. To solve such engineering problems, inspiration can be taken from natural gust responses employed by a bird. To study these responses, an indoor flight arena was constructed incorporating perches, gust generators, and high-speed cameras. Six industrial fans were used to produce vertical gusts with average speeds of 4 to 8 m/s at bird height, corresponding to different gust intensities. As the hawk flew through the tunnel, two Phantom VEO 640L and two Phantom VEO 4k 990L captured the three-dimensional motion occurring just before, during, and after the gust. The hawk's wing, tail, and body were tracked to measure their response to the gust. A lower-order unsteady aerodynamic model was applied to the response data to estimate lift coefficients across the wing during gust interaction. The hawk used a similar downward-pitching wing response at all gust intensities, while the tail response varied. These results suggest that this bird could not fully mitigate gust effects with its wing alone, and that the tail response plays a role in producing stable flight through a gust.

53 Aidan Bannon, Simon Thill, Sophie Frem, S. Tonia Hsieh, Suzanne Kane

Mind the trap: how spotted lanternflies negotiate terrain transitions during climbing

Detection and management of the invasive spotted lanternfly (SLF, Lycorma delicatula) is a pressing environmental concern. This pest is rapidly spreading across the eastern US, where it feeds on and injures native plants, crops, and trees, while secreting a sugary substance that promotes the growth of black sooty mold. The effectiveness of SLF trap designs has been studied using field-based catch-and-report methods in which different traps are deployed under identical conditions and the number of insects captured is recorded after a set time. These studies accurately measure trap effectiveness in the field, but do not reveal how SLF

interact with and escape from traps, information useful for improving control methods. This study considered how SLFs negotiate the plant-trap interface using methods developed to study locomotion at terrain transitions. We used video analysis to observe 1st-4th instar SLF nymphs as they climbed a tree trunk and interacted with SLF sticky traps and circle traps. This data was used to categorize their behaviors on or before the trap-bark interface and on the trap itself (e.g., climbing speeds and paths in relation to surface features, how SLFs negotiate the trunk-trap transition and the trap's surface, and trap escape strategies and success rates). Based on our observations, we also designed and tested kirigami-based sticky trap modifications meant to take advantage of SLF natural behaviors and increase trap effectiveness.

80 Jasmine Yimeng Bao, Hannah Gruner, Bradley Davidson

Heart development in the tunicate Ciona robusta (Ciona intestinalis type A)

In the phylum Chordata, a compact, anteriorized heart is conserved in tunicates and vertebrates but not cephalochordates. The heart, therefore, appears to represent a shared, derived trait that arose in the common ancestors of vertebrates and tunicates. Embryonic cardiac development in Ciona robusta, a sessile tunicate, has been extensively studied, but heart organogenesis and morphology in post-larval stages are poorly characterized. Here we propose a novel model for Ciona heart growth during early juvenile through adult stages. We have found that a linear population of cells, termed the undifferentiated line (UL), runs along one side of the tubular myocardium and enlarges into two distal triangular zones. We hypothesize that distal UL enlargements are growth zones that differentiate into myocardial and pericardial cell types. We have begun to characterize distinct transitional populations connecting these distal enlargements to mature myocardium and pericardium. The myocardial transitional population exhibits morphological features consistent with those of transit-amplifying cells. Cell proliferation assays indicate that elevated proliferation occurs in distal regions of the adult and juvenile hearts and is often localized along the UL and distal growth zones. Future directions include scRNA-seq to confirm Ciona cardiac cell types and to validate our current cardiac growth model. A more sophisticated understanding of heart organogenesis in basal chordates such as Ciona will provide insight into the evolutionary origin of a compact, central circulatory organ in addition to peripheral vessels.

551 Shir Bar, Shai Avidan, Roi Holzman

Low feeding rates of larval fish persist across a range of environmental conditions

The notoriously inefficient feeding of early-stage larval fish has been speculated to drive their "critical period" of extreme mortality. Larval feeding success is constrained by the viscous hydrodynamic regime they experience at small size, which is ameliorated as larvae grow. However, how larval feeding success is affected by variation in environmental conditions is poorly understood. Here, we investigated age-dependent effects of temperature, pH, O2 and turbulence on larval fish feeding in large mesocosms. We tracked these parameters and the strike rate of undisturbed larvae for 17 cohorts of Sparus aurata larvae throughout their ontogeny; collecting 268 high-speed videos, each $\sim$ 5 min in length. We then constructed a pipeline of machine learning algorithms to detect feeding events within this massive dataset. In the mesocosms, strike rates were $\sim$0.01 times lower than in the laboratory. These low rates led to high occurrences of false detections by our pipeline, requiring a manual review of its outputs; though still improving analysis times considerably. Additionally, we observed a repertoire of frequent abrupt behaviors, including c-start, and spitting of prey. Although more common than feeding behaviors, their relationship with larval growth and well-being is unclear. Statistical analysis of over 300 feeding strikes indicated that larval fish maintain an extremely low feeding rate. This happens regardless of environmental conditions and despite of high encounter rates with prey in our mesocosms.

1769 Nicole Barber, Christophe Soligo, Anjali Goswami

Morphological disparity and rates of evolution in the primate astragalus and calcaneus

Primates demonstrate one of the most diverse ranges of locomotion among mammals. The tarsal skeleton, which forms the hind- and midfoot, is likely to have played a critical role in the evolution of this diversity, often undergoing significant remodelling in clades with specialised locomotion. As a result, we expect that morphological disparity and rates of evolution have varied, both between elements and across lineages, in response to different functional pressures.Here we characterise disparity and rates of evolution in the primate astragalus and calcaneus, applying 3D geometric morphometric approaches to a dataset of CT and surface scans representing 45 extant species. We developed landmark schemes employing both fixed landmarks and curve semilandmarks to capture the shape of the astragalus and calcaneus, including defining articular surfaces. We analysed shape data in a phylogenetic framework to calculate disparity and rates of evolution for each element. The highest levels of disparity in both elements were observed in strepsirrhines, notably in lorisiforms. The lowest disparity was observed in platyrrhines for the astragalus, and in catarrhines for the calcaneus. By contrast, the lowest rates of evolution were observed in strepsirrhines, particularly lorisiforms, and the highest rates were observed in catarrhines for both elements. These results suggest a disconnect between evolutionary rates and disparity in primates, with exploration of novel regions of morphospace coupled with specialisation that may hinder further evolution.

762 Raven Barbera, Tony Williams

Is egg mass a phenotypically-plastic trait in the European starling, Sturnus vulgaris?

Egg mass varies markedly within populations, with the largest eggs measuring up to twice the size of the smallest, and ∼ 70% of this variation is due to variation among individual females (Christians 2002). In contrast, some studies continue to suggest that there can be substantial, 'adaptive' plasticity in egg investment in individual females (cf. among female differences). However, numerous meta-analyses have failed to find compelling evidence for fitness advantages of large egg size. If egg size is a phenotypically-plastic life-history trait, we would predict that it would show potentially adaptive variation in different ecological contexts. In our study population of European starlings (Sturnus vulgaris), most females are double-brooded with second clutches being produced in different ecological conditions. There is seasonal variation in other life-history traits, these also vary among years and with time (laying date). Here we tested whether egg mass showed similar relationships, i.e. whether it is a plastic life-history trait. We predicted that individual females would adjust egg size in second clutches, where productivity and other traits are affected by generally poorer conditions and, consequently that egg mass would have low repeatability among broods. Preliminary analysis suggests that, on average, individual females show no significant seasonal change in egg mass between broods. Marked individual variation in egg mass therefore remains unexplained and should be a focus of future research.

1287 Nicole Barbera, Joseph Leese

Does the relative size of potential mates affect the mate search process in female convict cichlids?

Sexual selection is the evolutionary mechanism driven by the selection of mates with traits preferred by the other sex (intersexual selection) or via competition within members of the same sex (intrasexual selection). Here we explore the mate search process of monogamous female convict cichlids, Amatitlania nigrofasciata, and what effect the relative size of potential mates may have on this process. We hypothesized that females would more quickly form a preference for a male when provided with males much larger than herself, compared to males closer to her own size, as previous studies have shown female preference for larger males. The mate search process was observed using two treatment groups consisting of males that were size-matched to each other, with either a 5-10% or 30% larger relative size difference in standard length from the focal female. Aquariums containing dividers that only permitted the focal female to travel throughout the tank were used for observation of focal female's behavior. We found that the relative size of two potential mates does not affect the patterns of time and visits females spend in the search process, although there was a significant effect on the behavior. This suggests that relative difference in quality between two mates may have more of an impact on the mate search process than the relative difference between the female and mates available to her.

1615 Theresa Barden, Diraliz Cruz, Sara Filler, James Waters

Rapid antennation by Brachyponera chinensis needle ants: does it pass the vibe check?

Needle ants, Brachyponera chinensis, are a species of ponerine ants originally from the Asian continent, established as an invasive species in the mid-Atlantic region of the eastern USA, and recently identified from a single location in Rhode Island, coincidentally, on our college campus. While studying their metabolic physiology, we observed rapid antennation behaviors both around their nest sites in the field and in artificial enclosures within the lab. We are characterizing the nature of these relatively unique and intriguing interactions, specifically documenting the patterns and high-speed kinematics of antennal contacts, the demography of their occurrences, and their effects on individual trajectories and behaviors. This project was supported by funding from the National Science Foundation (IOS-1953451).

1628 Katie Barott, Kristen Brown, Matheus Mello-Athayde, Eugenia Sampayo, Aaron Chai, Sophie Dove

Environmental memory of extreme diel pCO2 variability promotes coral cellular acid-base homeostasis

Ocean acidification is a growing threat to coral growth and the accretion of coral reef ecosystems. Corals inhabiting environments that already endure extreme diel pCO2 fluctuations, however, may represent acidification-resilient populations capable of persisting on future reefs. Here, we examined the impact of diel seawater pCO2 variability on the cosmopolitan reef-building coral Pocillopora damicornis originating from reefs with contrasting environmental conditions (variable reef flat vs. stable reef slope) following reciprocal exposure to stable (218 ± 9) or variable (911 ± 31) diel pCO2 fluctuations (μatm) in aquaria over 8 weeks. Endosymbiont density, photosynthesis and net calcification rates differed between origins but not treatment, whereas primary calcification (extension) was affected by both origin and acclimatization to novel pCO2 conditions. At the cellular level, corals from the variable reef flat exhibited less intracellular pH (pHi) acidosis and faster pHi recovery rates in response to experimental acidification stress (pH 7.40) than corals originating from the stable reef slope, suggesting environmental memory gained from life-long exposure to pCO2 variability led to an improved ability to regulate acid-base homeostasis. These results highlight the role of cellular processes in maintaining acidification resilience and suggest that prior exposure to pCO2 variability may promote more acidification resilient coral populations in a changing climate.

1660 Loubna Baroudi, Alex Shorter, Stephen Cain, Kira Barton, Mark Newman

The economy of walking in the real world.

It is often assumed that humans select energetically optimal locomotion strategies: movement patterns are driven by the central nervous system that results in walking speeds that minimize the cost of transport (CoT). However, experimental investigation of human movement has traditionally been carried out in laboratory environments. In this work, we used wearable sensors and lab measurements to investigate whether humans select gait speeds that minimize CoT in the real world. Gait speed estimates were derived from a foot-worn inertial measurement unit. Lab-based CoT estimates over a range of walking speeds were used to complement real-world data collection. Metabolic rate was measured using a portable indirect calorimetry system, and motion capture data were collected during treadmill walking over a range of speeds. We fit a 2nd order polynomial to the CoT vs. speed curve, and defined a minimum speed range as minimum CoT + 10%. The speed range that minimized CoT was then compared to the range of speeds selected by participants during real world data collection (10% most used speeds). We found that speeds used by the participants during daily life were consistently higher than the subject-specific lab-based optimal speed range ($p < 0.001$). As such, these results suggest that locomotion strategies selected in the real world are influenced by a variety of factors in addition to energetic cost.

71 Sofia Barreira, Andreas Baxevanis

Deducing the Common Ancestor of the Nucleolar Transcription Factor and its Role in Regeneration

The process of regeneration depends on proper cell growth throughout numerous cycles of cell division that, in turn, depend on the timely and flawless assembly of ribosomes, regulated by the binding of the nucleolar transcription factor. Interestingly, protein domain structural analyses indicate that Hydractinia, a colonial marine cnidarian and a proven model for the study of regeneration with pluripotent stem cells present throughout its life, does not possess the canonical UBF protein found in humans.This absence suggests that Hydractinia may employ a different mechanism for regulating transcription of rDNA genes than that used by higher eukaryotes, perhaps providing important insight as to the regenerative capacity of this organism. A comparison of proteomes generated from de novo assembled transcriptomes across a wide taxonomic range indicates the canonical UBF protein is also not present in other early branching phyla, further suggesting the involvement of a novel protein or UBF precursor. We are using phylogenetic inference methods to deduce the common ancestor of the nucleolar transcription factor (and associated proteins) to establish its evolutionary history and putative role in regeneration. These studies have the potential to advance our understanding of the initiation and maintenance of ribosome biogenesis, an established canonical hallmark of cell growth and proliferation, enabling research into the mechanisms underlying regulation of this important biological phenomenon, with the results having potential applicability to human health.

1173 Melissa Bates

Long-term impacts of prematurity on cardiorespiratory control

Survival of extremely low birth weight (ELBW) infants has improved dramatically over the past 20 years. The nature of these advances is multifactorial and relates to increased appreciation of organ vulnerability, improved understanding of disease mechanisms, enhanced diagnostic precision, and improved therapeutic options. Unfortunately, enhanced survival does not necessarily guarantee against adverse long-term outcomes in adulthood. This talk will highlight the impact of prematurity on the ability to regulate ventilation in response to hypoxic and exercise-induced stress, and the durable impact of prematurity on the systemic vasculature. Together, these physiological phenotypes may underlie the increased risk of early onset heart failure observed in this population.

1057 Nick Battista

Paddling and squirming: exploring swimming performance in an idealized Tomopteris model

The soft-bodied, midwater polychaete Tomopteris is an interesting swimming system. Not only do Tomopteris swim continuously throughout their life, they also perform two modes of locomotion simultaneously: metachronal paddling and bodily undulation. Tomopteris have two rows of flexible parapodia positioned on opposite sides of its body. Although each row performs a metachronal beating pattern, they paddle out of phase to one another. Both of these paddling behaviors occur in concert with its lateral bodily undulation, which appears to further displace its parapodia, assisting the metachronal paddling process. In this work we created a self-propelled, idealized computational fluid dynamics model of a Tomopteris to better help understand how these two modes of locomotion synergize to generate effective swimming. In particular, we investigated how variations of parapodia length, paddling amplitude, and undulation amplitude affect its swimming performance.

594 Gia Bautista, Bradley Davidson, Hannah Gruner

Characterizing cardiac cell proliferation in the tunicate Ciona robusta

Ciona robusta have been widely used as a model organism to study heart development because of their genomic and cellular simplicity and close evolutionary relationship to vertebrates. Classic studies of the adult Ciona heart have identified different cell types: pericardial, myocardial, and an undifferentiated line, possibly composed of residual stem cells, running along one side of the myocardium. We have begun characterizing the undifferentiated line, including extensions in the distal regions of the heart that may serve as myocardial and pericardial growth zones. Additionally, we have shown that the myocardium's distal regions have relatively high amounts of proliferation. Intriguingly, the Ciona heart can regenerate in response to injury, a process that has not been characterized. We are currently investigating normal growth patterns and growth in response to injury. Here we show that in uninjured hearts, distal myocardial cells proliferate at a faster rate than apical myocardial cells. Cell proliferation was detected using EdU cell labeling. Quantification was performed using confocal imaging and image analysis software. This data supports the hypothesis that the distal region represents a proliferative zone. Our preliminary results also indicate that pericardial cell proliferation has greater variance in the apical and distal regions than in myocardial cells. To better understand the role of these proliferative distal regions during regeneration, follow-up studies must investigate the injury response within transitional myocardial and undifferentiated line cells.

384 Ursula Beattie, Emma Rosen, L. Michael Romero

Chronically stressed house sparrows prioritize wound healing over constitutive innate immunity

Previous studies show a decrease in immune function with chronic stress, however the majority of studies use only one or two bouts of stress. To study immune function with chronic stress in a more ecologically relevant manner, we varied both the intensity and duration of applied chronic stress in house sparrows (Passer domesticus) over a period of 6 months. The four treatment groups were lowest stress, low stress, medium stress, and high stress. To evaluate immune function, we performed a 4 mm biopsy punch on each bird and monitored healing every day until wounds were fully healed. We hypothesized that higher stress birds would heal their wounds more slowly and have a lower bacterial killing capacity. Paradoxically, the opposite was true – high stress birds healed their wounds fastest. Additionally, regardless of treatment group, all birds dramatically reduced their bacterial killing capacity after wounding, perhaps to shift immune resources to a more immediate concern (the wound). Furthermore, post-biopsy increases in plasma uric acid derived from food suggests that birds ate more to compensate for increased energy expenditure during wound healing. When considering how a wound might affect a bird in its natural habitat, a visible wound might signal to a conspecific or predator that the bird is weakened, so prioritizing healing over other physiological processes would be the best defense.

1823 Tsevi Beatus, Noam Lerner

Flying mosquitoes use their legs as inertial rudders

Animals use inertial steering to generate torque on their body by rapidly rotating their limbs or tail. The torque that the body exerts on an appendage is accompanied by a counter torque that can rotate the body. Cheetahs, lemurs, kangaroos, and some lizards use their tails to stabilize their body, bats use their wing inertia to roll, human athletes use their limbs in extreme maneuvers and less athletic humans swing their arms to regain balance after a stumble. While inertial steering has been studied in many animals, to the best of our knowledge, it has not yet been demonstrated in free flying insects. Here, we show that Culex pipiens mosquitoes use their legs, together with their wings, to recover from mid-air perturbations. We use a magnetic perturbation experiment with an array of fast cameras and a novel tracking algorithm, to measure mosquito flight kinematics during these maneuvers. In response to an external perturbation in the roll or pitch axis, the mosquito rapidly swings some of its legs in the same direction of the perturbation, to generate an impulsive and correcting counter torque. Our analysis shows that despite the small mass of the legs relative to the body, and although they can be used only once per maneuver, mosquito legs have significant inertia and move very fast, which make them effective inertial rudders.

618 Kelsey Beavers

Stony Coral Tissue Loss Disease Triggers in situ degradation of Dysfunctional Endosymbionts

Stony Coral Tissue Loss Disease (SCTLD), one of the most pervasive and virulent coral disease outbreaks on record, affects over 22 species of reef-building coral and continues to decimate reefs throughout the Caribbean. To understand how different coral species and algal endosymbionts respond to this disease, we leveraged a disease transmission experiment in which five species of coral with varying susceptibilities were exposed to SCTLD. The gene expression profiles of coral hosts and their endosymbionts were examined independently by bioinformatically separating the RNA-seq reads prior to analyses. We show that SCTLD exposure induces significant transcriptional changes in both the coral animal and their algal symbionts, altering normal host-symbiont interactions. We identify orthologous coral genes exhibiting lineage-specific differences in constitutive expression that correlate to disease susceptibility, as well as orthologous genes that are significantly differentially expressed in all coral species in response to SCTLD infection. Specifically, we find that SCTLD-exposure induces initial shifts in endosymbiont gene expression, followed by expression of coral genes involved in phagocytosis and starvation. Overall, our results indicate that SCTLD infection induces in situ degradation of dysfunctional endosymbionts across species and that the severity of disease is strongly influenced by the identity of the symbiont genera within the coral.

79 Daniel Becker, Amanda Vicente-Santos, Guang-Sheng Lei, Michael Janech, Alison Bland, Brock Fenton, Nancy Simmons, Ryan Relich, Benjamin Neely

Leveraging serum proteomics to characterize bat immune phenotypes and response to viral infection

Bats are natural hosts for many viruses. Our ability to characterize immune mechanisms of viral tolerance in wild bats is limited by small sample volumes and few species-specific reagents. Proteomics holds promise for illuminating immune factors involved in bat responses to infection, because it can accommodate small sera volumes and can thus be applied to large and small species and in longitudinal studies. As the serum proteome includes proteins secreted from not only blood cells but also proximal organs, it provides a broad characterization of immune proteins. We used 2 μL serum, LC-MS/MS, and data-independent acquisition to characterize serum proteomes of wild vampire bats, compared protein abundance to humans, and tested how proteomes differed by coronavirus infection. We identified nearly 600 proteins in bat serum covering five orders of magnitude. Bats shared most proteins with humans, but many innate immune proteins had greater abundance in bats. Infected and uninfected bats did not differ in proteome composition, and we observed weak evidence for differential protein abundance. Classifier analyses identified 32 protein biomarkers of infection, and enrichment analyses suggested coronavirus-infected bats had upregulated cellular immune response and downregulation of complement. Our findings highlight the untapped potential of serum proteomics to characterize wild bat immunity. Applying a proteomic approach across many bat species could improve our understanding of the evolution of bat immunity and mechanisms of virus tolerance.

450 Adam Becker, Heather Watts

A role for gonadal steroids in the onset of spring nomadic migration in pine siskins (Spinus pinus)?

Most of what we know about endocrine regulation of migration comes from studies of obligate migrants, which make consistent movements from year to year. Less well studied are facultative migrations, which can be highly variable in timing and/or direction. In obligate migrants, increases in circulating gonadal steroids, particularly testosterone, appear to play an important role in stimulating physiological preparations for migration (e.g., hyperphagia and fat deposition) and the expression of migratory behavior in spring. Some facultative migrants also express a period of spring nomadism; however, whether gonadal steroids play a similar role in coordinating this migratory transition in these species is unknown. The pine siskin (Spinus pinus) is a songbird that exhibits spring nomadism, which is stimulated in part by increasing photoperiod. Using this species, we test the hypotheses that circulating gonadal steroids stimulate (i) physiological preparation for migration and (ii) expression of migratory behavior in a nomadic migrant. These hypotheses predict that blocking the action of androgens and their aromatization to estrogens around the spring migratory period will inhibit (i) physiological preparations and (ii) migratory behavior, respectively. To test these predictions, we subcutaneously implanted wild-caught male pine siskins with flutamide (an androgen blocker) and 1,4,6-androstatriene- 3,17-dione (ADT, an aromatase inhibitor) in combination, or empty implants as a control, just prior to spring nomadism and monitored changes in (i) body condition and (ii) locomotor activity.

213 Avraham Beer

Biophysical aspects underlying the swarm to biofilm transition

Bacteria organize in a variety of collective states, from swarming—rapid surface exploration, to biofilms—highlydense immobile communities attributed to stress resistance. It has been suggested that biofilm and swarming areoppositely controlled, making this transition particularly interesting for understanding the ability of bacterialcolonies to adapt to challenging environments. Here, the swarm to biofilm transition is studied in Bacillus subtilisby analyzing the bacterial dynamics both on the individual and collective scales. We show that both biological andphysical processes facilitate the transition. A few individual cells that initiate the biofilm program cause nucleationof large, approximately scale-free, stationary aggregates of trapped swarm cells. Around aggregates, cells continueswarming almost unobstructed, while inside, trapped cells are added to the biofilm. While our experimental findingsrule out previously suggested purely physical effects as a trigger for biofilm formation, they show how physicalprocesses, such as clustering and jamming, accelerate biofilm formation.

1788 Sophia Beery, Rachel Oslon, Stephane Montuelle, Hannah Curtis, Susan Williams

The effect of sensory input on occlusal dynamics during chewing tough foods in ferrets.

In mammals, occlusal interactions are assumed to rely on sensory information from the oral cavity about the properties of the food being chewed to affect motor output. However, the morphology of the feeding apparatus also influences the occlusal kinematics. In many carnivorans, such as the ferret, jaw joint and occlusal morphology limit the range of motion that can occur during chewing. Here, we use X-ray Reconstruction of Moving Morphology to examine how differences in food toughness impact the kinematics and temporal dynamics of occlusion during chewing in ferrets chewing chicken and jerky before and after complete oral sensory nerve blocks. We hypothesize that differences in food toughness will alter occlusal dynamics but that blocking sensory input will initially not significantly impact these dynamics due to the restrictive TMJ and carnassial morphology of ferrets that guide overall movements. Prior to and after the block, there were no differences in occlusal duration between foods, although occlusal duration significantly increased after the nerve block for chicken ($p < 0.01$), but not for jerky. No translations and only a subset of jaw rotations (especially Ry) differed significantly between foods or pre- or post-nerve block. Thus occlusal dynamics respond minimally to changes in food toughness and loss of oral sensory information. Rather jaw joint and tooth morphology limit the extent to which fine adjustments can be made during chewing tough

1259 Rachelle Belanger, Mariana Muskovac, Diana Chammout, Kenia Contreras, Dorian Goolsby, Reema Hamdan, Christina Rabban, Kendra Evans

A morphological and biochemical analysis of crayfish tissues post-atrazine exposure

Atrazine is one of the most widely used herbicides in the United States. It is applied to agriculture areas to control the growth of broadleaf weeds. Atrazine can enter local streams and rivers through run-off, ground water seepage, and regional transport. Several studies have shown that atrazine exposure has negative impact on aquatic organisms, including crayfish. In this study, we seek to determine if atrazine-induced changes in morphology are correlated with increased atrazine concentrations in the hemolymph and hepatopancreas of atrazine-exposed crayfish. We exposed crayfish (Faxonius virilis) to 100 ppb (μg/L) atrazine for 96 hours. Following this acute exposure, we collected hemolymph and hepatopancreas tissue for morphological and biochemical analyses. When the morphology of the hepatopancreas of atrazine-exposed crayfish was examined, we noted that lobules lumens were dilated, tubule tissue was degenerated and also contained an increase in vacuoles. An assessment of hemolymph and hepatopancreas atrazine concentrations was also performed using liquid chromatography-mass spectrometry (LC-MS).

Data presented will correlate exposure and tissue concentrations with the morphological changes visualized. Overall, atrazine exposure may lead to increased concentrations in the tissues and long-term damage, resulting in impairments to detoxification, digestion, and molting.

1302 Rachelle Belanger, Diana Chammout, Hussien Hazime, Mariana Muskovac, Gregory Grabowski

Mitotic activity in the hepatopancreas of crayfish (Faxonius virilis) following an atrazine exposure

Atrazine exposure at environmentally relevant concentrations causes DNA damage, apoptosis, and changes in the lobules of the hepatopancreas of both crayfish and fish. Post-exposure, one of the questions that has yet to be addressed is whether or not tissue repair and cell regeneration occurs. In this study we wanted to determine if cells of the hepatopancreas could regenerate following an acute exposure to atrazine. To determine if mitotic activity occurs in the hepatopancreas post-atrazine exposure, crayfish were injected with 5-bromo-2'-deoxyuridine (BrdU) prior to a 10-day, 80 ppb atrazine exposure. Control crayfish were treated with a vehicle control (0.004% ethanol). Following the 10-day exposure, crayfish were transferred to atrazine-free water, and the hepatopancreas of crayfish was examined for BrdU localization at regular intervals for 20 days. A critical aspect of determining whether crayfish can recover from exposure to atrazine during the seasonal period is the ability of hepatopancreas cells to regenerate.

850 Anat Belasen, Anna Savage, Michael Campana, Kevin Mulder, Robert Fleischer, Kelly Zamudio

Leveraging the Past to Preserve the Future:Using Museomics to Understand Amphibian Disease Responses

Historical genomics can provide insights into wildlife responses to stressors through time, with applications to future conservation efforts. For example, predicting future susceptibility to the frog-killing fungus Batrachochytrium dendrobatidis (Bd) is difficult in amphibians that show variable disease outcomes; tracking historical responses of amphibian populations to Bd outbreaks may reveal markers that can serve as signals of future susceptibility. In the lowland leopard frog, Rana yavapaiensis, both genetic and environmental factors may drive observed variation in Bd susceptibility across the species' extant range (Arizona). A number of genetic loci, some of which are known to mediate immune function, are hypothesized to play significant roles in Bd susceptibility in R. yavapaiensis and other amphibian species. If populations that survived historical Bd outbreaks exhibit selection or allelic shifts at these loci, this could validate the use of these loci as signals of future Bd susceptibility. In our study, we are addressing this need for empirical validation using a "museomics" approach: we are leveraging historical museum collections and molecular methods designed for Ancient DNA to test for genetic responses to historical Bd outbreaks. Pilot studies have shown that this approach is effective for capturing and sequencing a set of ~800 candidate Bd response genes. Our goal is to generate data that will improve prediction and mitigation of disease outbreaks in vulnerable wild amphibian populations.

26 Caitlin Bemis, Kiisa Nishikawa

Using in vivo length and activation during in vitro experiments to model scaling of muscle force pro

There is a gap between understanding of in vitro muscle mechanics and in vivo muscle function, including relationships among force production, strain, and activation. To investigate the relationship among these parameters, we used in vitro extensor digitorum longus muscles (EDL) of mice as an "avatar" for locomotor function of limb muscles. In addition to sinusoidal length inputs typically used in traditional work loop experiments, strain trajectories from the rat medial gastrocnemius (MG), recorded in vivo using sonomicrometry, were used as inputs for in vitro work loop experiments. Muscles were stimulated submaximally with similar onset and duration as observed in vivo at three different frequencies (walk 2.8Hz, trot 3.3Hz, and gallop 6.8Hz). Work loops recorded in vitro in EDL strongly resembled ($r2 = 0.72 - 0.94$) those from the rat MG during in vivo treadmill at all frequencies. Both in vitro EDL and in vivo work loops deviated substantially (r2 0.109 – 0.70) in shape from sinusoidal in vitro work loop experiments, demonstrating the importance of small high-frequency strain perturbations to muscle force production. A comparison of strain and activation variables across species (size, activation dynamics fiber types) in avatar experiments can provides insight into differences in muscle properties such as stiffness and damping, as well as differences in time constants for muscle activation and deactivation. Quantifying these muscle properties in vitro and in vivo will facilitate more robust bioinspired muscle models and help us connect in vitro muscle mechanics to in vivo muscle function.

148 Ian Bentley

Tracking and Counting Bats Across the United States using Neural Networks

Providing accurate counts of bats is of interest to researchers studying various phenomena including monitoring the relation between environmental stresses and the spread of disease with population. Both small roosts and large colonies provide challenges when attempting to determine an accurate population count. As part of an NSF Bio-Informatics grant and working with researchers at the Department of Fish and Wildlife, we are developing free tracking software that allows for the analysis of videos of bats in flight. When compared with manually counting the bats, the software provides counts that are substantially less labor intensive, that are determined more quickly, and that are more accurate. An aspect of the software that is currently under development is the use of neural networks to distinguish the difference between one bat flying and multiple bats that happen to overlap. This is a critical improvement for high density emergence events. This talk will include the biological motivations, a brief overview of artificial intelligence (and how it is being implemented), as well as other interesting innovations in the software, and how applicable the software that has been trained on bats is when applied to videos of other animals.

457 Vanessa Bentley, Austin Ellingworth, Wen Zhou, Donald Mykles

From water to land: the impact of methyl farnesoate and JH-mimics in decapod ecdysteroidogenesis

Methyl farnesoate (MF) synthetic and signaling genes are differentially expressed in the crustacean molting gland or Y-organ (YO) thus suggesting MF acts as an autocrine factor controlling ecdysteroidogenesis of 20-hydroxyecdysone (20-E). Analogous to insect juvenile hormone III (JH III), it is hypothesized that MF binds to the Methoprene tolerant (Met) receptor thereby inducing the Krüppel homolog 1 (Kr-h1) transcriptional cascade which subsequently regulates the expression of downstream ecdysone response genes. To determine the effect MF and JH-mimics has on 20-E secretion, YOs from adult intermolt green shore crabs (Carcinus maenas) and blackback land crabs (Gecarcinus lateralis) were incubated with either MF or a JH-mimic in vitro. 20-E accumulation in the culture media after 48 hours was measured with a competitive ELISA. In both decapod species 20-E secretion was inhibited by Fenoxycarb, stimulated by Methoprene, but showed no effect to MF. Exposure to Hydroprene inhibited 20-E synthesis in G. lateralis but was stimulated in C. maenas. These results indicate that low 20-E hemolymph titers impact YO ecdysteroidogenesis through differential binding of the compounds to Met. Future work will determine the effects of MF and JH-mimics on the YO from late premolt animals and quantifying the expression of MF and 20-E signaling genes. Supported by NSF IOS-1922701 and IOS-1456942.

1405 Ehren Bentz, Alexander Ophir

The olfactory and vomeronasal transcriptomes of the African giant pouched rat (Cricetomys ansorgei)

The African giant pouched rat, Cricetomys ansorgei, is a large rodent best known for land-mine detection attributable to its impressive sense of smell. Their powerful chemosensory abilities also enable them to discriminate subtle differences in chemical social signals indicating sex, physiological state, and reproductive status. Additionally, female pouched rats demonstrate a unique reproductive physiology, which renders some adult females reproductively unavailable and that has been hypothesized to be mediated by pheromonal mechanisms. Thus, C. ansorgei represents a unique and valuable novel mammalian model for chemosensory physiology, social behavior, and pheromonal control of reproductive physiology. We provide the first genome-wide glance into the evolutionary history of this lineage. We used long-read sequencing and, in collaboration with the DNA Zoo consortium, produced the first high quality, chromosome-scale genomic assembly of the pouched rat. Functional enrichment analysis revealed that genetic expansions specific to the pouched rat lineage are enriched for functions related to olfactory perception. We used a manual annotation pipeline and full-length transcript sequencing to identify the genomic repertoires of olfactory, vomeronasal type-1, and vomeronasal type-2 receptor genes. We report more than 2000 apparently functional OR genes, indicating that the pouched rat may have the largest OR repertoire of any organism sequenced to date. Finally, we describe gene expression profiles within main olfactory and vomeronasal sensory epithelium with respect to sex, physiological state and female reproductive status.

1520 Ayala Berger, Polly Campbell, Christopher Clark

An Apparent Match in Signal Form in two Acoustic Courtship Displays in Calypte Hummingbirds

Complex courtship displays are of central interest in animal behavior. Lacking is research into the potential emergent features of these signals. Anna’s and Costa’s hummingbirds (Calypte anna, C.costae) produce complex acoustic courtship signals mechanically with wing and tail feathers during a dive, and vocally with their syrinx. Despite having different mechanisms of production, the song acoustically resembles the sounds of the dive displays. In Anna's hummingbirds, both signals are comprised of four syllables and include trills, polyphonic and pure sounds, whereas in Costa's hummingbirds both signals consist of a one-phrase upsweep-downsweep. We investigate to what degree there is a match between an individual's dive-sounds and their songs. We audio-recorded twenty iterations of each signal from twenty individuals. Both dive-sounds and songs were elicited with a mount and the bird's position in relation to the microphone was standardized. We quantified the degree of temporal and frequency correspondence between dive-like songs and dive-sounds within an individual as compared to the population by measuring peak frequency, trill rate, and duration. Results from this study will provide insight into signal evolution and highlight potential emergent properties.

342 Philip Bergmann, Maxwell Olson

Diversification of salamander body form, as mediated by the evolution of the number of vertebrae

Vertebrates have evolved a huge diversity of body forms, and a primary axis of this diversity is defined by how elongated the body is and how reduced the limbs are. Snake-like forms have evolved at least 75 times among vertebrates, with examples from all major clades except birds. Although salamanders have evolved elongate bodies with reduced limbs multiple times, how this was mediated through vertebral evolution has not been well characterized, and there is only rudimentary knowledge of the evolutionary dynamics of this phenomenon in the group. For example, we do not know how many times snake-like forms have evolved in salamanders, the relative roles of the trunk and tail in each of these examples, or whether body elongation always involved an increase in vertebral number. We collected a body shape and vertebral number dataset for 359 species of salamanders, representing all major clades, 88% of genera, and 46% of extant species, to address these questions. We found that snake-like forms have evolved at least six times in salamanders, most commonly through elongation of the trunk. There is a continuum of salamander body forms ranging from short bodies with well-developed limbs to elongate bodies with highly reduced limbs, with multiple intermediate forms. Our work identified clades with highly constrained vertebral numbers and body forms, and those with high levels of evolutionary lability.

1137 Daniel Berning, Tyler Boggs, Alyssa Hamm, Joshua Gross

Gustatory evolution in response to environmental pressure

The subterranean environment presents numerous challenges for survival. These challenges can include the absence of light, limited oxygen and minimal nutrition. Examining organismal response to these environmental challenges can provide powerful insight to the evolution of adaptive features. Cave-dwelling animals tend to evolve a suite of convergent features including regressive losses and constructive gains. A likely constructive feature is taste (gustatory) sensation, which is often expanded in cave-dwellers compared to closely related surface-dwelling morphs. Here, we sought to examine how taste tuning may differ in the context of a microevolutionary model system. For this project, we examined the blind Mexican cavefish (Astyanax mexicanus), a robust model for cave biology owing to the presence of extant surface-dwelling morphs alongside 30+ different cavefish populations. We focused our attention to the "organic tastes" of bitter, sweet and umami – three canonical tastant types presumably present in the cave microenvironment. Our work shows that the receptor structure encoded by taste receptor genes differs by morphotype (cave v. surface) as well as across the demography of cave localities. We discuss these results in the context of the natural nutritional environment of caves of the Sierra de El Abra, that likely present differing tastants to cave inhabitants. Collectively, this work reveals diversity in the development and tuning of gustation, and underscores the value of non-visual sensation for survival in total darkness.

810 Michael Berthaume, Sarah Elton

Accounting for evolutionary relatedness in biomechanical data

Comparative biomechanical data is analysed either independently of phylogeny or in a phylogenetic framework. The former assumes biomechanical data is statistically independent of the clade's underlying evolutionary structure, while the latter assumes biomechanical data is statistically dependent on the variation the underlying molecular / genetic data captured in the tree. Here, we test whether existing phylogenetic methods can accurately detect phylogenetic signal in biomechanical data. Nine muscle force and lever arm characters were varied with a constant mutation rate and used to calculate bite force/mechanical advantage for each generation. A pure-birth model with 199 random uniformly distributed speciation events after 10,000 generations. Two sets of evolutionary simulations (499 runs each) were run to create hypothetical clades, where characters were varied under unconstrained (Brownian motion) or constrained (log-normal) neutral selection, the latter ensuring continuous parameters stayed positive, and speciation events were uniformly or exponentially distributed. Phylogenetically independent contrasts showed character states were uncorrelated with biomechanical data. In the constrained simulations, Pagel's lambda and Blomberg's K correctly detected phylogenetic signal and predicted neutral selection. In the constrained simulations, phylogenetic signal was often not detected, and lambda and K were often < 1. Our results imply variation in biomechanical data is poorly correlated to the underlying genetic / molecular tree data, and existing phylogenetic methods only consistently yield correct results when physiological, anatomical, and mechanical constraints are ignored.

1672 Ioulia Bespalova, Rebecca Bachtel, Heather Axen

Testing Acclimation Hypotheses in Drosophila pseudoobscura

Temperature has a significant effect on metabolic activity, growth rate, and other critical physiological processes. Considering that global climate change alters the thermal environment of many species, understanding how a population's adaptive background can help it cope with thermal extremes is of ongoing interest. The Beneficial Acclimation Hypothesis posits that acclimation to hot or cool environments leads organisms to better tolerate heat or cold, respectively. On the other hand, according to the tolerance-plasticity trade-off hypothesis, populations adapted to living close to their thermal limits may not be able to use plasticity to extend their thermal range. To investigate the relationships between acclimation ability and thermal limits, we evaluated thermal tolerance (CTmax/CTmin) in stock-center maintained D. pseudoobscura raised at different temperatures (low medium or high) from populations that varied in the mean temperature of their habitat.

825 Hayden Biggs, Karly Cohen, Stephanie Crofts

Functional heterodonty vs homodonty in extant crocodilians

For most vertebrates, teeth are the primary tools used to process food, and a wide variety of shapes and specializations have evolved to handle different types of food. This variation exists between species, but can also occur within a single mouth, with regional specialization within a single tooth row. Teeth of the same size and shape are morphologically homodont, while teeth that are of different sizes or shapes are heterodont. These descriptions, however, are mainly morphological and don't consider how tooth position in the jaw interacts with tooth shape during food processing. Despite looking the same, morphologically homodont teeth may not function in the same way. Our goal for this study was to measure and compare functional heterodonty in extant crocodilians, using 3D analysis of crocodile skulls. Measuring tooth surface area and position allows us to estimate the stress experienced by each tooth, and by comparing stress between teeth we can identify heterodont teeth as functional outliers based on k-means cutoffs. In extant crocodilians, our data show a difference in normalized stress between teeth near the jaw joint and those further away. This indicates that the species have a functionally heterodont dentition. Teeth closer to the jaw joint will generate more power and are commonly used for crushing, while teeth further from the jaw joint move more quickly with less force, serving another evolutionary purpose.

767 Mohammad Maruf Billah, Margaret Grizzaffi, Mar Huertas

Neuromodulation of Olfactory Immune Responses In Rainbow Trout (Oncorhynchus Mykiss)

We hypothesize that activation of steroidogenic enzymes, and concomitant production of neurosteroids, are involved in modulating olfactory immune responses evoked by bacteria Yersinia ruckeri in Rainbow trout. Y. ruckeri vaccine was nasally administered in rainbow trout. Next, six different parts of the olfactory tract (nose, olfactory bulb, cerebellum, diencephalon, telencephalon, and optic tectum) were collected at different time points (15 minutes, 4 hours, 24 hours, and 7 days after bacteria exposure). After that, RNA expression of four steroidogenic enzymes (3HSD, 11HSD, 17HSD, and p450) was determined by RT-qPCR. Preliminary comparisons at the 4-hour time point showed a significant increase of 3βHSD mRNA expression levels in the diencephalon (between 0.07 and 7-fold increase in control and treatment respectively). Increased levels of 3βHSD expression were also noted in the cerebellum (control 0.32 and treatment 23.64-fold increase) and optic tectum (control 0.85 and treatment 1.46-fold increase). Moreover, a significant increase of 11βHSD expression levels were detected within the cerebellum, with 0.53 and 5.14-fold increase in the control and treated individuals, respectively. Similarly, an increased level of 11βHSD mRNA expression was noted in the diencephalon (0.08 and 2.35-fold in control and treatment group, respectively). Further analysis of data will show differences in the other sampled time points (24 hours and 7 days). Our findings show that neurosteroids play key role in olfactory immune responses in vertebrates.

142 Sydney Birch, David Plachetzki

Phototactic preference and its genetic basis in the planulae of the Hydractinia symbiolongicarpus

Sessile marine invertebrates commonly possess motile larval stages that make settlement decisions based on environmental sensory cues. Phototaxis, which is the movement toward or away from light, is a common feature of marine larvae for a diversity of taxa, but the behavioral and genetic details are only characterized in a few systems. In cnidarians, most research investigating phototaxis has been conducted in Anthozoans (corals and sea anemones) and little is known about the photosensory capabilities of hydrozoan larvae, which have morphologically different planula larvae. Here we show that Hydractinia symbiolongicarpus planula larvae are sensitive to specific wavelengths of light and express photosensory genes just prior to settlement competency. We performed a behavioral phototactic study using three wavelengths of light and found that larvae are significantly phototactic to green and blue wavelengths of light, but not red. Additionally, we performed a developmental transcriptome study of planulae collected from four developmental time points. We found that many genes critical to the development of ciliary photosensory systems are expressed early in development and that genes involved in phototransduction are expressed later in development when larvae are phototactic, suggesting a role for opsin-mediated phototransduction. Together, this study reveals that hydrozoan planula larvae are capable of distinguishing between different wavelengths of light and utilize an ancient molecular toolkit reminiscent of that associated with ciliary photoreceptors from bilaterian animals.

278 Sydney Birch, Adam Reitzel, Ed Smith, Yehu Moran

Connecting copy number variation to microbial and viral diversity of an estuarine anemone

The estuarine environment has a plethora of microorganisms that allow for diverse animal-microbe interactions which may impact the behavior and physiology of host animals. The sea anemone Nematostella vectensis, is a model cnidarian found along the east coast of North America, ranging from Nova Scotia to Florida. Previous research has shown that anemones from different locations have unique microbial communities and that some of these differences are maintained in the laboratory for long periods of time. However, how the genome varies for distantly related N. vectensis individuals remains unknown, which could inform why the microbiome may differ across locations. Here we sequenced and assembled genomes for individuals from four locations (Nova Scotia, Maine, North Carolina, and Florida) for comparison with the currently published reference genome produced from individuals originally collected in Maryland. We found numerous structural variants, including copy number variation of genes. Interestingly, several genes that vary in copy number across the locations are involved in a hypothesized antiviral pathway and other immunity-related gene families. Furthermore, we recently completed a mesocosm experiment examining how anemones from different locations respond to shared microbial and viral communities. We will present our current findings and future plans for this research which is focused on characterizing how genomic variation can help explain the diversity of the associated microbes and viruses of coastal invertebrates.

116 Peter Bishop, Stephanie Pierce

Limb performance and versatility across the synapsid sprawling-to-erect postural transition

The transition from sprawling to erect limb postures was pivotal in synapsid evolution, paving the way for the origin of modern mammalian locomotion. Understanding when, how and why this transition occurred has remained difficult to elucidate. To address this, we developed a new musculoskeletal modelling method for calculating the maximum magnitude of force able to be produced by a limb in all possible directions, via a rapid optimization procedure. This overcomes obstacles imposed by muscle biarticularity, co-contraction and redundancy on inferring limb mechanics, and directly relates whole-limb anatomy to function. Having benchmarked our method with representative extant amniotes that span the sprawled-to-erect postural continuum (e.g., lizard, opossum), we investigated patterns of how hindlimb performance and functional versatility co-vary with posture. We identify a posture-mediated tradeoff between these aspects of limb function, and show that certain metrics (e.g., peak force production) are maximized around the postures used in vivo during locomotion. We then applied our methodological framework to a variety of extinct synapsids ranging from pelycosaurs (e.g., Dimetrodon) to cynodonts (e.g., Massetognathus). Our results highlight a broad diversity in postures and muscle function across the taxa sampled to date. Not only does our method offer a new way of reconstructing whole-limb posture and function in extinct animals, but it reveals novel insight into functional tradeoffs that would have been accommodated during evolutionary postural transitions.

244 Taylor Black, Thomas Sanger, Michele Johnson

The Evolution of Dentition in Long- and Short-Faced Anolis Lizards

Vertebrate teeth serve a variety of functions, including initiating the digestive process, serving as weapons, or acting as tools to manipulate objects. Despite their importance, we know little about how tooth morphology evolves as the dimensions of the jaw evolve. Anolis lizards offer an excellent model to address this question, as all anoles are insectivores who utilize their teeth to capture and manipulate prey, and species in this group have evolved remarkably variable jaw lengths. To determine how tooth number, shape, and spacing have evolved with jaw size, we focus on 30 Caribbean species exhibiting diversity in snout lengths. We use the program 3D Slicer to measure CT scans from 3 specimens of each species. We collected total tooth count from the upper jaw of each specimen. From the left and right sagittal positions of each scan, we measured the length and width of five of the back (tricuspid) and front (unicuspid) teeth, and the distance between these teeth. Preliminary data suggest that snout length is not correlated with tooth number. Through analysis of tooth morphology in a comparative framework, these data will provide a novel understanding of how dentition evolves in the vertebrate jaw.

823 David Blackburn, Rachel Keeffe, Paulo Pinheiro

Hyperelongated finger evolution in the African squeakers, family Arthroleptidae

Homoplasy in frog body forms in different microhabitats (e.g., arboreal, burrowing) provides an excellent opportunity for understanding how similar ecology and functional demands drive convergence in form. But what of the rare traits, those that have not repeatedly evolved? Male secondary sexual traits in frogs provide an opportunity for integrating phylogenetic, behavioral, anatomical, genetic, and other tools to study morphological novelties. Here, we will present what is known of the elongate third finger in males of the African frog genera Arthroleptis and Cardioglossa (family Arthroleptidae). Hyperelongation of the third manual digit evolved in the ancestor of these two genera and been both elaborated and reduced multiple times. Males of appear to use these digits in male-male wrestling, including rapidly vibrating and wiping the fingers across the dorsum of competing males. The elongation of this digit is associated with sexual maturity and occurs through elongation of the distal cartilaginous epiphysis of the phalanges, metacarpal, and radioulna. This hypertrophy and subsequent ossification create a composite skeletal element that is unique among anurans, but likely co-opts existing developmental mechanisms. We will also present details on the way that these bones experience stress and how their associated muscles differ from other frogs. An integrated, organismal approach allows us to begin making sense of the evolution and function of novel traits in these poorly studied frogs.

982 Jeremy Blackburn, Grace Anderson, Mia Kholy, Akshaya Ranjit, Taylor Black, Michele Johnson

Behavioral Indicates of Stress in Captive Green Anole Lizards

Laboratory research with captive animals requires that animal subjects be healthy. Despite their frequent use in biological research across the world, little is known about the welfare and stress of captivity on green anole lizards (Anolis carolinensis). In this study, we examined the relationship between research-related stress and a series of behavioral traits in captive green anoles. We captured 40 free-living green anoles (20 males, 20 females), and assigned half to the “stress” group, which were exposed to a series of common research stressors (handling, transfer to new cages, and behavioral arena trials). The other half were assigned to the control group, which lived in captivity but were not further manipulated. During the study, we collected undisturbed behavioral data, and samples for two subsequent measures of long-term (several-days) stress: fecal samples for measures of glucocorticoid metabolites, and blood smears for analysis of heterophil to lymphocyte levels. Preliminary analysis of behavior showed sex-specific effects of stress; at the end of the three-week stress period, stressed females had a lower latency to move in open field tests, and stressed males exhibited more exploratory behaviors during the tests. Yet, both control and stressed lizards exhibited more refuge-seeking behaviors within their home cages across the duration of the study. This study may ultimately provide a better understanding of how researchers may collect reliable, non-invasive measures of captive animal stress.

57 Emily Blackwell, Alise Newman, Chris Law

Mandibular sexual dimorphism in canids

Morphological sexual dimorphism is the result of behavioral, ecological, and competitive differences between the sexes. Thus, studying sexual dimorphism can help us better understand how sexual differences have acted as a selective pressure throughout evolution. Two leading hypotheses for sexual dimorphism are sexual selection, in which competition for mates leads to dimorphism, and resource partitioning, in which intersexual competition for food and other resources leads to dimorphism. The mandible is an interesting site for the study of sexual dimorphism as it is relatively evolutionarily plastic, so it could show morphological responses to selection that other structures may not. We used 3D geometric morphometrics to quantify sexual dimorphism in mandibular size and shape in canids, a clade that exhibits variation in diet and social system. We found that, across the clade, there is little to no dimorphism in mandibular size or shape, and there were no significant differences in the degree of size or shape dimorphism between dietary (carnivorous vs. omnivorous) or social system (group- vs. pair-living) categories. Further, we found that there was no significant Rensch's rule trend for size or shape. However, three Vulpes species exhibited significant dimorphism in either mandibular size or shape. Overall, these results suggest there is no clade-wide trend in mandibular sexual dimorphism for canids, though selection may be influencing sexual dimorphism on a species-specific basis.

498 Emily Blackwell, Shenni Liang, Sophia Wolfe, Irby Lovette, Donald Powers, Anusha Shankar

Surface body temperature as a proxy for metabolic rate during torpor in hummingbirds

In deep torpor, animals slow multiple internal bodily processes, including metabolism, and drop body temperature to within a few degrees of ambient temperature (Ta). Surface body temperature (Ts) is an accurate proxy for core body temperature (Tb). Previous research for our project involving partial-night observance of Anna's hummingbirds (Calypte anna) showed that Ts correlates with metabolic rate during normothermic sleep, transition into torpor, and deep torpor. To further evaluate this link, we performed whole-night simultaneous measurements of metabolic rate and Ts using open flow respirometry and infrared thermography. Measurements were made on C. anna (4.7g), black-chinned hummingbird (Achilochus alexandri, 2.8g), blue-throated mountaingem (Lampornis clemenciae, 7.9g), and Rivoli's hummingbird (Eugenes fulgens, 7.9g) individuals. All species are migratory except C. anna, which is a year-round resident in a broad range of climates in western and southwestern US. We conducted whole night runs in all four species, as well as additional partial night runs with C. anna, to analyze the correlation between metabolic rate and Ts in hummingbirds during normothermic sleep, the transition into torpor, torpor, and arousal. Average Ts during nighttime runs was 29.3°C (C. anna), 26.7°C (A. alexandri), 27.8°C (L. clemenciae), and 27.4°C (E. fulgens). The minimum temperature reached by each species was 8.6°C (C. anna), 9.8°C (A. alexandri), 13.8°C (L. clemenciae), and 11.1°C (E. fulgens). The positive correlation between Ts and metabolic rate was upheld.

1249 Annelise Blanchette, Myra Finkkelstein, Jordan Karubian, Alex Gunderson

Lead exposure is associated with significant physiological detriments in urban lizards

Lead exposure can have serious negative implications for humans and urban wildlife that are exposed through contaminated food, water, and soil. That said, there is a gap in our understanding on how natural chronic lead exposure affects wildlife beyond key taxa such as birds of prey. We predicted there would be a negative physiological effect of lead exposure on a common urban lizard (the brown anole, Anolis sagrei) in New Orleans, LA. Anoles were collected from two neighborhoods that differ significantly in lead contamination. We measured lead exposure and the physiological effects of lead ingestion on multiple dimensions of whole organism physiology. To quantify exposure, we analyzed bone and blood lead concentrations. To test for physiological effects, we measured sprint speed, balance, and endurance. Anoles from the high-lead neighborhood had on average 8.5x higher bone-lead and 25.5x higher blood-lead levels than those from the low-lead neighborhood. Lead exposure had no negative effects on sprint speed. However, males from the high-exposure neighborhood had worse balance. In addition, anoles from the high-exposure neighborhood had lower endurance than anoles from the low-exposure neighborhood, and the effect was greatest in males. These results highlight that lead contamination may affect more than large charismatic animals, and that lead exposure needs to be considered in studies investigating the effects of urbanization on wildlife.

731 Krystle Boadi, Kaja Arusha, Sabrina Ellah, Daniela Kim, Carolyn Bauer

Relationships between maternal care and the endocrine stress response in Octodon degus

Maternal care is an important factor in rodent postnatal development. Studies have shown that offspring receiving low rates of care usually develop hyper-reactive stress responses, which are typified by high stress-induced cortisol levels and weak negative feedback. In order to test this specific hypothesis, we worked with degus (Octodon degus), a rodent species native to Chile that provides high rates of maternal care to offspring.

By cross-fostering certain litters, we increased the variation of maternal care rates, as degu mothers provide lower rates of care to fostered vs. biological offspring. Maternal care was assessed through analysis of licking/grooming rates, maternal presence on the nest, and pup retrieval rates. We predicted that mothers that spent less time on the nest and less time licking/grooming their offspring would have pups with higher stress-induced cortisol levels and weaker negative feedback. These data will further inform how fostering impacts mammalian development.

1655 Yuriy Bobkov, Alexandra Hernandez, Joseph Ryan

Molecular and physiological properties of ctenophore excitable cells

Recent phylogenetic evidence placing ctenophores as the sister group to the rest of animals has challenged existing views as to the origins of neurons and nervous systems. Most of the electrophysiological and morphological data that exist in ctenophores were generated prior to the genomic age and lack integrated cellular, genomic, and transcriptomic approach. Accordingly, there is essentially no information on what structural and functional algorithms might be utilized by the ctenophore nervous system to detect, process ex-/internal signals, and coordinate relatively complex behavioral output. Here we show that excitable cells of M.leidyi neuromuscular infrastructure express basic set of "neuronal" voltage-gated channels (ML190424a,Cav1; ML17059a, ML358826a, Nav2s and a great variety of potassium channels) and are capable of generating and transmitting action potentials. Activation of the cells and generation of action potentials is accompanied by recurrent transient elevations in cytoplasmic $Ca2+$ allowing calcium imaging and evaluating the activity of populations of sensory cells, neurons, and muscles. This work provides the foundation of our efforts to characterize the molecular and physiological properties of M. leidyi excitable cells and to construct a circuitry map of M. leidyi multimodal sensory organs. Our data provide important insights into origin of the specialized excitable cells in general and the sensory and neuromuscular systems of ctenophores in particular.

407 Samantha Bock, Yeraldi Loera, Josiah Johnson, Christopher Smaga, Junsoo Bae, David Lee Haskins, Tracey Tuberville, Randeep Singh, Thomas Rainwater, Philip Wilkinson, Benjamin Parrott

The adaptive significance of temperature-dependent sex determination in a long-lived reptile

Many ectotherms rely on temperature cues during development to determine offspring sex. Ever since the first descriptions of temperature-dependent sex determination (TSD) were made over 50 years ago, an understanding of its adaptive significance has remained elusive, especially in long-lived taxa. One novel hypothesis predicts that TSD should be evolutionarily favored when two criteria are met – (1) incubation temperature influences juvenile survival and (2) sexes mature at different ages. Under these conditions, a sex-dependent effect of temperature on fitness arises through differences in age at sexual maturity, with the sex that matures later benefiting disproportionately from incubation temperatures that promote juvenile survival. Here, we test this hypothesis in the American alligator, a TSD species displaying a stark sex difference in age at first reproduction. By implementing a combination of artificial incubation experiments and mark-recapture methods, we disentangle the effects of incubation temperature and sex on annual survival in alligator hatchlings at two geographically distinct sites. Hatchlings incubated at male-promoting temperatures consistently exhibited higher survival compared to those incubated at female-promoting temperatures. Interestingly, this pattern appears independent of hatchling sex, as females incubated under male-promoting temperatures exhibited similar survival to their male counterparts. These findings support the hypothesis that TSD represents an adaptive sex-allocation strategy in this species. Ongoing work aims to uncover the roles of temperature-dependent hatchling phenotypes in mediating observed differences in survival.

497 Samantha Bock, Christopher Smaga, Matthew Hale, Benjamin Parrott

Epigenome-by-environment interactions underlying temperature-dependent sex determination

Incubation temperature acts on a bipotential genome to determine sexual fates in species with temperature-dependent sex determination (TSD). Despite TSD being common in non-mammalian vertebrates, the mechanisms by which thermal signals experienced during discrete periods in development determine offspring sex remain unresolved. Epigenetic mechanisms including DNA methylation appear to integrate environmental temperatures into stable transcriptional changes that act on endocrine signaling pathways to ultimately produce sexually dimorphic phenotypes. Here, we profile the gonadal transcriptome and DNA methylome during TSD in the American alligator to resolve the epigenome-by-environment interactions steering gonadal differentiation. Using a combination of incubation temperature and exogenous hormone treatments we further disentangle the roles of

temperature and endocrine cues in establishing sexually dimorphic transcriptional and DNA methylation patterns. Analyses of gonadal transcriptomes revealed 6,932 differentially expressed genes (DEGs; FDR < 0.05) between embryos incubated at a male-promoting temperature (MPT; 33.5˚C) and a female-promoting temperature (FPT; 29˚C). Approximately 56% of DEGs appear to be primarily regulated by temperature as they are also differentially expressed in embryos incubated at MPT but sex-reversed via exogenous 17ß-estradiol exposure (MPT+E2). Further, ~15% of DEGs between control FPT and MPT embryos appear to be primarily regulated by estrogen as they are also differentially expressed between control MPT embryos and sex-reversed MPT+E2 embryos. Ongoing work aims to link patterns at the level of the DNA methylome to observed transcriptional dynamics.

1339 Antonia Bock, Hereroa Johnston, Park Masterson, Jessica Goodheart, Deirdre Lyons

Insights into the nervous system during metamorphosis in the nudibranch Berghia stephanieae

During metamorphosis of species ranging from insects to amphibians, the nervous system is reconfigured along with the body plan and behaviors. The nudibranch Berghia stephanieae, an emerging model system for gastropod brain development, can be cultured through the metamorphic stages and does not require any hatching cue. Additionally, its highly detailed staging system exposes fine-scale distinctions, allowing nuanced descriptions of changes during metamorphosis. As in other animals, B. stephanieae's adult brain expresses over 60% of the genome, but the mRNA expression trajectories of these genes during development are not yet known. Using a developmental transcriptome spanning twelve distinct stages–from two-cell to feeding juvenile–we tracked expression of genes exclusively present in adult brain tissue. Based on ontological analysis, nervous system genes peak in pulses at gastrulation, the earliest veliger stages, the latest veliger stages, and post- metamorphosis. We identified lineage-restricted genes, including several that may regulate brain development, from the species to the phylum level. Of particular interest were transcription factors, which can direct the specification of cell identity and may allow us to trace changes in cellular differentiation. Among Berghia-restricted unannotated genes, we identified potential transcription factors and traced their expression, finding that they peak with the nervous system genes.These analyses address the hourglass model of development, provide insights into expression of both novel and conserved genes, and ground future molecular work.

944 Emily Bode, SoYoung Park, Harold Gibbs, Kenneth Petren, Eric Gangloff, Andrew Mason

Genomic impacts of population reduction and biological invasion on the common wall lizard

Biological invasions are an ecological hallmark of the 20th century and also serve as natual experiments for evolutionary study. Many invasive species are remarkably successful despite establishment by very small initial populations, which are expected to exhibit reduced genetic diversity. The Common Wall Lizard (Podarcis muralis) is a small, conspicious lizard species native to southern Europe that was intoduced to Cincinnati, Ohio, USA through a single founding event in 1951. Despite this severe bottleneck, the population has successfully expanded across the greater Cincinnati region since their introduction. We sought to understand the genomic impacts of the initial invasion by P. muralis and identify subsequent genomic differntiation in invasive populations. We conducted whole genome resequencing and comparison of 35 individual P. muralis from three time points and three populations including the source population in northern Italy, the established population in Cincinnati, and a recent invasion to Columbus, Ohio. We observed clear genetic structure acorss both sampled locations and time points. Despite both historical accounts and empirical estimates of a very small effective population size immediately following invasion, we observed limited impacts on contemporary genetic diversity. These findings suggest that severe population reductions do not necessarily negatively impact population growth, expansion, and adaptive potential. Rather, species that experience dramatic reductions in population size may still expand, maintain, and/or recover genetic diversity given suitable ecological conditions.

1521 Brooke Bodensteiner, Martha Munoz

Thermal physiological and parity mode evolution across squamates

Ectotherms like reptiles and amphibians rely on their external environments to regulate body temperature, and are, correspondingly, particularly sensitive to global warming. Among ectotherms, vulnerability to rising temperature magnifies even further for species that are relatively cool-adapted, as rising temperatures are more likely to push such organisms beyond tolerable limits. Among lizards, vulnerability may be correspondingly amplified in viviparous (live-bearing) species, which are generally thought to be relatively cool-adapted when compared to their egg-laying counterparts. Yet, this inference is based on data from only a handful of live-bearing species, limiting our ability to make robust predictions of vulnerability. Live birth is a remarkable evolutionary innovation that enables enhanced maternal control over developing embryos. Whereas mammals represent but one origin of viviparity, this innovation has arisen more than 115 times in squamate reptiles, accounting for ~75% of the origins of viviparity among all vertebrates. I will test whether (and how robustly) transitions to live birth are associated with enhanced cool adaptation, both in thermal behavior (i.e., downshifts in body temperature) and in thermal physiology (i.e., reduced heat tolerance). Here we focused on discovering how thermal physiological traits evolve in transitions to live birth in lizards, to infer patterns of vulnerability to climate change across lizard species and across geographic areas.

1443 Samuel Bogan, Olivia Porat, Gretchen Hofmann

Thermal plasticity has higher fitness costs among thermally-tolerant genotypes

Climate change will likely impose selective pressures on biodiversity to adapt to intensifying means and variance in temperature by increasing thermal tolerance and thermal plasticity. Ectotherm populations commonly exhibit negative correlations between upper thermal tolerance and its plasticity, a trade-off hypothesized to be the result of phenotypic limits to tolerance or adaptive canalization where strong directional selection on tolerance increases plasticity's fitness costs. Determining the extent to which thermal plasticity evolves via limits or selection would improve predictions of adaptation to novel thermal environments. Studying the intertidal copepod Tigriopus californicus, we measured directional selection on thermal tolerance and its plasticity by rearing lines from 4 latitudinally-distributed populations under a common garden for two generations before splitting 50 full-sibling families from G3 across 16.5 and 21.5°C developmental environments. We then measured upper thermal tolerance, body size, and fecundity in order to model the fitness costs of thermal tolerance, thermal plasticity, and their interaction using a selection gradient model. Populations and sibships exhibited a negative correlation between thermal tolerance and its plasticity. Thermal tolerance underwent positive directional selection during the experiment. A significant and strong effect of antagonistic selection acted on thermal tolerance and plasticity: selection was greater and negative among sibships with higher thermal tolerance. These results indicate that thermal plasticity may evolve via adaptive canalization driven by higher fitness costs among thermally-tolerant genotypes.

1028 Tyler Boggs, Joshua Gross

Adaptation to subterranean hypoxia: Insights from the blood transcriptomes of blind Mexican cavefish

Despite dramatically reduced levels of oxygen, cave animals often thrive in subterranean environments. The cave model system, Astyanax mexicanus (blind Mexican cavefish) harbors features reflecting adaptation to low oxygen environments including increased hemoglobin concentration and larger red blood cells compared to conspecific surface-dwelling morphs. However, the underlying transcriptomic basis for elevated hemoglobin, and other relevant blood factors, are unknown. Here, we performed an RNA-seq analysis of blood collected from surface fish and three cavefish populations to identify patterns of gene expression associated with adaptation to hypoxia. This approach allowed whole transcriptome comparisons between surface and cavefish, as well as between fish from different cave localities. Thus, convergent (shared) and divergent (unique) expression patterns were identified when comparing each cave population to surface fish. Of particular interest were the hemoglobin family of genes, for which two populations of cavefish (Pachón and Tinaja) expressed highly similar hemoglobin gene family members. Cavefish from the Chica location, however, unexpectedly displayed patterns closely aligned with surface fish. This work reveals a complex mosaic of convergent and divergent patterns of blood-derived gene expression across natural populations of cavefish. These findings provide additional insight into the complex evolutionary history of Astyanax cavefish, the genetic mechanisms enabling survival in low oxygen, and a novel case study for increasing hemoglobin through the recruitment of diverse family members.

501 Emily Bogner, Z. Jack Tseng

Is More Data Worth It?: Creating lifelike finite element models for paleobiological studies

Finite element (FE) methods have been utilized by paleontologists for over two decades comparing inter/intraspecific differences in bone mechanics of modern and fossil specimens. However, with a paucity of validation testing, it is unknown how accurate most model outputs are compared to their real life counterparts. This project aims to validate FE models based on homogeneous, literature-based, and experimental material properties. It is hypothesized that the more site-specific material properties assigned to the model, the more accurate it will be when cross validated with experimental data from mechanical bending tests. Humeri from a domestic dog (Canis familiaris) and cat (Felis catus) were subjected to a three-point bending experiment with an electromechanical testing frame, and in three FE analyses; one with a single material property as in current practices, the second with three material properties based on values found in the literature, and the third including material properties based on new experimentally collected relative hardness data. FE models produced tension values two orders of magnitude lower than the values of the experimental data, and while compression values fell within the same magnitude, they were also incorrect in explaining strain produced in the biological specimens. Based on these results, future use of FE should be performed with caution if strain magnitudes are the values of interest, and when using mechanical property values published in the literature.

826 Karen Grace Bondoc-Naumovitz, Georg Pohnert, Kay Bidle, Heidi Fuchs, Kirsty Wan

Of chalk and glass cells, and the scale they live in

Microscale processes shape aquatic communities and affect microbial trophodynamics and nutrient cycling on a larger scale. Microalgal communities are critical players in the marine system as they form the basis of marine food webs, thereby driving the carbon pump and influencing ecosystem functioning. Herein, I present two model systems that can give an overview of how microscale dynamics can influence larger-scale processes. Diatoms are a group of highly diverse microalgae which are significant players in biofilm formation in intertidal communities. Unlike other motile organisms, diatoms lack cilia, flagella, or the flexibility to change shape due to their rigid glass/silicified cell walls, and hence represent a novel system for understanding cellular movement and adaptability on surfaces. We characterized the baseline motility patterns of diatoms through behavioral phenotyping and explored their response to chemical signals to better understand how they shape benthic communities.Meanwhile, in the pelagic zone, lytic viral infection of the coccolithophore Emiliania huxleyi enclosed within chalk disks drives the turnover and cycling of oceanic microbial biomass. We combined empirical and observational data of E. huxleyi-EhV dynamics with encounter theory to predict infection rates in the Northeast Atlantic across a range of relevant turbulence conditions. Lytic infection is rare and unlikely in the upper 30 m of NEA and observed infection-driven bloom collapse requires storms as catalysts and/or temperate infection to adequately propagate viruses.

1384 Reed Boohar, Lauren Vandepas, Nikki Traylor-Knowles, William Browne

CD36 'apex' variation: implications for ligand sensing?

The cluster of differentiation 36 (CD36) domain defines a characteristic ectodomain associated with scavenger receptor class B (SR-B) proteins. In bilaterians SR-Bs play critical roles in diverse biological processes that include innate immunity functions such as pathogen recognition, phagocytosis, and apoptotic cell clearance, as well as metabolic sensing functions such as fatty acid and cholesterol uptake. While previous studies show this protein family is ancient, SR-B diversity across Eukarya has not been robustly characterized. We analyzed SR-B homologs identified from the genomes and transcriptomes of 134 diverse taxa spanning Eukarya. The presence of conserved amino acid motifs across major eukaryotic supergroups suggests a SR-B homolog was likely present in the last eukaryotic common ancestor (LECA). Our comparative analyses of SR-B protein structure predictions from AlphaFold2 and RoseTTAFold support the presence of a highly conserved beta barrel tertiary structure within the CD36 ectodomain. We also identify multiple instances of independent lineage-specific sequence expansions localized to the 'apex' region of the CD36 ectodomain — a region associated with ligand sensing in functionally characterized bilaterian SR-Bs. We hypothesize that a combination of both sequence expansion and structural variation associated with divergent CD36 apex regions may reflect the evolution of SR-B ligand sensing specificity between diverse eukaryotic clades.

1326 Holly Booth, Amanda Burkey, Mary Kate O'Donnell, Charlotte Easterling

Swimming performance of desmognathine salamanders

Plethodontid salamanders have radiated into a variety of microhabitats and morphological phenotypes. Desmognathus is a speciose clade within Family Plethodontidae which exhibits diversity of body size, tail morphology, life history traits, and microhabitat use in overlapping geographic areas. In this study, we examined Desmognathus quadramaculatus, a large, semi-aquatic predatory salamander with a lengthy larval phase, and D. ocoee, a direct developing, small-bodied, semi-terrestrial species. In shared streams, D. quadramaculatus is one of the major predators of D. ocoee. We explored linkages between morphology and

ecology by examining tail morphology and steady-state swimming kinematics and performance. In addition to kinematic variation during swimming, the two species showed significant differences in tail shape and size-corrected swim performance. By examining morphology and performance across multiple locomotor modes, we hope to better understand evolutionary constraints and drivers of microhabitat diversification in sympatric species. Within Desmognathus salamanders, evolutionary constraints may be acting to maintain locomotor performance across aquatic and terrestrial environments, and in the context both of prey capture and predator avoidance.

694 James Boothroyd, Christine Miller

Ejaculate Size Variation Under Weapon Loss

It is predicted that the more sperm a male can provide during mating, the more eggs he is likely to fertilize. Sperm is costly to produce, however, and males likely do not invest maximally in sperm production, as they must also acquire access to mates. Many studies have in fact found that when males are inhibited from investing in reproductive structures like weapons, which aid in acquiring mates, they increase the amount of sperm they produce. Yet the amount of sperm used in mating, or ejaculate size, is not always proportional to total sperm produced, and it has been noted that many organisms are able to adjust their ejaculate size. Therefore, to fully understand male patterns of reproductive allocation, it is imperative to investigate how ejaculate size responds to increased sperm production. Narnia femorata (Hemiptera:Coreidae) provides a powerful tool to investigate this topic, as they can naturally, permanently lose their weapons, which has been shown to increase sperm production. Females of this species store sperm, which affords both an arena for sperm competition, and a mechanism to measure ejaculate size. Here, we compare the ejaculate size of males who have experienced weapon loss to intact males, relative to the male's body size, and as his mate's.

1038 Erin Borbee, Isabella Changsut, Kira Bernabe, Alicia Schickle, David Nelson, Koty Sharp, Lauren Fuess

New insights on immunity in temperate coral larvae in response to pathogenic and probiotic bacteria

Coral reefs are some of the most biodiverse ecosystems on earth, and among the most economically and ecologically valuable. However, corals, the organisms that are the trophic and structural foundation of these ecosystems, are threatened by the impacts of climate change. In particular, increased sea surface temperatures have been associated with an increase in frequency and severity of coral disease outbreaks across the tropics. The increase in the prevalence of coral diseases has sparked research on coral immunity and response to disease as well as heightened efforts to identify conservation methods to reduce coral mortality from disease outbreaks and restore ecosystems impacted by disease outbreaks. In this study, we use Astrangia poculata, an emerging temperate coral model system, to understand the development of coral immunity in early life stages when exposed to pathogenic and probiotic bacteria. We exposed A. poculata larvae to a common coral pathogen, Vibrio corallilyticus, and a strain of probiotic bacteria, Phaeobacter inhibens. Following exposure, A. poculata larvae were sampled for transcriptomics, and differential gene expression analysis was conducted to identify common and divergent signatures of response to each treatment. The data presented in this study will provide insight on early development of immunity in corals and potentially offer understanding of the differential impacts of pathogen and probiotic exposure on the development of coral immunity.

919 Tia Bottger, Brett Klaassen-van-Oorschot, Rachel Pepper

The effect of ambient flow on the 3D kinematics of the sessile microorganism, Vorticella convallaria

Vorticella convallaria are common microscopic sessile suspension feeders that live attached to substrates in aquatic environments with diverse flow conditions. Vorticella help maintain the health of aquatic ecosystems by consuming bacteria and detritus and depend on a self-generated current to feed. They are important in wastewater treatment and may benefit bioremediation efforts. Their environmental impact is mediated by their feeding rate. In ambient flow, feeding rates are highly dependent on organism orientation relative to the surface and the direction of flow. Organisms oriented downstream experience recirculation in their feeding current, depleting their supply of food particles, and leading to reduced feeding rates. Therefore, we hypothesized that individuals actively orient to avoid reduced feeding rates. We cultured organisms attached to the bottom surface of a flow chamber and exposed them to unidirectional laminar flow at four speeds. We recorded the 3D orientation of 18 individuals over a span of 20 minutes using a simultaneous top- and side-view microscope. We determined that Vorticella's orientation becomes increasingly tilted downstream, with some loss of motion and orientation ability as the flow speed increased. However, organisms spent little time in orientations with reduced feeding rates, even at the fastest flow speeds. The frequency of periodic rotations each individual performed during feeding remained consistent as flow speed increased, and the stalk remained more upright than the cell body.

806 Colleen Bove, Annabel Hughes, Alexa Huzar, Karl Castillo, Daniel Segrè, Sarah Davies

Environmental drivers of coral-associated algal and microbial communities across multiple scales

Rising ocean temperatures arguably pose the greatest threat to coral reef persistence, as thermal stress can lead to breakdown of coral-algal symbiosis in a process known as bleaching. Recent studies have suggested that prior exposure to thermal variability can lead to enhanced coral performance under thermal stress, and that thermal tolerance may be further shaped by microbial and algal associations. However, the mechanisms shaping these algal-microbial networks, especially how these networks are structured across space and time, remain largely unexplored. Here, we assess diversity and community composition of coral-associated algal and microbial communities across four ecologically relevant scales, from individual coral colonies to reefscapes. We collected samples of congeneric coral holobionts (Siderastrea siderea, Siderastrea radians) from four paired inshore-offshore reef sites across the Florida Keys, Belize, and Panama, covering a 15º latitudinal gradient that span environments that vary in their daily, seasonal, annual, and historical temperature, tubidity, and light regimes. We leverage algal and microbial community metabarcoding of these corals across multiple spatial scales to explore how patterns of environmental variation shape community composition, diversity, and network complexity of symbiotic partners. Our overarching hypothesis is that corals from more variable environments (e.g., inshore, higher latitude) will host lower algal symbiont and higher microbial community diversities compared to less variable sites and that these communities will exhibit increased network stability between symbiotic partners.

1543 RAFAEL BOVO, LUIS SENZANO, DENIS ANDRADE

Estimating resistance to water loss in amphibians: Error sources and methodological recommendations

Most amphibians are prone to dehydration because of their highly permeable skin. Skin resistance to evaporative water loss (EWL) constitutes a standardized metric for assessing the permeability of animal skin and, consequently, its vulnerability to dehydration. However, estimates of resistances to EWL, from both animals and biophysical models, may be biased due to a series of measurement errors in the parameters used to calculate EWL rates. Here, we quantified how much experimental error in each parameter to calculate EWL rates impacts the estimation of resistance to EWL. Specifically, we anchored empirical values of EWL rates previously measured in an open-flow system and performed computational simulations isolating and varying (10% up and down) each parameter of the equations commonly used to estimate resistance to EWL. We found that water vapor density and temperature measurements were the most influential parameters resulting in the greatest bias in the estimation of resistances to EWL. Inaccurate measurements of experimental airflow system and body mass biased resistance estimation in a lesser proportion. However, the relevance of the parameters to under or overestimate resistance to EWL changes with body mass (small or large). We provide a list of potential error sources and also methodological recommendations for future studies.

1328 Jessica Bowers, Cheng-Yu Li, Theresa Alexander, Scott Juntti

Single nucleus RNA-seq of the olfactory epithelium in an African cichlid fish

Fish use olfaction to drive key behaviors such as feeding, predator avoidance, and reproduction. While it is hypothesized that fish use distinct populations of olfactory sensory neurons (OSNs) to facilitate these behaviors, little is known about the specific sensory transduction mechanisms used by different OSN populations. Furthermore, despite the availability of single cell sequencing technology, the overall cellular composition of the fish olfactory epithelium (OE) has not been comprehensively described. To characterize OSN sensory transduction mechanisms and cellular makeup of the OE, we performed single nucleus RNA-seq (Sn RNA-seq) on the African cichlid, Astatotilapia burtoni.We discovered that the two major populations of OSNs (ciliated and microvillous) express distinct genes related to signal transduction, including different olfactory receptor classes, sensory transduction channels, G-proteins, and second messengers. We identified unique genetic markers for additional putative cell types in the cichlid OE, including immature OSNs, sustentacular cells, immune cells, goblet cells, lipocalin-producing cells, and ciliated non-sensory cells. Using genetic markers identified with Sn RNA-seq, we further characterized the spatial arrangement of OSN signal transduction molecules and cell types in the OE with in situ hybridization. Our work represents the first single cell atlas of the OE in any fish, and provides a new foundation for future studies investigating OSN signal transduction mechanisms, as well as diverse non-sensory functions of the fish OE.

1539 Chelsea Bowers-Doerning, Justin Hertel, Ashley Ibrahim, Misty Paig-Tran

Ingestion and assimilation of microplastics in the Pacific sardine, Sardinops sagax

Microplastics (MPs; 20 μm to 5 mm in diameter) are ubiquitous pollutants in marine environments. A major source of MPs is anthropogenic, plastic-littered effluent draining into coastal waters worldwide. The Southern California Bight (SCB) is inhabited by subpopulations of Pacific sardines (Sardinops sagax), a commercially and ecologically important fish. Pacific sardines filter-feed on zooplankton whose body size falls within the same size range as marine MPs and therefore are vulnerable to ingestion. We aimed to: 1) determine whether sardines were ingesting MPs and if so, 2) determine if the ingested MPs were then assimilated into body tissues. MPs were chemically extracted and processed from 20 sardine stomachs, livers, and axial muscle tissues (both epaxials and hypaxials). We used fluorescent microscopy combined with Nile Red staining to quantify and measure the Feret's diameter of extracted MPs using MP-VAT software. We found that sardines had an average of 1599 MPs/stomach, 407 MPs/liver, and 216 MPs/muscle in the form of fibers, fragments, and particles. Fourier Transform Infrared spectroscopy analysis showed that the dominant MPs in muscle tissues were polytetrafluoroethylene (Fluorocarbon fishing line), polyamide (fast fashion and fishing nets), and polyepichlorohydrin (fuel hoses). This study shows that wild-caught Pacific sardines do consume and likely assimilate MPs into both muscle and liver tissues.

623 Grace Bowman, Glenna Clifton

The influence of extreme heat on lady beetle walking

As the earth's climate changes, insects are increasingly exposed to and affected by extreme temperatures. Ladybird beetles (Coccinellidae) prey on aphids and other pests and therefore serve important ecological and agricultural functions. As ladybirds are ambulatory predators, studying how exposure to extreme temperatures influences walking performance would provide important insight into their ability to predate pests in a changing climate. To explore this question, we performed a population survey collecting ladybirds from Portland's International Rose Test Garden from May through July 2022. Both wild-collected and store-bought Hippodamia convergens ladybirds were filmed (250Hz) walking up a dowel before and after exposure to 23 hours of room temperature (22 ± 5C, 60% humidity) or hot (35 ± 1C, 60% humidity) conditions. During the control or hot exposure, ladybird activity was recorded (2Hz) for 30 seconds every 30 minutes. Our survey found that Cycloneda polita was, by far, the most frequently collected beetle. During and for 3 weeks after a short heat wave (temperature highs >93°F) no beetles were observed. Beetles exposed to laboratory hot conditions had a higher mortality rate and were more lethargic, with slower walking speeds, than beetles kept in control conditions. These findings demonstrate the adverse effect of extreme heat on ladybirds, which will help in understanding beetle ecology and evolution, as well as agricultural policy.

1826 Gillian Bowser, Carmen Cid

Knowing your field community: a model for effective applied ecology

Where we do applied ecology and how we characterize the socioecological community influences research questions, field methods, and sets the parameters of safety and inclusion for diverse researchers. We need to define what is applied, who is the researcher and who benefits from that application, i.e. who is part of the community and their influence on the research processes themselves. To broaden participation in applied ecology requires that we include multicultural ways of knowing and provide safe field experiences for all. We discuss how to: 1) characterize the safety of a geographical site for research and educational purposes so that students and practitioners of color are safe to collect environmental data, 2) integrate community perceptions and environmental needs into research design, and 3) reach out to community stakeholders to define the parameters for environmental problem solving. We describe how seasonal and geographical variation in people encountered affects the field site community. We focus on short-term "sense of belonging" interventions to promote positive change in institutional and discipline culture that nurtures career development of ecologists of color. We describe the mosaic of unsafe environments that can be encountered across the landscape of field biology courses and give advice on how to prevent problems for students and practitioners of color who have to drive through unsafe areas to get to the chosen research sites.

1641 Lisa Brady, Tobias Ziemke, Amu Tawawalla, Greg Pask

Constructing an Improved System for Decoding Insect Odorant Receptors

Insects use smell for a variety of purposes, including finding mates, locating food, and communication. A popular method of studying mechanisms of insect olfaction involves expressing odorant receptors (ORs) in Drosophila melanogaster to allow a single odorant receptor to be studied. This method, although effective in Dipteran insects, has varied efficacy in other insect groups, partially because the presence of endogenous D. melanogaster receptors impacts the reliability of OR screening and complicates data analysis. We present a new fly decoder system with a construct that can both promote expression of an insect OR and disrupt the endogenous receptor. We performed a four-piece Gibson Assembly to create a plasmid with a dominant marker, a neuron-specific promoter, and a GAL4 coding sequence to express the OR of interest. The new plasmid was inserted into a MiMIC fly line with a disrupted Or59b receptor. We validated the new decoder system using the localization of fluorescent proteins and the expected functional responses of previously characterized insect ORs from four different insect orders. The new decoder system will serve as another tool for the functional characterization of insect ORs.

1713 Danielle Bragg, Elizabeth Borda

Transcriptomes and Aquifers: How do anchialine cave shrimp respond to salinity change?

Karst Subterranean Estuaries (KSEs) of the Yucatan Peninsula, Mexico, are coastal ecosystems characterized by stratified water layers (freshwater-to-saline), with direct or indirect connections to the surrounding Gulf of Mexico and Caribbean Sea, and to an extensive freshwater aquifer. Also known as anchialine caves, KSEs are dominated by taxonomically diverse crustaceans that exhibit strict adaptations to cave (e.g., lack of sunlight, hypoxia) and salinity conditions. Species of the shrimp genus Typhlatya belong to an anchialine adapted clade within the freshwater shrimp family Atyidae. Recent phylogenetic work identified the Yucatan Typhlatya dzilamensis as restricted to KSEs and euryhaline. The goal of this study is to gain insight into the genes that potentially support adaptation to anchialine habitats, specifically in response to environmental and salinity change. Transcriptome data of T. dzilamensis were de novo assembled, functionally annotated, and screened for genes (~40 identified) associated with respiration (aerobic and anaerobic), osmoregulation, oxidative stress, and response to environmental stimuli. Functional gene expression profiles of specimens exposed to fresh (0 psu) and brackish (15 psu) water for 15 minutes, respectively, with native water (>30 psu) specimens serving as a control, were evaluated to investigate the biological, cellular, and molecular basis underlying the salinity preferences and deeper cave specific adaptation of T. dzilamensis relative to congenerics associated with the low salinity meteoric lens (< 5 psu) and cavernous regions where light may still penetrate.

677 Nicholas Brandley, Claire Campbell

Coarse Vison, Small Legs: Active Space of Visual Signaling in the Carolina Grasshopper

The active space of a signal is defined as the area over which a signal can successfully propagate to be detected by a receiver. In vision, the active space of a signal is not only affected by visual obstacles, but also by 1) the receiver's visual capabilities and 2) properties of the initial signal (including its size and contrast). Here, we investigate the active space of femur movements produced by the Carolina grasshopper (Dissosteira carolina) through a combination of visual modelling and behavioral observations in the field. We find that these signals involve exposing a highly contrasting black-and-white stripped region of the femur. However, the grasshopper's coarse visual acuity (~2°) and small legs (width of femur = ~2 mm) suggest that the signal's active space may be limited. We suggest that human's fine vision and large size may make us overestimate the active space of many small invertebrates.

1579 Artis Brasovs, Pavel Aprelev, Alexandre Palaoro, Charles Beard, Peter Adler, Kostya Kostya

How blood viscosity correlates with the hawkmoth size

For flying insects, blood viscosity is a major physiological parameter limiting flight performance by controlling the flow rate of fuel and oxygen to the flight muscles, circulating other nutrients, and rapidly removing metabolic waste products. The more viscous the blood, the greater the metabolic energy needed to pump it through vessels. Employing Magnetic Rotational Spectroscopy with Ni nanorods, we analysed the viscosity of resting hawkmoths and showed that viscosity depends on wing and body size non-monotonically. It increases for small hawkmoths with high wingbeat frequencies, reaches a maximum for middle-sized hawkmoths with moderate wingbeat frequencies, and decreases in large hawkmoths with slower wingbeat frequencies but greater lift. Accordingly, small and large hawkmoths have viscosities approaching that of water, whereas mid-sized hawkmoths have up to threefold larger viscosity. The metabolic demands of flight correlate with significant changes in circulatory strategies via modulation of hemolymph viscosity. Thus, the evolution of hovering flight would require fine-tuned viscosity adjustments to balance the need for the blood to carry more fuel to the flight muscles while decreasing the viscous dissipation associated with its circulation.

289 Anthony Breitenbach, Ryan Paitz, Rachel Bowden

The role of transient thermal cues in temperature-dependent sex determination

One likely consequence of climate change is that organisms will experience transient exposure to unseasonable temperatures (both warm and cold). Therefore, temperature manipulations in ecophysiological studies should be designed to determine how organisms might respond to these transient, unseasonable temperatures. To investigate the effects of transient thermal cues during development, we have exposed red-eared slider (Trachemys scripta) embryos to constant or fluctuating temperatures across development with varying duration and timing of exposures. T. scripta has temperature-dependent sex determination in which warm temperatures during development produce females and cool temperatures produce males. We found that exposure to constant temperatures (26°C or 31°C) induced genes involved in gonadal development earlier than fluctuating temperatures (26 ± 3°C or 31 ± 3°C). Interestingly, transient exposure to 31 ± 3°C, from a baseline of 26 ± 3°C, sped up development but delayed upregulation of genes involved in either the male or female pathway until later embryonic stages. These results show that multiple factors related to how temperatures are administered, especially exposure to transient temperatures, can affect physiological responses and ultimately highlight the importance of investigating exposure to transient temperature cues in the face of a changing climate.

239 Noah Bressman, Doug Fudge, Andy Turko, Peter Ly, Christian Quinteros

Vertical jumping from extremely shallow water by the amphibious killifish Fundulus heteroclitus

To exit water, fishes typically orient their body roughly vertically and then accelerate rapidly until they launch out of the water in a ballistic flight path. However, we observed amphibious mummichogs (Fundulus heteroclitus) jumping vertically from water too shallow to allow for a vertical body orientation (i.e., water depth was

689 Valerie Brewer, Jamie Cornelius, Suzanne Austin

Western bluebird sex ratios over years with varying temperature and precipitation

In sexually dimorphic animals, sex ratios may be driven by differences in offspring fitness benefits or production costs. Evidence indicates that organisms exposed to environmental stressors or with poorer condition may alter their offspring sex ratios to produce more females. Females may benefit from this adjustment in sex ratios to maximize fitness in more stressful environments. Here, we examined variation in nestling sex ratios within season and across years in breeding western bluebirds (Sialia mexicana), including during a historic heat wave in western Oregon. We assessed sex ratios in broods based on plumage color dimorphism in late stage western bluebird nestlings. We compare sex ratios with average temperature and precipitation using NOAA weather data in Benton County, OR. Specifically, we compare the hatch date, average daily temperature and precipitation with sex ratios between multiple years of breeding data. This study will contribute to our understanding of how sex ratios can be influenced by weather stress and between years.

1643 Stephanie Bristow, Samantha Skerlec, Krista Ward, Thomas Luhring

Limits of phenotypic plasticity and implications for collateral effects on fitness

The ability of organisms to navigate global climate change is constrained by their ability to respond evolutionarily or through phenotypic plasticity. Aquatic ectotherms show an immense capacity to adapt to their environment during early development through plastic responses. For example, larval amphibian maturation and growth rates are highly responsive to predation risk. However, growth and maturation rates are simultaneously constrained by resource availability and temperature. Although there is considerable work on how these factors singly alter growth and development, they are commonly experienced simultaneously within natural systems. Here we investigate the limits of phenotypic plasticity in the face of resource limitation across thermal regimes. Using Lithobates blairi (Plains Leopard Frogs), we applied 2 predation risk, and 3 resource availability treatments over a thermal gradient (15, 20, 22, 24, 26, 28°C). Preliminary results suggest strong unimodal responses of growth and development to temperature that interact with predation risk and resource availability. Furthermore, initial data from post-metamorphosis juvenile frogs show that the effects of these treatments carry over into terrestrial jumping performance.

898 Cara Brittain, Haruka Wada, Dan Cristol

Neural effects of lifelong dietary methylmercury in a model songbird

Methylmercury is a toxicant known to impair neural function and neurogenesis. While most research has focused on the effects of mercury in the aquatic environment and during development, our work seeks to understand the effects of sublethal, environmentally relevant levels of mercury on spatial learning in adult terrestrial songbirds, using zebra finches (Taeniopygia guttata) as a model species. Finches exposed to dietary methylmercury throughout their lifespans displayed impaired spatial learning and increased perseveration in a five-step spatial memory task. The hippocampus is a region of the brain related to spatial learning and memory, thus we hypothesize methylmercury is impairing neural function in the hippocampus. We observed neither a significant difference in hippocampus-to-telencephalon volume ratios between treatments nor a significant difference in density of immature or mature hippocampal neurons. However, in the finches exposed to methylmercury, we observed increased immunolabeling of doublecortin - a protein expressed in immature neurons - in the ventricular area, where hippocampal neurons are generated. Because birds exposed to methylmercury show increased immunoreactivity against doublecortin, yet display no difference in neuron number in the hippocampus, cellular migration could be hindered. Additionally, neurons may have increased damage and/or cellular death that was not observed with our methods. These results suggest mercury contamination could have severe implications for songbird conservation, particularly migratory and/or food-caching species with stronger demands on spatial memory.

1365 Sarah Britton, Goggy Davidowitz

Context Dependent Benefits of Melanism Explain Pigmentation Plasticity

Plasticity is the ability of a genotype to produce multiple phenotypes in response to environmental stimuli. Adaptive plasticity is expected to evolve when different phenotypes are optimal in different environments. In order to understand the evolution of plasticity we need to understand costs and benefits of trait expression across environments. In Hyles lineata, the white-lined Sphinx moth, melanin pigmentation is a plastic trait. Maximal melanization is induced in response to seasonal cues, including low temperatures and short photoperiods, and is expected to be beneficial in cold environments due to its ability to absorb radiant heat. In this study we test the hypothesis that melanin pigmentation plasticity is an adaptive response to temperature variation. We induced melanic versus non-melanic larvae of H. lineata and raised them in cold (21°C) versus warm (33°C) environments under a source of radiant heat. We measured survival, growth rate, and development time in the 5th instar. In cold environments melanic larvae grow significantly faster than non-melanic larvae and had lower mortality. In the warm environment, however, growth rates, development periods, and mortality of the two morphs were similar. These results suggest that melanic individuals have an advantage over non-melanic individuals in cold environments but not warm environments, consistent with the hypothesis that melanin plasticity is adaptation to temperature variation. This study contributes to our understanding of the evolution of phenotypic plasticity.

1245 Robert Brocklehurst, Magdalen Mercado, Stephanie Pierce

Adaptive landscapes reveal complex evolution of forelimb posture in stem mammals (Synapsida)

The 'sprawling–parasagittal' transition was a major postural shift during mammal evolution, but 'when' and 'how' it occurred has been debated for decades. Previous work focused on a few exceptional fossils from discrete points in time, but broader studies of individual limb elements may provide a more comprehensive evolutionary perspective. Here we address when and how parasagittal forelimb posture evolved in the ancestors of mammals, the non-mammalian synapsids (NMS), using functional adaptive landscape analysis of the humerus bone, incorporating data from morphology, function, and phylogeny, to assess forelimb evolution in deep time. The humerus is subjected to different functional stresses in parasagittal vs. sprawling limbs, and so its morphology is expected to reflect postural differences. We measured humerus shape and various functional traits on a large sample of NMS (n = 61), with a diverse array of extant taxa (n = 140) serving as a robust comparative dataset. We recover distinct adaptive landscapes for extant sprawling and parasagittal taxa, highlighting functional specialization of the humerus associated with different postures. The landscapes for NMS had distinct adaptive peaks from extant sprawlers. While there is repeated evolution of humeri representing 'transitional' postures in NMS, humeri consistent with parasagittal posture do not appear until the crown group. Our data reveal the complexity of postural evolution within Synapsida, with the 'sprawling-parasagittal' transition typified by considerable homoplasy, and postural variation within individual synapsid clades.

916 Lance Brooks, Peter Weyand

From humans to hounds: gravity and balance limit sprint running acceleration

Maximal sprint accelerations by humans are far less rapid than those of the swiftest quadrupedal runners despite both being subject to the same mechanical constraints which impose a theoretical maximal acceleration capability of 1 G. This constraint is a direct result of the need to satisfy the demands of gravity to both support one's body weight and to avoid loss of balance. We evaluated two hypotheses: first, that the acceleration capabilities of bipeds and quadrupeds are limited to 1 G, and second, that two-legged runners' acceleration capabilities are limited relative to their four-legged counterparts due to the requirement for intermittent aerial periods. To evaluate our first hypothesis, we examined kinetic data available for both human and quadrupedal runners from the existing literature and original kinetic data from our lab. We then evaluated whether maximal human acceleration is constrained by required aerial periods between steps, limiting the fraction of time of force application. Our findings demonstrate that bipeds and quadrupeds push with submaximal force during all-out acceleration efforts, limited to 1 G. Quadrupeds can achieve greater velocities in less time than bipeds during early acceleration in the absence of the intermittent aerial periods required of bipeds. Therefore, greater running accelerations are likely only possible in conditions of hypergravity.

1729 Christofer Brothers, Daniella Guizarnotegui-Gomez, Stacey Combes

Striking Dragons: Dragonfly nymph attack frequency and success at varying angles on live prey

Dragonflies are predatory insects well known for their incredible predatory success as adults, but are also formidable predators as aquatic nymphs, hunting both invertebrate and vertebrate prey with their ballistically extending labial mask. Several recent studies examined the biomechanical structure and mechanism of labial masks, but mostly focused on forward facing predatory strikes. However, many dragonflies, especially sit-and-wait predators in the family Libellulidae, successfully attack prey at angles exceeding 90 degrees from their body axis. We filmed libellulid nymphs interacting with freely swimming prey (Daphnia spp) to examine the frequency of oblique predatory strikes, and the extent to which the angle between predator and prey affects capture success. Nymphs and Daphnia were filmed at 60 fps over hour-long sessions within a small glass dish, lined with grip tape to provide traction for the nymphs' legs during strikes. We overlaid recorded frames of labial strikes immediately before extension and at maximal labial extension, to quantify the angles of labial strikes relative to the nymph's body axis. We determined whether strikes were successful, and calculated success rate as a function of strike angle. We found that both frequency of capture attempts and capture success rate decreased with attack angle, from 0 degrees (directly in front) to 90 degrees (directly to the side). Future studies will examine how leg-substrate interactions might influence capture success at different angles.

795 Jacob Brotman-Krass, Tal Perevolotsky, Adam Summers, Lauren Simonitis, Cassandra Donatelli

Grunting and Groaning: Characterizing Sound Production in Poachers

Fish use sound production for attracting mates, intimidating rivals, and warning off predators. Characterizing these sounds may help us interpret the vast amount of bioacoustic data collected by monitoring stations around the world and provide alternative ways of measuring species density and interactions. Poachers (Agonidae) are a group of armored fishes that produce buzz-like sounds when startled. In this study, we used underwater recordings and a variety of signal analysis techniques to characterize sound production in two species of Poachers, Bathyagonus alascanus and Agonopsis vulsa. We also used scanning electron microscopy and micro-CT scanning to examine the possible mechanisms behind sound production in these agonids, with special attention to the pectoral girdle. Bathyagonus alascanus makes drawn out groans with an average duration of 323.8 ms and a fundamental frequency around 122 Hz. Agonopsis vulsa generates short, rapid bursts of one to seven grunts with an average duration of 89.7 ms and multiple harmonic series' present (fundamental frequencies of 70 Hz and 105 Hz). Stridulation along the cleithrum on the pectoral girdle appears to be a possibility as the source of sound production for future investigation in agonids. While both species examined in this study produce harmonically rich sounds, we found significant differences in duration, structure, fundamental frequency, and harmonic content in the sounds produced by these fishes.

41 Kristen Brown, Elizabeth Lenz, Benjamin Glass, Rayna McClintock, Craig Nelson, Hollie Putnam, Katie Barott

The acclimatization and sensitization of reef-building corals in response to repeat marine heatwaves

As the frequency of extreme marine heatwaves increases, the time available for recovery between events is decreasing, opening the possibility that accumulation of heat stress may preclude acclimatization. To better understand which of these trajectories are occurring, we have been following the in situ heat stress responses of bleaching-susceptible and bleaching-resistant individuals of two dominant Hawaiian reef-building coral species (Montipora capitata and Porites compressa) over the last 8 summer seasons, encompassing 2 severe marine heatwaves (2015 and 2019). Our data indicate that there are both inter- and intraspecific differences in response to repeat heatwaves, with bleaching-susceptible colonies of P. compressa showing acclimatization to heat stress (i.e. no bleaching) during the second heatwave, whereas bleaching-susceptible M. capitata exhibited moderate bleaching during the second heatwave as well as in response to seasonal temperature maxima in non-heatwave years. Through high-frequency physiological sampling, we further explored recovery capacity over 2 years following the second heatwave. By 29 months post-heat stress, photosynthetic rates, symbiont densities and host biomass of P. compressa reached an asymptote, suggesting near-complete recovery. Conversely, M. capitata displayed incremental yet only partial recovery, with bleaching-susceptible corals continuing to exhibit reduced metabolic rates compared to bleaching-resistant conspecifics. In the absence of a sufficient recovery period, frequent marine heatwaves may compound organismal stress, threatening the maintenance of coral reef ecosystem function into the future.

567 Christian Brown, Erik Sathe, Robert Dudley, Stephen Deban

Skydiving salamanders: How some lungless salamanders jump, glide, and generate lift

We present a comparative approach to studying how Aneides vagrans, a salamander from the complex crowns of earth's tallest trees, handles the biomechanical challenges of its extreme arboreal niche. First, we recorded salamanders jumping, locomoting vertically, dropping, and flying in a vertical wind tunnel. Then, we laser-scanned and 3D reconstructed salamanders to compare morphological contributions to aerodynamics with computational fluid dynamics (CFD). Arboreal salamanders (Genus Aneides) jump slower but assume skydiving postures more quickly after jumping. In Aneides, aerial performance follows an arboreality gradient with the more arboreal A. vagrans and A. lugubris capable of aerial righting, parachuting, and gliding at angles hypothetically sufficient to reach another branch or home-trunk, but insufficient to reach another tree. The less arboreal A. flavipunctatus and Ensatina eschscholtzii rarely parachute, never glide, and display erratic aerial behaviors, such as flailing. CFD analyses show a stronger dorso-ventral pressure gradient in the reconstructed A. vagrans, suggesting higher capacity for lift (CI); A. vagrans has a positive CI of $\sim$0.02 that increases with angle of attack up to 10°. The long limbs and active tail of arboreal salamanders, often cited as adaptations for climbing, may also contribute to parachuting and gliding when falling from trees. Hundreds of lungless salamanders climb trees, so we hope to determine how widespread aerial adaptations are in this family and the respective roles of morphology and behavior.

836 Patrick Brown, Abigail O'Hara, Jaime Gutierrez-Portillo, Elizabeth Walsh

Do colonial rotifers display allometric scaling of respiration with colony size?

The repeated occurrence of coloniality across disparate taxa suggests that colonial lifestyle is adaptive to the organisms that possess it. For rotifers, one explanation is that colonies may provide an energetic advantage to their members. An energetic advantage may take the form of lower respiration rates for colony members relative to solitary animals. Respiration rate scales allometrically with size according to Kleiber's law. For many colonial animals, colony respiration scales with colony size in the same manner that respiration rate scales with body size in solitary animals. To test whether coloniality provides an energetic advantage, we compared the allometric relationships of respiration rate and size in colonial (Sinantherina socialis & Lacinularia flosculosa) and four non-colonial species. Oxygen consumption was measured using a Loligo microplate system. Rotifers were measured and individual/colony volumes were estimated using ImageJ. From colony volume and respiration, allometric scaling factors were estimated through regression analysis. Colonies respired at $\sim$1.3 O2pm/ind/min whereas solitary rotifers had higher respiration rates (e.g., 2.3 O2pm/ind/min in Euchlanis kingi). We estimated a scaling factor of 0.5 or 1.0 for colonial rotifers, similar to scaling factors found for groups of individual animals. For example, we found scaling factors between $\sim$1.2 and $\sim$1.0 for solitary rotifers measured. These findings suggest that coloniality may not confer an energetic advantage to rotifers.

1556 Eric Brown, Danielle Levesque

Modeling Treeshrew Climatic Niches to Approximate Thermoregulatory Physiology

Treeshrews (Order Scandentia) are an evolutionarily significant mammalian clade given their phylogenetic proximity to primates, morphological similarities to ancestral mammaliaforms, and subtropical-tropical South and Southeast Asian endemicity. As ancestral mammals evolved in comparable climes, treeshews are uniquely suited for exploring evolutionary questions about mammalian physiology. As a consequence of climate, tropical mammals are not expected to exhibit cold-adapted thermoregulatory physiology. However, the uncoupling protein 1 (UCP1)-mediated nonshivering thermogenesis (NST) critical to cold adaptation in many eutherian mammals is expressed in at least one treeshrew species (Tupaia belangeri). Scandentia is an understudied and cryptic clade, and it is unknown whether other treeshrew species also use UCP1-mediated NST. Here we model treeshrew species' climatic niches for comparison with that of T. belangeri to approximate species' thermoregulatory response to climate. These remote predictions of treeshrew ecology can lead to a more holistic description of Scandentian physiology that is currently limited by a lack of field studies.

1595 Ahmani Browne, Tyler Daly, Christine Ramsay

Physiological tolerance to salinity predict the invasion of a marine biofouler Tricellaria inopinata

Invasive marine fouling organisms can have significant ecological and economic impacts in recipient communities. The bryozoan, Tricellaria inopinata, has recently invaded western Atlantic shorelines, fouling natural, as well as anthropogenic structures, such as docks, rocks, and effluent pipes. Through a series of laboratory mesocosm experiments, we assessed the physiological tolerances of this colonial organism to a wide range of salinities to predict the environmental range over which T. inopinata could spread along the western Atlantic coastline. Results from our trials show that T. inopinata can withstand salinities less than 10ppt up to 35ppt, suggesting that this bryozoan is able to invade a wide range of coastal marine habitats, such as open coasts, enclosed bays and estuaries, where these ranges of salinities are typically found. Visual surveys and previous reports of this invader confirm these laboratory findings, with T. inopinata reported in a variety of environments from lagoon ponds to open exposed coastlines. Through the combination of laboratory experiments and field surveys, we can begin to predict the types of habitats in which these invasive organisms can spread in non-native ranges, thereby increasing the awareness for stakeholders and preparations for mitigation of the impacts of these non-native organisms.

556 Whitney Brownlee, Jennifer Bronson, Brittany Burton, Max Ellsworth, Baudry Ilunga, Samuel Perez, Harrison Piper, Nathan Walker, Eric Domyan

Successful Derivation of Embryonic Pigeon Melanocytes

Domestic rock pigeons (Columba livia) have been bred for thousands of years to display an immense variety of ornamental attributes such as feather color and color patterns. These ornamental attributes make this species an ideal candidate for experiments concerning melanin production and studying the loci that regulate the production of such variety. Melanocyte cell culture is a key step in the study of pigment production and variation. Here we present the viability of utilizing pigeon melanocytes for cell culture and transfection. We adapted techniques originally developed for chicken melanocyte culture and find that they work very well for pigeon melanocyte culture as well. Our results show that pigeon melanocytes can be successfully cultured via the dissection of a pigeon embryo's neural tube after 3 days of incubation. We also find that coating culture vessels with poly-L lysine and supplementing the culture medium with Endothelin-3 both enhance the growth of cultures relative to published protocols. Furthermore, we find that pigeon melanocytes acquired in this manner can be successfully transfected with RNA and DNA, and that the CMV promoter is able to drive gene expression in pigeon melanocytes. Future work will involve optimizing transfection techniques and attempting knock-down of candidate pigment genes using siRNA.

1005 Katie Brust, Andrea Liebl, Andrew Russell

Measuring sex biases: the effect of variable sex ratio on provisioning rate in Pomatostomus Ruficeps

In cooperatively breeding species, some individuals defer breeding, and, alternatively, opt to help others raise their young as non–breeding 'helpers'. One such species is the chestnut-crowned babbler (Pomatostomus ruficeps), a cooperatively breeding bird endemic to the Australian Outback. Helpers in this species help by provisioning chicks, but both among- and within-individual variation in provisioning exists. Although we know group size does not influence how much an individual helps (i.e. we see no load-lightening in this species), little is known about how group composition, such as sex ratio, influences individual rates of provisioning. Using data collected across multiple years, we tested how sex ratio of the brood and of the adult social group influenced provisioning rate in male helpers. We found that male helpers provisioned more when more females were present in either the brood or adult social group. As females are the more dispersive sex in this species, female chicks may require additional nutrition throughout development to facilitate successful dispersal. Further, as non-breeding adult females may represent potential breeding partners for male helpers, helping behavior may be a sexually selected trait in this species. Understanding the proximate mechanisms that drive individual variation in cooperative behavior help us to understand the environments and contexts in which cooperation is most likely to arise, and therefore may have implications for how it evolved.

969 Amanda Bryant, Caitlin Gabor

Are organic agricultural practices less stressful? How farming methods alter immune and GC responses

The glucocorticoid (GC) response helps mediate responses to environmental stressors. Agricultural pollutant exposure can cause dysregulation of the GC response, leading to changes in related systems due to energetic trade-offs. Their highly porous skin makes amphibians are particularly susceptible to the effects of pollution. Organic agriculture has been promoted as a sustainable alternative to conventional agriculture. There is some data to support this, however the consequences of organic agriculture on amphibians have not been well tested. We hypothesized that GC profiles would differ in individuals across three treatment groups: conventional agricultural ponds, organic agricultural ponds, and natural ponds due to differences in stressors encountered and that these differences in stressor exposure would cause trade-offs in body condition and parasite loads. We collected GC profiles for tadpoles (baseline, agitation, and recovery GC) rates and measured body condition. We measured Echinostoma trivolvis parasite loads by analyzing tadpole kidneys under microscope. The body condition/parasite load relationship was negative for natural and organic tadpoles, with no relationship for conventional tadpoles, indicating differences in resistance and tolerance strategies between treatments. Organic tadpoles were slower to recover than natural or conventional tadpoles, indicating less efficient negative feedback of the GC response, causing individuals to spend more time at elevated GC levels. These data indicate that organic practices can still incur costs in associated wildlife.

1581 Tyler Buchinger, Ke Li, Ugo Bussy, Belinda Huerta, Sonam Tamrakar, Nicholas Johnson, Weiming Li

Male lake char release taurocholic acid as part of a mimetic pheromone

Research on the origin of preferences for sexual traits is challenging for chemical signals due to a lack of information on the specific molecules involved. For example, fish are commonly used to study sexual selection and known to rely on olfaction for mate choice, yet the identity of their pheromones remains unknown in all but a few species. In this study, we identified a male pheromone in lake charr (Salvelinus namaycush) to test the hypothesis it exploits an ancestral preference for juvenile odor. Anadromous charr species, which reside in the ocean as adults but reproduce in streams, locate spawning streams using the odor of stream-resident juveniles. Lake charr have lost the anadromous phenotype and spawn in lakes, but juvenile cue is unlikely useful for locating spawning reefs because juveniles emigrate from the reefs several months before the spawning season. However, previous behavioral data indicates males may release a pheromone that mimics juvenile odor. Using metabolomics, we identified taurocholic acid (TCA) as an abundant compound in male and juvenile odor that was absent in female odor. TCA was released at high rates via the urine of males during the spawning season and attracted spawning females but not males. Our results indicate TCA acts as a male pheromone in lake charr and support the hypothesis that the pheromone mimics juvenile odor.

1653 Katherine Buckley

The Florida false coral (Ricordea florida) mucus harbors an abundant bacterial assemblage

Animal immune systems mediate interactions between the host and the microbial world. One of the most fundamental mechanisms by which animals maintain distance between self-tissues and microbes is the production of mucus. This mucus serves as a unique niche in which specific bacterial strains can form symbiotic relationships with hosts. Here, we characterize the bacterial assemblage within the mucus of the Florida false coral Ricordea florida, a tropical corallimorpharian that inhabits the Caribbean Sea. Culturing mucus from R. florida on marine agar plates reveals that this species harbors a complex assemblage of marine microbes enriched in Vibrio species. We further find that this microenvironment supports a broad range of strains within the gamma-proteobacteria phylum. We have complemented this work with analysis of the transcriptome of R. florida. This cnidarian expresses a complex assemblage of pattern recognition receptors, secreted immune effectors, and transcription factors with conserved roles in the immune response. While research has been conducted on the microbial assemblages of other cnidarians, little is known about the microbiomes of mucosal layer of corallimorpharians. Identifying the bacteria present in the mucus of the common Caribbean corallimorpharian R. florida may allow for a better understanding of cnidarian-bacterial relationships including the discovery of secondary metabolites that could contribute to host defense against pathogens.

1555 Molly Buehler, Joseph Leese

The effect of predator exposure on territorial aggression in female Amatitlania nigrofasciatas

Territoriality is an important aspect of behavior in animals as it gives individuals access to food, mates, and protection from predators, thereby increasing relative fitness. Amatitlania nigrofasciata, convict cichlids, are territorial when in breeding pairs and demonstrate territorial aggression as individuals in lab settings. We explored whether internal factors, specifically stress levels, influence defensive behaviors. To induce a general stress response, residents were given a visual exposure to a predator, Parachromis dovii. We hypothesized that predator exposure would induce a stress response and increase acts of aggression in response to a territorial intrusion. To test this, we staged territorial encounters between female convict cichlids exposed to a predator ($N = 8$) compared to control females ($N = 9$). Before exposure, residents were acclimated to a home tank for 24 hours and then shown to a predator for 10 minutes. Simultaneously, an intruder female was placed into the resident's tank where the resident was returned after exposure. The interaction between the resident and intruder was then observed. The results demonstrate predator exposure impacts the time to initiate a contest. Females exposed to a predator initiate more quickly. While predator exposure overall did not have a significant effect on aggressive behaviors (bites, displays, chases), the severity of the predator exposure seemed to impact contest duration. Further studies could explore whether this effect was mediated by stress hormones like cortisol.

1604 Arianna Buehler, Emily Levy, Liz Aguilar, Kimberly Rosvall

Adrenal steroidogenesis in territorial female tree swallows

The challenge hypothesis, which posits that breeding males increase circulating testosterone to facilitate aggression, is an influential framework for examining testosterone and male-male competition. While aggression may be beneficial, elevated testosterone is sometimes associated with physiological costs. These costs should be mitigated via tissue-specific steroidogenesis. For example, some species synthesize testosterone precursors in adrenal glands during the nonbreeding season and convert these precursors to testosterone in the brain. Whether animals use their adrenals in this way during the breeding season is less clear. To address this gap, we studied adrenal gene expression in female tree swallows (Tachycineta bicolor) during territorial establishment, when they are highly aggressive. Ten study subjects were socially challenged with a simulated territorial intrusion, and ten controls were unchallenged. Using qPCR, we quantified adrenal gene expression of steroidogenic enzymes. Based on the notion that high levels of circulating androgen precursors are less physiologically costly than high levels of circulating testosterone, we hypothesize females synthesize androgen precursors in their adrenals. Compared to unchallenged controls, we predict that challenged females will have higher adrenal gene expression for the enzymes used to synthesize androgen precursors (e.g., dehydroepiandrosterone). Our study expands the challenge hypothesis by studying adrenal androgenesis and proximate mechanisms of territorial aggression in females as they prepare to reproduce.

764 Jesus Buenrostro, Nathalie Alomar, Martha Munoz

The Effects of Temperature Preference in Salamander Physiology.

Plethodontid salamanders, being lungless ectotherms, are faced with constant physiological and environmental challenges to ensure cutaneous respiration. For example, drastic temperature changes or variations, like hot and dry conditions, can make it a challenge to absorb oxygen through their skin. Understanding which environmental factors play a role in constraining these organisms' physiology is needed to understand their diversification. Do salamanders preferentially select certain temperatures, and do preferred temperatures vary among salamander species? To get at these questions, I looked at how the thermal preference of six lungless terrestrial species varied. To do this, I set up a thermal preference arena with one end at 5C and the other at 25C and measured what temperature the salamander preferred every five minutes over several hours. During the experiment, the arena was kept consistently moist throughout the gradient. Then, I mapped these data onto a phylogenetic tree. From this analysis, I learned that there was no major differ in thermal preference among the species, with the averages being about 1C from each other. Because the arena was kept saturated during the experiment, we infer that salamanders can be flexible about the temperatures they experience while still maintaining cutaneous respiration, leading to the broad thermal preference ranges we observed. Key follow-up studies could vary hydric limitation in the arena to determine whether salamanders become more thermally selective under drier conditions.

520 Kira Buford-Rucker, Christopher Smaga, Benjamin Parrott

Non-lethal sexing of hatchling alligators (Alligator mississippiensis) using plasma AMH

Unlike mammals that rely on sex chromosomes to determine sex, many reptiles utilize temperature-dependent sex determination, in which the temperature experienced during a window of thermosensitivity during development drives ovarian or testes fate. This includes the American alligator, which has emerged as a model species for TSD research. Male and female hatchlings are not reliably distinguished by morphological traits, and non-lethal methods of sexing neonatal alligators are not available. Yet, sexing hatchlings is vital for understanding how nest temperatures translate into natural sex ratios. In this study, we examine the use of plasma anti-mullerian hormone (AMH) as a biomarker of sex in hatchling American alligators. AMH plays a conserved role in the development of testes and inhibition of ovaries across vertebrates. Therefore, we hypothesize that males will express significantly higher levels of AMH relative to females. To test this, we first validate the use of chicken enzyme-linked immunosorbent assay (ELISA) to detect circulating AMH in hatchling alligators. We then test our hypothesis on a dataset of known sex individuals incubated at male- and female-promoting temperatures. Lastly, we implement our method by sexing hatchlings from eggs incubated under natural thermal regimes from wild nests. The overall objective of the project is to facilitate monitoring of sex ratios in the wild and understanding how natural thermal regimes translate into sex ratio variation, especially with respect to global climate change.

470 Paul Bump, Blair Benham-Pyle, Carolyn Brewster, Lauren Lubeck, Catherine Rogers, Alejandro Sánchez-Alvarado, Christopher Lowe

Building larvae and adults cell by cell: insights from the hemichordate Schizocardium californicum

Observations of the general morphological disconnect between larval and adult forms of many species in the ocean beg the question — how does the same genome build distinct life history stages? As a way of evaluating this, we took a genomics-based approach, first sequencing a chromosome-level genome assembly and then generated a comprehensive cellular atlas across the varying life history stages of the California Broken-Hearted Worm, the hemichordate Schizocardium californicum, from Morro Bay, CA. In contrast to animals that have a "catastrophic metamorphosis" this species of hemichordate has a metamorphosis that gradually transforms the larva into the adult. At a morphological level however, they are strikingly different: one a pelagic, simple, filter-feeding, epithelial larva, and the other a benthic, deposit feeding, burrowing worm. Combined with a spatial characterization of these cell clusters, this study has revealed several possibilities in transcriptional cell state composition across life history stages. Firstly, there are cell states that are specific to life history stage such as those enriched in the ciliary band. Secondly, there are cell states that are more similar to each other regardless of life history stage like those enriched in muscle. And finally, there are neural cell states that form differing cell clusters that correspond to life history differences.

1262 Alexandra Burdette-Lapuz, Ione Hunt-von-Herbing, Jack Eudy, Hollie Greer, Kaili Abram

The effects of acidification on development and metabolism of zebrafish (Danio rerio) embryos

Increasing global aquatic acidification due to anthropogenic activities poses a threat to future fish populations. Acidification has been shown to adversely affect physiological processes such as metabolism, respiration, reproduction, and behavior. However, little work has been conducted to determine the effects of acidification on the growth and metabolic costs of stress, as well as development of key osmoregulatory and ionoregulatory systems in the most vulnerable early life history stages of fish, (I.e., embryonic and larval stages). We are investigating the effects of acidification, as measured by pH, on the survival, growth, development, and metabolism (measured by oxygen consumption) of zebrafish embryos and larvae up to 7dpf. We hypothesize that decreased pH will cause decreased survival, growth, and developmental rate due to energy being diverted away from growth and development towards acid-base regulation. Additionally, we predict an increase in metabolic rate, as exposure to acidic environments requires an increase in ion exchange across the gills, thereby increasing energetic demands. Experimental work and analysis will be completed during the fall term. Future work will investigate potential detrimental shifts in energetic budgets of early stages in both the zebrafish, a freshwater species, as well as a marine fish to compare the resilience of these species to rapidly changing environments.

357 Isabella Burger, Evin Carter, Eric Riddell

Assessing hybrid vigor based on the thermal sensitivity of physiological trade-offs in ambystomids

One of the central goals in evolutionary biology is to understand the mechanisms underlying speciation, including the improved performance of crosses between parental lineages, or hybrid vigor. Our understanding of hybrid vigor often lacks an explicit test of improved physiological performance in hybrids relative to parental lineages. Here we used a physiological trade-off between water loss and gas exchange to compare metabolic efficiency of hybrids and the parental lineages of two tiger salamander species. We used flow through respirometry to estimate a metabolic efficiency ratio (MER; ratio of oxygen consumed to evaporative water loss) of native California tiger salamander (N-CTS), invasive barred tiger salamanders (I-BTS), and N-CTS x I-BTS hybrids at three temperature treatments (13.5°C, 20.5°C, and 23.5°C) to compare efficiency. We found that the invasive species had the highest MER at 23.5°C, followed by hybrids and then the native species. Interestingly, the thermal sensitivity of hybrid MER was more similar to natives than invasives, indicating that hybrids exhibit a similar respiratory strategy as the native species. These results provide greater insight into the mechanisms driving hybrid vigor because the rapid spread of hybrid tiger salamanders in California may be due to the combination of increased metabolic efficiency inherited from their invasive parental lineage combined with the thermal sensitivity of their native parental lineage.

525 Sean Burke, Nicolas Walker, Isaac Ligocki

The morphological impacts of competition and perceived predation risk in two teleost fish

In many organisms, phenotypic plasticity may facilitate responses to environmental change. Gambusia holbrooki is a globally introduced species, but its native range in the eastern United States is also expanding as a result of climate change. Through this study we investigated interactions between the livebearing eastern mosquitofish (G. holbrooki) and fathead minnow (Pimephales promelas) to examine the effects of competition and perceived predation risk on individual growth, morphology, and behavior. We established cohorts of each species in outdoor mesocosms that were raised i) as a single species shoal, or ii) with both species present. Within each treatment, half of the mesocosms also contained a largemouth bass (Micropterus salmoides) that was physically separated from the focal fish, but focal fish were exposed to visual and chemical cues of the predator. After 6 weeks in the mesocosms, fish were collected and photographed for morphometric analysis using MorphoJ. We found that in female G. holbrooki, both competition and predator presence were associated with differences in body shape. These differences were most pronounced in the abdomen and may related to differences in reproduction. In contrast, we found no significant difference in P. promelas body shape associated with predator presence or competitors. Our findings suggest that environmental factors may influence reproductive output in G. holbrooki, which may have consequences for its success expanding its range and as an invasive species.

751 Shania Burkhead, Krista Ward, Emily Stybr, Thomas Luhring

Drying and rewetting of wetland soil alters larval anuran growth rates, survival, and metamorphosis

Intermittent streams are hydrologically dynamic within and among years, leading to episodic bouts of local extirpations and subsequent recolonization of vertebrate groups such as fish and larval amphibians. To avoid pools with fish adult amphibians frequently oviposit in ephemeral pools. However, the effects of drying and rewetting of wetland soils on larval amphibians are unknown. Using 64 1000 L cattle tanks to create replicate aquatic mesocosms, we investigated the effect of drying and rewetting of pools on growth rates and survivorship of larval amphibians. We hypothesized that drying and rewetting of pools will negatively affect growth and/or survival of larval amphibians. Four trophic treatments (no vertebrates, fish, amphibians, and fish and amphibians) were crossed with two drying treatments (non-dry and dry-rewet). We collected data on larval amphibian growth rates, total emergent amphibian biomass, time/size at metamorphosis, and emergence rate (survivorship) from May 9th, 2021 to August 1st, 2021 for a total of 12 weeks. Drying and rewetting significantly reduced larval amphibian growth rates and size at metamorphosis, and increased time to metamorphosis and asynchrony of metamorphosis.

1411 Chloe Burkholder, Goggy Davidowitz, Natasha Tigreros

Effects of Increased Flight on Allocation of Nectar-Derived Nutrients in the Cabbage White Butterfly

Active flight directly impacts the dispersal, predator avoidance, foraging, and reproduction of many insects, birds, and bats. Flight is also, however, an energetically expensive mode of animal locomotion that might cause organisms to divert nutrients away from somatic maintenance and reproduction. Adult butterflies and moths rely primarily on floral nectars to acquire nutrients, which can be allocated to either flight or reproduction. Floral nectar contains not only carbohydrates, but also trace amounts of both essential and nonessential amino acids. Using artificial nectars spiked with 13C-labeled carbohydrates and nonessential amino acids, we examined how these nutrients are utilized by females of the cabbage white butterfly, Pieris rapae. Specifically, we tested whether and how allocation of nectar derived-carbohydrates, proline, and glycine to flight versus reproduction is altered by increased flight costs. Preliminary results indicate a difference in the utilization of nonessential amino acids in response to increased flight. This study provides new insights into the nutritional value of nutrients in nectar for flying insects.

381 Gary Burness, Joshua Tabh, Mariah Hartjes

Do birds and mammals trade-off thermoregulation for the stress response?

Exposure to a stressor often leads to rapid, and sometimes dramatic, change in the core body temperature of endotherms. Why such thermal responses occur is little known and relatively little studied. We tested the hypothesis that this thermal response occurs to reduce energy expenditure toward body temperature regulation when the same energy is needed for use in the stress response. To test the hypothesis, we used a meta-analysis of data collected from 65 studies and representing 24 species of birds and mammals. Our results support the idea of an energetic trade-off. We show that body temperature often decreased following a stressor in the cold, and particularly in species with proportionally high energetic costs of warming (i.e., those with low body mass) and proportionally high energetic costs of maintenance (i.e., relatively high resting metabolism). We suggest that in these species, energy available for use in the stress responses is likely limited and should be freed by lowering body temperature toward ambient. Under warm conditions, body temperature typically increased after a stressor, thus allowing energy typically used for cooling to be allocated toward the stress response. To our knowledge, this is the first comparative analysis to support a function for a stress- induced change in body temperature and suggests, that in endotherms, investment in thermoregulation may trade-off with investment in the stress response. Funding: NSERC (Canada).

1360 Nicholas Burnett, Emily Keliher, Stacey Combes

Maximum force production is robust to changes in spanwise wing stiffness in mason bees

In flying insects, chordwise wing flexibility (leading to trailing edge) can increase force production and flight stability. Few studies have examined the impact of spanwise flexibility, although some models suggest it reduces force production. Bees are ideal for manipulating wing flexibility, as their wings contain small patches of the flexible protein resilin along some supporting wing veins, where passive, localized bending can occur. We manipulated spanwise wing flexibility in the mason bee Osmia lignaria by placing glitter splints on (treatment) or adjacent to (control) the resilin-filled gap in the leading-edge vein of the wings. We measured changes in spanwise stiffness and performed load-lifting assays to test how altering spanwise stiffness affects maximum vertical force production. Experimental splints nearly tripled spanwise wing stiffness but did not increase force production; in fact, force production was higher on average with control splints. High-speed videos of wings during flight showed that experimental splints reduced bending at the resilin-filled gap but increased bending in more distal wing regions. Thus, the precise location of spanwise wing bending is not a major factor influencing force production, and resilin patches in the spanwise direction may be adapted for functions besides aerodynamic performance, such as limiting damage from wing collisions.

1792 Pablo Burraco

Ageing across the great divide: telomere dynamics through amphibian metamorphosis

Three quarter of existing animal species undergo metamorphosis. However, the putative effect of this dramatic life transition on the senescence of tissues remains unknown. The shortening of the end cap of the chromosomes, called telomeres, are often considered as a reliable marker of cellular and organismal ageing. Therefore, the study of telomere dynamics can allow to determine whether metamorphosis has a role in the ageing process. Here, we investigated whether the re-modelling of tissues that occurs during metamorphosis allows an individual to re-set its telomeres and so leave behind this legacy of past environments. This issue is pertinent to amphibians, a group likely to be heavily impacted in the larval stage by extreme weather events and global warming. Our results show that telomere length is affected not only by the rate of somatic growth, but also by the degree of metamorphic transformation experienced by particular tissues, and by temperature conditions earlier in life. During metamorphosis, telomere length can either decline, remain stable or dramatically increase. Therefore this life history transition may be able to buffer the impact on telomeres of harsh conditions in early life. This leads us to suggest directions for future research on telomere dynamics in amphibians and other species with complex-life cycles.

1501 Edward Burress, Meaghan Gade, Eric Riddell, Martha Munoz

Innovations and mountains act synergistically to drive the evolution of lungless salamanders

Functional innovations are held as catalysts of ecological diversity, often resulting in rapid phenotypic evolution as lineages adapt to new niches. Yet, classic macroevolutionary signatures of adaptive radiation may be obscured if many potential catalysts are confluent. We test the effect of an array of functional innovations and elevation (a proxy for environmental gradients) on the evolutionary history of a charismatic radiation, lungless plethodontid salamanders. This lineage exhibits a paradoxical mixture of prolonged ecological stasis, interrupted by bouts of adaptive radiation. The origination of functional innovations led to accelerated rates of phenotypic evolution as well as shifts in elevation and microhabitat use. We find that rates of phenotypic evolution, the diversity of microhabitat specialists, and ecological lability decline with elevation. Contrary to expectations, our results point to mountains being ecological dead ends and sinks for morphological evolution. Evolutionary rate heterogeneity in lungless salamanders is on par or greatly exceeds that of several iconic adaptive radiations including Anolis lizards and cichlid fishes, and the mountain effect on such heterogeneity was comparable to or beyond that of islands, lakes, and coral reefs. Lungless salamanders are a unique radiation in which functional innovations and mountains operated synergistically to drive their phenotypic and ecological diversity.

1050 Jenny Burrow, Maggie Mayberry, Jacob Francis, Faith Dall, Michelle Bowe, Anne Leonard, Avery Russell

Picky eaters: generalist bees sample pollen on flowers by ingestion before collection

Determining how animals assess food quality is fundamental to understanding foraging behavior. Generalist bees collect floral nectar and pollen, and the quality of these two foods is highly variable among plant species. Given often strong nectar and pollen preferences, bees likely assess the quality of both foods. Yet while bees assess nectar quality while ingesting it, pollen is stored externally in pollen-baskets. We investigated how bumblebees might assess pollen quality, predicting they might assess quality by ingesting small amounts while foraging. We collected foragers from the field and quantified pollen species diversity and abundance in the pollen-baskets and gut. Field results in combination with a controlled lab assay established that foragers consume pollen directly from flowers. We also found that pollen foragers were more likely to have pollen in their crops than nectar foragers and that pollen diversity was greater for pollen foragers. Our results implicate ingestion and potentially gustatory cues as mechanisms used by generalist bees to assess pollen quality, suggesting that pollen and nectar are assessed similarly, even though stored very differently.

953 Emily Buska, Arthiur Martin

The impact of a predator, Largemouth Bass, on the shelter usage of the Rusty Crayfish

Crayfish utilize resources such as food, shelter, and mates. Extrinsic factors such as resource availability, environmental conditions, and the presence of predators or conspecifics can influence the acquisition and use of resources. Crayfish occupy shelter for protection from conspecifics, predators, and other environmental factors. The present study is designed to examine the influence natural predators have in altering a crayfish's frequency of shelter usage and shelter preference. A series of 24-hour trials were designed to allow rusty crayfish (Faxonius rusticus) to choose between differing shelters when exposed to largemouth bass (Micropterus salmoides), a natural predator of the rusty crayfish. During trials the number of entries and time spent in each shelter were recorded as well as predation rates. Crayfish and fish were paired depending on the carapace to gape size ratio. Crayfish selected had a carapace to gape size ratio less than that of 96%, as previous studies have shown this to increase predator-prey interaction behavior. The aim of this study is to address the correlation between predator presence and the usage of shelters.

259 Mike Butler, Zachary Cullen, Caroline Garti, Dory Howard, Bridget Corpus, Bridget McNish, Justin Hines

Physiologically relevant levels of a putative antioxidant do not oppose oxidative damage in plasma

Antioxidants have important physiological roles in limiting the amount of oxidative damage that an organism experiences. One putative antioxidant is biliverdin, the pigment most commonly associated with the blue of avian eggshells. However, despite claims that biliverdin

functions as an antioxidant, typical physiological concentrations of biliverdin in most species have never been examined, nor has biliverdin's ability to oppose oxidative damage at these concentrations. Therefore, we quantified biliverdin in the plasma of six bird species, and found they circulated levels of biliverdin between 0.02 and 0.5 μM. We then used plasma from northern bobwhite quail (Colinus virginianus) and spiked it with one of seven different concentrations of biliverdin, creating plasma-based solutions ranging from 0.09 to 231 μM biliverdin. We then compared each solution's ability to oppose oxidative damage induced by hydrogen peroxide relative to a control addition of water. We found that hydrogen peroxide consistently induced moderate amounts of oxidative damage (quantified as reactive oxygen metabolites), but that no concentration of biliverdin ameliorated this damage. However, biliverdin and hydrogen peroxide interacted, as the amount of biliverdin in hydrogen peroxide-treated samples was reduced to approximately zero unless the initial concentration was over 100 μM biliverdin. Our findings indicate that while biliverdin may have important links to metabolism and immune function, at physiologically relevant concentrations, it does not detectably oppose hydrogen peroxide-induced oxidative damage in plasma.

471 Melissa Butler, Calvin Vary, Anyonya Guntur, Markus Frederich

Dietary effects on lipid composition and subsequent phenotype in the American lobster

To provide a constant supply of economically important lobsters (Homarus americanus) in New England, animals are kept intermittently in impoundments for months and are typically fed herring, which differs significantly from wild-caught lobsters, which consume a natural diet. In this study, we compared the lipid composition of lobsters fed exclusively herring (pound-fed) to those fed mussels (wild-fed) and tested whether this leads to differences in their phenotype. Preliminary lipidomic data suggested significant differences in the lipid composition of pound-kept and wild-caught lobster hearts and some differences in tail and hepatopancreas tissue. Lipid groups that were most up- or down-regulated included phosphatidylglycerols, dihexosylceramides, and cardiolipins – which are typically found in mitochondria. The efficiency of an organism's mitochondria can affect the overall energetic state of its cells which, in turn, influences thermal tolerance under the Oxygen and Capacity Limited Thermal Tolerance hypothesis (OCLTT). Thus, we tested mitochondrial efficiency using Seahorse XF Cell Mito Stress Tests, gene and protein expression of cellular stress markers (HSP70, AMPK), and thermal tolerance of whole animals by heart and ventilation rate as well as hemolymph oxygenation to determine phenotypic differences expressed from lobsters with differing lipid membranes. These results indicate that nutrition-dependent changes in lipid composition of lobster tissue have no detectable impact on their thermal tolerance.

637 Julie Butler, Penelope Baker, Lauren O'Connell

Sensory Basis of Caregiver Recognition in Mimetic Poison Frog Tadpoles

During early life stages, animals often rely on their parents for their nutritional needs. Begging displays are found across the animal kingdom and require the ability to determine if an individual is a potential caregiver. This can be a life-or-death decision for Mimetic Poison Frog (Ranitomeya imitator) tadpoles. After hatching, tadpoles are transported to small, nutrient-poor nurseries by dad and rely on egg meals from mom. Tadpoles signal hunger and beg for food by vigorously shaking their body. However, which sensory modalities tadpoles use to assess the identity of visitors is unknown. We tested the role of visual, chemosensory, and mechanosensory cues during interactions with potential caregivers. Visual and chemosensory caregiver cues alone were not sufficient to initiate begging, but tadpoles beg when presented with both. Interestingly, vision and olfaction alone are not necessary for begging, as blind and anosmic tadpoles beg to a caregiver. However, anosmic tadpoles also beg to heterospecific females, indicating olfaction underlies caregiver recognition. Ablating the mechanosensory lateral line did not impact begging in older tadpoles but reduced begging in young tadpoles. Mechanosensory cues may be more important for young tadpoles due to their poor vision than older tadpoles with more developed vision. Together, these data indicate that chemosensory cues mediated caregiver recognition and that multimodal cues are needed for begging, but that the composition of multimodal cues varies across development.

1553 Marguerite Butler, Ethan Hill, Diana Gao, Dan Polhemus, Allen Allison

Geological drivers of diversification in Papuan microhylid frogs

Asterophryine frogs are a hyperdiverse clade representing half the world's microhylid diversity centered on New Guinea and its satellite islands. Lying at the junction of five tectonic plates, this region has experienced a turbulent geological history producing towering mountains, island archipelagos of varying distance, and active margins where land masses have collided and subsequently rifted apart creating a mosaic of intermixed terranes. We show that vicariance facilitated by geological history, and not elevational specialization best explain the far and wide distribution of these poor dispersers. We recovered a mainland tectonic unit, the East Papua Composite Terrane (EPCT), as the center of origin and no fewer than 71 long-distance dispersal events, 29 between mainland regions, and 42 from the mainland to the islands. We find strong support for a Slow and Steady hypothesis of formation of New Guinea?s northern margin by many separate accretion events, over other major geological alternatives, consistent with arrival via the EPCT 20 MYA. Our results show that Asterophryinae did not have to repeatedly disperse across large ocean barriers. Rather, vicariance and short-distance oceanic dispersal could explain the distribution as historical land connections disappeared and islands slowly separated. We show that islands can evolve in distance from other land masses, with consequent opportunities for dispersal, isolation, and cladogenesis of their biotas resulting in the rapid accumulation and staggering biodiversity.

757 Steven Byrum, Gareth Fraser, Gavin Naylor

Development of the Bonnethead shark (Sphyrna tiburo)

The hammerhead sharks (family Sphyrnidae) are a charismatic and immediately recognizable monophyletic group of sharks, readily identified by their flattened and laterally expanded heads. Though there has long been an interest in hammerhead development, there are currently no explicit staging tables published for any members of the group. The bonnethead shark Sphyrna tiburo is the smallest member of Sphyrnidae and is abundant in waters along the Gulf Coast and Southern Atlantic. Due to their relative abundance, close proximity to shore, and brief gestation period, it has been possible to collect multiple embryonic specimens at varying stages of development. Here, I compare the developmental trajectory of the bonnethead with those of other chondrichthyans to establish a staging series for this species. With an emphasis on the emergence of the unusual cartilaginous skull (chondrocranium) in the bonnethead, I have employed several morphological (CT, histology) and molecular (localized protein and gene expression) techniques to characterize the developmental deviation in head shape at precise embryonic stages. This work will serve as a platform for future comparative developmental research both with hammerhead sharks and across chondrichthyan fishes, underpinning the extremes of morphological diversity in this groups of fishes.

119 Abigail Cahill, Emily Rollinson, Katie Ferrero, Patrick Mayo, Elizabeth Deecher, Brittney O'Connor, Nijmih Siryani

Population sizes of introduced milkweed aphids (Aphis nerii) and their effect on plant traits

Aphis nerii, the oleander or milkweed aphid, is a widespread introduced species in North America. In the northern part of their introduced range, they specialize on milkweed plants. The species is obligately parthenogenetic and can quickly reach very high densities, leading to speculation that aphids may lead to a decline in milkweed quality (and therefore declines in monarch butterfly habitat). We conducted an observational study of aphid population sizes and traits of common milkweed (Asclepias syriaca) in Michigan and Pennsylvania. We found no clear relationship between aphid population density and plant height, leaf number, or pod number. The occurrence of monarch caterpillars was likewise not related to aphid density or occurrence, probably because caterpillars were very rare. In a subsequent field experiment, we manipulated aphid density on milkweed plants and measured seed set in plants with and without aphids. Taken together, our results suggest that A. nerii may not be a major threat to A. syriaca populations (and subsequently to monarch butterflies).

1459 Liming Cai

The Bloody Queen Hypothesis for the Evolution of Parasitic Plants

The need for photosynthesis has largely shaped the body plan, physiology, as well as gene repertoire of seed plants. However, shifts to a heterotrophic lifestyle have independently evolved twelve times in more than four thousand parasitic plants. Among these parasites, otherwise rare features have evolved repetitively at both the molecular and phenotypical levels, including reduced vegetative body, carrion mimicking, and abundant alien genetic materials. Here, I propose an integrated conceptual model to describe the general evolutionary trajectory of parasitic plants and provide a mechanistic explanation for their convergent evolution. This model is termed as the 'Bloody Queen Hypothesis' and it connects recent empirical findings with classic theories in molecular and population genetics. The name of the hypothesis is derived from the classic Red Queen Hypothesis, where evolution is fueled by the arms race of opposing species such as hosts and parasites. The Bloody

Queen Hypothesis, instead, emphasizes the irreversible genome degradation as the opposing force that parasitic plants strive to battle with. Such genome degradation originates from the cascading gene loss triggered by the loss of photosynthesis, including directly linked functional modules such as pigment synthesis, circadian rhythm, and cellular redox homeostasis. These genetic modifications further lead to phenotypic changes such as the lack of certain floral pigments, which can contribute to specialized reproductive strategies and ultimately translate to macroevolutionary consequences.

1666 Mandy Cai, Stephen Yanoviak, Alyssa Stark

The Effect of Humidity and Substrate Hydrophobicity on Ant Adhesion, Locomotion, and Behavior

Ants use adhesive tarsal pads coated in a glue-like secretion to climb while foraging, escape from predators or unfavorable conditions, and defend territory. In Pennsylvania where Camponotus pennsylvanicus forage, variation in temperature and humidity change the quality of the substrates they adhere to. In particular, relative humidity (RH) can range from 20-100% and substrate hydrophobicity will dictate if water layers are deposited on a substrate surface as a function of high RH. Despite highly variable RH in their environment and the ability of thin water layers to disrupt the ant adhesive system, nothing is known about how temperate ant adhesion, locomotion, and behavior may vary across substrates that range in wettability. To test for the effect of substrate wettability and RH on ant performance and behavior, we tested shear adhesion and running speed of C. pennsylvanicus on three substrates (hydrophilic glass, hydrophobic polypropylene, and intermediately wetting polycarbonate) in seven RH setpoints (30, 40, 50, 60, 70, 80, 90% RH). We hypothesized that adhesion and running speed would reduce, and mitigating behaviors (stop, turn around) would increase on glass more than the other substrate due to elevated water layer deposition at high RH on this hydrophilic substrate. The results of this study will improve predictions about how variable climate conditions, particularly in the face of climate change, will influence this key member of most global ecosystems.

1282 Fernando Calderon-Gutierrez, Brett Gonzalez, Thomas Iliffe, Jessica Labonté, Lauren Ballou, Luis Mejía-Ortíz, Elizabeth Borda

DNA barcoding reveals cryptic diversity in the aquifer of the Yucatan Peninsula and Cozumel, Mexico

Karst subterranean estuaries are coastal ecosystems characterized by vertically stratified groundwater, where one or more layers of fresh to brackish water are buoyed over marine groundwater, each separated by a halocline interface. The Yucatan Peninsula and Cozumel Island are considered prime examples of Karst subterranean estuaries. 223 recorded species have been recorded in this area (∼45% represented by Crustacea), of which 91 are considered obligate stygobionts (i.e., aquatic cave adapted). Identification of groundwater species heavily relies on morphological taxonomy; however, increasing use of molecular tools support the presence of cryptic species to be more widespread than previously thought. This study employs DNA barcoding (cytochrome c oxidase subunit I; COI) through the analysis of both published and novel sequences, sampling from type localities and the inclusion of non-crustacean phyla, typically overlooked in biodiversity assessments of fauna from this environment. Phylogenetic and DNA-based species delimitation methods were employed to evaluate the presence of cryptic linages and identification of true stygobionts versus stygophilic taxa. Cryptic linages detected not only evidenced of misidentification of undescribed species, but also junior synonymies. As several species from these aquifers are federally listed as vulnerable to endangered, the use of barcoding approaches will improve biodiversity estimates and highlight overlooked cryptic lineages in need of evaluation of conservation status.

615 Joseph Caldwell, Patricia Couvillon

Category and Relational Learning in Honeybees (Apis mellifera)

From the groundbreaking work of von Frisch on the foraging behavior of honeybees to the recent discoveries of vertebrate-like concept learning in their choice decisions, honeybees have continuously provided new windows on the cognitive capacities of an invertebrate. A recent study showed they can discriminate two color categories, single colors vs. two-color patterns, and can choose the odd category in an oddity task. In Experiment 1, bees were trained to discriminate two novel color categories, both with two colors, arranged in different circular patterns (splits vs. quads). In Experiment 2, bees were trained in an oddity task with the split and quad categories. In both experiments, free-flying forager bees were trained to shuttle between the hive and the laboratory where they found either a pair or a trio of choice stimuli on each training visit (trial). They had a unique set of stimuli on each trial. Choice of the correct category was rewarded with sucrose and choice of an incorrect category was punished with stevia solution. Foragers were trained individually in ∼3-hour sessions. The bees in Experiment 1 learned to discriminate

the new categories. The bees in Experiment 2 learned to choose the odd category. The ability of honeybees to learn an oddity relationship based on category is remarkable. It is not shared by all vertebrate species and is slow to develop in young children.

405 Michael Calicchia, Rui Ni, Rajat Mittal, Jung-Hee Seo

Reconstructing the pressure field around an undulating body using a physics-informed neural network

Hydrodynamic pressure is a physical quantity that is utilized by fish and many other aquatic animals to generate thrust and sense the surrounding environment. To advance our understanding of how fish react to unsteady flows, it is necessary to intercept the pressure signals sensed by their lateral line system. In this study, the authors propose a new, non-invasive technique for reconstructing the instantaneous pressure field around an undulating body from particle image velocimetry (PIV) data. The proposed method utilizes a physics-informed neural network (PINN) to predict an optimized solution for the velocity and pressure fields that simultaneously satisfies the governing equations (i.e the Navier Stokes equations) and the constraints put forth by the measurements. We will show that the PINN-based method is less sensitive to the spatio-temporal resolution of the velocity field measurements and provides a more accurate pressure reconstruction, particularly on the surface of the body, when compared to traditional methods that rely on directly integrating the pressure gradient field. These results demonstrate that PINNs are a useful data assimilation tool for studying biolocomotion or fluid-structure interaction.

1738 Jose Camara-Lavadores, Amie Romney, Jason Podrabsky

The microbiome of Austrofundulus limnaeus with respect to vertebrate Diapause

There is an growing body of literature that emphasizes the interdependence between microbes and multicellular organisms. These studies continue to broaden our understanding of how symbiotic relationships can drive form, function, and performance. Previous work shows that microbes can aid hosts through a variety of mechanisms including metabolism, neuro development, physical performance, and behavior. An area that has received relatively little attention is the potential contributions of microbes to survival and tolerance of environmental stresses during embryonic diapause, a dormant state of metabolic depression during development. In this study we use Austrofundulus limnaeus, a tropical killifish residing in ephemeral ponds, as a research model to understand the relationship between microbes and embryonic diapause. We hypothesize that microbes play essential roles in metabolic adaptations that support survival of extreme environmental stresses. Here we used aseptic technique to isolate gonads, intestines, and embryos of A. limnaeus for DNA extraction using a Qiagen DNeasy blood and tissue kit. Isolated DNA was used to create cDNA libraries of 16S rRNA genes using barcoded universal primers 27F and 1492R, for genus level identification. DNA libraies were then sequenced using an Oxford Nanopore minION. Here we debut the most abundant microflora in A. limnaeus in the intestines, gonads, and developing embryos to explore the potential role of microbes in supporting diapause in this species.

1526 Henry Camarillo, Bhart-Anjan Bhullar, Martha Munoz

Comparative anatomy of the musculoskeletal feeding system in plethodontid salamanders

Lungless salamanders (Family:Plethodontidae) represent the largest family of extant salamanders. Like most terrestrial salamanders, plethodontid salamanders primarily rely on tongue prehension for prey capture (both muscle-powered and spring-powered). In addition to differences in feeding mode, salamanders in this family are diverse in their microhabitat use (aquatic; semi-aquatic;terrestrial) and in life history mode (biphasic; direct developers; and paedomorphic). While much has been done to understand morphological differences of the tongue skeleton (particularly between spring-powered- and muscle-powered feeding modes), studies understanding how other morphological structures vary are lacking. For example, are there differences in cranial musculature between salamanders that vary in feeding modes, microhabitat, or life cycle? Understanding how these other morphological structures vary allows for a more integrative understanding of the salamander feeding system. Here, we utilize diceCT and digital segmentation to describe differences in feeding musculature and connective soft tissues for salamanders representing spring-powered tongue prehension (Eurycea) and muscle-powered tongue prehension (Desmognathus).

414 Mary Campbell, Bryon Tuthill, Isabela Velasquez-Gutierrez, Eve Milusich, Jessica Hua

Costs of pesticide tolerance influence the effect of habitat structure on amphibian disease outcomes

As humans continue modifying natural ecosystems, understanding how anthropogenic and natural factors (e.g., habitat structure) interact to influence host-parasite interactions has broad ecological and conservation implications. While growing evidence suggests that wildlife populations can adapt to anthropogenic change, costs associated with these adaptations may influence disease outcomes by altering host susceptibility to pathogens, host interactions with their physical environments, and patterns of disease transmission. Here, we evaluate how evolutionary responses to pesticides interact with habitat structure to influence disease outcomes. We conducted two mesocosm experiments where we manipulated: (1) vegetation density or (2) water depth. We generated artificial wood frog (Rana sylvatica) populations by adding pesticide-tolerant or non-tolerant tadpoles to mesocosms. Frog-virus-3 (FV3), an amphibian pathogen, was introduced to mesocosms with subsequent measurement of transmission behavior and disease outcomes. For the vegetation experiment, both tolerant and non-tolerant tadpole populations had a higher survival after exposure to FV3 in the higher vegetation treatment. For the depth experiment, we found a depth-by-pesticide tolerance interaction. Pesticide-tolerant populations had higher survival in shallow compared to deep environments. In contrast, non-tolerant populations had lower survival in shallow compared to deep environments. Behavioral data suggest that variation in necrophagy between pesticide-tolerant vs. non-tolerant populations may be one mechanism influencing survival patterns. Collectively, this study contributes to the body of work investigating how anthropogenic and natural factors interact to shape disease dynamics.

1307 Timothy Campbell, Stephanie Baker, Sally Jo Detloff

A Case Of Bilateral Supracondylar Processes With High Radial Origins And Asymmetry in Pronator Teres

The supracondylar process is an atypical bony projection found on the anteromedial humerus ∼5 cm from the distal end. When present, it is associated with Struthers ligament which connects the process to the medial epicondyle and can serve as the superior origin for pronator teres. The fibro-osseous channel thus formed is hypothesized to represent an atavistic manifestation of the entepicondylar foramen found in other mammalian groups (e.g. Rodentia, Carnivora) as both are traversed by the median nerve and brachial/ulnar artery. This complex is clinically significant as a potential site of fracture or entrapment of the underlying neurovascular bundle. Here we report a case of bilaterally expressed supracondylar processes on a 54-year-old male donor. Both processes were well developed, easily palpated during initial examination, and served as superior attachment sites for pronator teres. Additionally, both radial arteries originated high in the proximal arm with the resulting ulnar arteries and accompanying median nerves traversing the fibro-osseous channel. For muscular origins, the left pronator teres exhibited the standard proximal attachments at the ulnar coronoid process and along the medial epicondyle of the humerus with a supernumerary belly arising from fibro-osseous channel roof. On the contralateral, a band of additional muscle fibers were also observed originating from flexor carpi radialis. These observations represent the first from an ongoing study that seeks to better document these clinically important atypical variations.

1734 Lori Campbell, Cláudia Garcia-Jou, André Fenton

A Step to Unveiling the Enigma of Memory: A Regard for Proteins through Behavioral Analysis

The fundamental question of how memory is formed is yet to be answered. Neurobiologists know that memory formation requires protein synthesis at learning-activated synapses in neural substrates like the hippocampus. But how do memories persist with protein turnover? Persistent enzymatic activity was found in a Protein Kinase C isoform called PKM?, important for memory maintenance for at least a month (Pastalkova et al., 2006). To further understand the molecular basis of memory, behavioral studies of memory formation and persistence are needed. Therefore, I used genetically different mice under different training conditions to investigate PKM?'s role in spatial learning and memory. Prkcz is a gene that, when transcribed into RNA, constructs PKM?. Prkcz-null mutant mice did not express PKM?, unlike Prkcz-controls. Half the mice were trained to avoid the shock location in a place avoidance task; controls were yoked, receiving shocks whenever a trained mouse was shocked. We expected memory persistence in Prkcz-nulls to be impaired. However, Prkcz-nulls and controls showed learning and memory of the task, as measured by shock zone entrances, time of first shock zone entrance, and longest shock zone avoidance. Trained mice were significantly better than yoked controls, indicating learned behavior. Thus deletion of Prkcz in adult mice did not impair long-term memory. These results indicate that either PKM? is unimportant for memory or that PKM? removal is compensated by other similarly-functioning molecules.

1403 Jordan Cannon, Craig McGowan

Individual muscle contributions to jumping by kangaroo rats using forward dynamics simulation

Kangaroo rats are small bipedal rodents that escape predators using explosive vertical jumping, reaching up to 10 times their standing hip height, by generating large ground reaction forces over a short time period to accelerate the body's center-of-mass. Previous work demonstrates that ankle power dominates joint contributions to jumping but that ankle extensor muscles and elastic energy storage and return by tendon cannot account for the total power observed. Rather, transfer of power from proximal muscles via biarticular ankle extensors likely enable the remarkable power output at the ankle joint. However, individual muscle contributions to vertical jumping by kangaroo rats are unknown and limitations exist when interpreting individual muscle function using in vivo data alone. In this study, we generate a muscle-actuated forward dynamics simulation of kangaroo rat vertical jumping to calculate each muscle's contribution to ground reaction forces, acceleration of the body center-of-mass and other body segments, and transfer of power between body segments. This enables us to determine how energy produced by individual muscles is transferred between segments and delivered to the environment. Our preliminary results suggest that biarticular muscles transfer energy generated by large uniarticular muscles in a proximal-to-distal sequence across the linkage to increase ankle power. Additionally, forward dynamics simulations resolve discrepancies between inverse dynamics analyses and in vivo muscle data by interpreting muscle function in the context of system dynamics.

635 Esmirna Cantu, MD Rahman

Pesticide Mixtures Influences the Physiology and Induces Oxidative/Nitrative Stress in Goldfish

Freshwater and marine life forms are damaging in toxic conditions, on account of escalating pollutants tarnishing their natural habitats. Man-made factors, more specifically agriculture, introduce an ever-increasing variety and volume of chemical contaminants into aquatic environments. These include compounds such as pesticides (more precisely biocides) that contribute to a wide variety of stressors corrupting aquatic ecosystems and deleteriously influencing the life of aquatic inhabitants. In this study, we analyzed dose-dependent and time-dependent effects of pesticide blends (metalachlor, linuron, isoproturon, tebucanazole, aclonifen, atrazine, pendimethalin, and azinphos-methyl) (exposure at 22 oC for 1 week) on the morphological and cellular changes in the gills and kidneys of goldfish. Fish exposed to pesticides showed a significant (P Predominantly, these results indicate that pesticide cocktail impair cellular functions in teleost species.

639 Esmirna Cantu, MD Rahman

Pesticide Cocktail Affects Free-swimming Behavior in Relation to Distance and Movement in Goldfish

Aquatic organisms are noxious in a toxic environment, on account of escalating pollutants defiling their natural habitats. Anthropogenic activities, including agriculture, introduce an ever-increasing variety and volume of chemical contaminants. These include compounds such as pesticides (more aptly called biocides) and contribute to a wide variety of stressors vitiating aquatic ecosystems and perniciously influence the life and behavior of aquatic organisms. In this study, we analyzed dose-dependent and time-dependent effects of pesticide mixtures (metalachlor, linuron, isoproturon, tebucanazole, aclonifen, atrazine, pendimethalin, and azinphos-methyl) (exposure at 22oC for 5 days) on the free-swimming behavior of goldfish, a model teleost species. Behavioral analysis showed a dose-dependent, time-dependent, decrease in distance swam and the prolonged time they stayed in each region of the tanks. Predominantly, these results indicate that pesticide cocktails influence fish behavior and negatively impact natural swimming patterns in goldfish.

1542 Yakun Cao, Ruiqi Wang, Nick Gravish

Development of an FTIR apparatus for observing the dynamics of adhesive engagement in Argentine Ants

Ants possess adhesive pads (arolium) on the distal end of their tarsi which help them climb on smooth substrates. Force sensors have enabled the measurement of the adhesive and shear forces from walking ants. However, it remains a challenge to study the spatial and temporal dynamics of adhesive engagement during free walking and climbing. To address this we developed a frustrated total internal reflection (FTIR) device to record the real-time adhesive contact area, and simultaneously track the body and limb kinematics in Argentine ant workers (L. humile) on vertical and horizontal surfaces. The FTIR apparatus consisted of a glass illuminated from the side by white LED lights. When the ant foot contacts the surface, light is scattered and only the areas in contact are illuminated. We validated our system from observations of ants walking on horizontal surfaces compared to climbing. We observed that the adhesive engagement primarily occurred during climbing bouts and was not present during walking on level ground. Ants climbed upwards at an average speed of 10.66±1.94 mm/s, and downwards at an average speed of 8.27±2.45 mm/s. In both upwards and downwards climbing, we observed that the total adhesive pad contact was primarily above the Center of Mass (CoM; 90%±10%) consistent with previous ground reaction force measurements.

1775 Ke Cao, Marguerite Butler, Ethan Hill, Allison Fisher

Phylogenetic Analysis of genus Aphantophryne

Aphantophryne is a proposed genus of montane and potentially fossorial frogs from New Guinea, and part of the Asterophryinae subfamily, a hyperdiverse clade of amphibians. A recent molecular phylogeny has confirmed the monophyly and intergeneric relationships of 16 genera, but members of Aphantophryne remained a puzzle, tentatively falling out as members of the distinct arboreal genera Oreophryne A and Oreophryne B. Since the discovery and naming of this Aphantophryne, only three species have been suggested with a handful of samples available for study. To further the understanding of genus Aphantophryne regarding its monophyly and position within the Asterophryinae subfamily, we expanded sampling to include multiple samples of all three candidate species. We sequenced five loci (BDNF, SIA, NXC, CYTB, ND4) using improved primers and add them to a dataset of over 200 species of Asterophryinae to infer a time-calibrated molecular phylogeny using Maximum Likelihood (IQTREE) and Bayesian Inference (BEAST2) methods. We confirm whether Aphantophryne is a valid monophyletic genus within the subfamily Asterophryinae, or whether these taxa represent the evolution of ecological novelty as members of other genera. This study will improve our understanding of these enigmatic species and contribute to our understanding of this biodiverse subfamily.

1374 Demi Carballosa, Katie Dobkowski

The Urch- to Eat: Effect of encrusting bryozoans on the growth and feeding behavior of green urchins

Symbiotic relationships are a fluid part of all ecosystems; these interactions occur when two species' biological relationships contribute to their respective roles. Kelp forests are biodiverse habitats that are home to a multitude of vertebrate and invertebrate species. One of the most common and dominant grazers of kelp forests is the Strongylocentrotus droebachiensis, the green sea urchin. S. droebachiensis feed on various seaweed species, including the kelp Agarum fimbriatum. The epiphytic bryozoan, Membranipora membranacea, often lives on the same blades of the kelp on which green sea urchins feed. We quantified S. droebachiensis' herbivorous relationship with kelp, investigating the symbiotic interaction between A. fimbriatum and M. membranacea. We used laboratory feeding experiments to assess urchin growth and feeding on kelp with and without encrusting bryozoans. Our observation of increased urchin feeding on bryozoan-encrusted kelp blades suggests that M. membranacea may have a parasitic relationship with the kelp A. fimbriatum, possibly deriving benefit at the kelp's expense. Still, we were not able to detect a statistically significant difference in urchin growth between the two diets. In choice feeding experiments, the urchins did display a significant preference for a diet of kelp with bryozoan colonies present. Continued analysis of the interaction between A. fimbriatum and M. membranacea will help further explain this symbiotic relationship and how it has affected and may continue to influence kelp forest ecosystems.

687 Connor Carbine, Karen Maruska

Neuropeptide-Y (NPY) as a candidate modulator of retinal function in an African cichlid fish

Neuropeptide-Y (NPY) is a widespread modulator with diverse functions in the vertebrate brain, but its role in the retina and visual processing is less understood. The African cichlid fish Astatotilapia burtoni relies heavily on vision to mediate social behaviors, and female vision improves at the time of ovulation possibly to facilitate mating decisions. The mechanisms responsible for this visual plasticity, however, are not known. Here we examined whether NPY might be a candidate modulator within the cichlid retina. Immunohistochemistry revealed NPY protein within amacrine cells and in axons that were abundant within the inner plexiform layer. To test whether NPY signaling might vary with reproductive state, we used qPCR to measure mRNA levels of npy and several npy receptor types in the eyes of females and males of different reproductive and social states. In males, npy levels were higher in dominant compared to subordinates, but receptor levels were similar between social states. In females, levels of npy and several npy receptor types were higher in ovulated compared to recovering and mouthbrooding individuals. These results suggest that NPY signaling in the retina might contribute to the improved visual sensitivity seen in ovulated females. While future functional studies are needed to test whether NPY signaling contributes to changes in vision, this work provides important comparative information towards understanding the evolution and function of NPY in the retina.

298 Shana Caro, Rebeca Moreno-Villarreal, Camilla Hinde, Hans Hofmann

Into the wild: How real-world complexity and fitness consequences shape decision-making in birds

Deciding how much to feed offspring is one of the most critical decisions parents make. However, despite knowing much about what choices parents make and why, we know little about how they make those choices. What we do know about the cognitive mechanisms underlying complex decision-making has come from laboratory studies, which may not adequately reflect decisions made in the real world, with real-world complexity, constraints and consequences. To overcome these issues, we conducted a non-invasive, naturalistic experiment on decision-making speed in a wild passerine songbird, using 62 parents of the great tit Parus major. Surprisingly, we did not find the canonical speed-accuracy trade-off: instead, we found that parents made slower decisions if they made an error (fed a non-preferred chick). We found that parents valued accuracy over speed especially in situations when offspring starvation was more likely, i.e. when the fitness consequences for making a wrong decision were higher. Finally, we found that parental decision speed was constrained by offspring behavior, their own sex, and prey characteristics. Overall, these results indicate that laboratory studies may overestimate the importance of speed-accuracy trade-offs when individuals are presented with complex evidence varying across multiple parameters; may underestimate the mediating effects of urgency on decision-making; and may underestimate the constraints under which decisions are executed. More broadly, our study demonstrates how crucial evolutionarily relevant experiments are for neuroethology.

915 Katrina Carrier, Daniel Powell, Yasemin Altug, Isabella Kane, Rania Janmohamed, Patsy Dickinson

Combinatorial effects of changes in ion concentration and temperature on the lobster nervous system

Climate change has resulted in altered patterns of rainfall globally. Consequently, sea water is both increasing and decreasing in salinity as a function of decreased and increased rainfall patterns, respectively. This includes changes in both surface and water column salinity. These changes are problematic for the nervous systems of marine osmoconformers as changes to the ionic concentrations in their extracellular environment can fundamentally affect neuron function. Simultaneously, ocean temperatures are rising, which can likewise alter neuron function in marine poikilotherms. Because changes in the extracellular concentrations of all permeable ion species and changes in temperature will affect the activity of all neurons in a network, the combinatorial effects of such perturbations on neural networks are of interest. Using the stomatogastric and cardiac nervous systems of the American lobster (H. americanus), we demonstrate that these circuits, which control movements of the foregut and heart, respectively, are able to maintain physiological function when the extracellular saline concentration is altered to 0.75x and 1.25x the normal concentration. We establish the upper limit of temperatures that the systems can withstand without "crashing" (ceasing function but recovering when returned to normal conditions) in normal (1x) physiological saline. We then determine whether combinatorial changes in temperature and salinity concentrations change the limits for each individual perturbation when they occur together.

73 Amanda Carter, Kimberly Sheldon

Plasticity of dung beetle mothers rescues offspring survival under climate change conditions

By influencing offspring development and survival, parental effects have the potential to aid responses to rapid environmental change. We examined whether Onthophagus taurus dung beetles modified breeding behaviors in response to climate change conditions, and as a result, buffered their offspring from increasing temperatures during development. We conducted a breeding experiment under miniature greenhouses in the field and tracked female reproductive behaviors and offspring phenotype and survival. Dung beetles lay eggs inside of brood balls made of dung and bury them underground. Burial depth influences the temperatures offspring experience during development – with deeper depths offering cooler, less variable temperatures – which can have profound effects on development. We put females in ambient or greenhouse treatments and measured brood ball production, mass, and burial depth. We allowed offspring to develop underground at the maternal burial depth until eclosion, and measured offspring survival, mass, and sex. Females in the greenhouse treatment buried brood balls deeper than those in the ambient treatment, such that offspring developed at similar temperatures in both treatments. As a result, offspring survival was similar between treatments, but body size was smaller, and more females were produced in the greenhouse treatment. Our results demonstrate that parental effects can buffer offspring survival from climate change, underscoring the importance of plasticity in climate change responses.

397 Richard Carter

Ontogeny of Bat Echolocation

The ontogenetic integration of flight and echolocation is vital to the survival of echolocating bats. How these behaviors came to be integrated through evolutionary time is a compelling question. As the fossil record and molecular data have so far not answered this question, development provides the only current source of data with which to test hypotheses. Postnatal development in particular, has provided insight into the precursors to echolocation vocalizations, how these precursor vocalizations are linked to locomotion, which derived morphological traits associated with echolocation are present at birth, and which develop as flight and echolocation become integrated. Neonate bats have the ability to produce nascent echolocation signals and receive and process the echoes in the CNS. Signal production happens before the development of flight in all species and is associated with nonflight locomotion in nonvolant bats and subsequently flight mechanics in volant bats. The postnatal development of sonar signal structure seems largely decoupled from communication vocalizations and instead may have ontogenetic and evolutionary origins in vocalizations that are by-products of locomotion. As flight and echolocation become integrated in subadults, the thoracic skeleton changes in form and significant reinforcement of the respiratory tract occurs. These ontogenetic data suggest that a rudimentary form of echolocation could have been inherited from the nonvolant ancestor to bats and coevolved with sustained flight, leading to the sophisticated echolocation observed today.

421 Christopher Carter, Sarah DuRant, William Kirkpatrick, Erin Sauer

Is there a sex-biased trade-off between growth and immunocompetence in Eastern Bluebird hatchlings?

Previous research shows that sex plays an essential role in immune health differences. Females exhibit less pathology from infections than males because their immune system is more robust; however, this increase in immune function may come at a cost. Immunocompetence can be associated with slower growth rates in both sexes. However, male birds tend to grow faster than females in early development, which may contribute to the greater pathology they express during infection. Therefore, I predicted that female Eastern Bluebirds would have a higher level of immunity, signified by a higher white blood cell count, but males would grow faster at the cost of immune development. We monitored eggs until hatching and measured nestling beaks, tarsus, and mass on days 1, 5, 10, and 13 post hatch. Using blood collected from 10 day old nestlings, we made and analyzed blood smears to determine the relative abundance of lymphocytes, monocytes, heterophils, and eosinophils. There was no significant difference in white blood cell counts between sexes. However, male nestlings had distinguishably larger tarsus and beak sizes than the female nestlings. Based on these results, we plan to examine other aspects of nestling immunity to determine if a trade-off occurs that was not captured by white blood cell counts. Understanding how Eastern Bluebird immune systems differs between sexes can expand upon existing knowledge around immune development and growth.

835 Aja Carter, Ethan Musser, Diego Caporale, Daniel Koditschek

Investigating Spinal Column Dynamics in Crown Terrestrial Amniotes

Technological advances have allowed paleontologists to investigate the mobility of the robust, crown-tetrapods that roamed terrestrial environments over 380 300 million years ago in previously impossible ways. The primary focus of this body of work has been quantitative investigations of appendicular skeletal mechanics during dynamic motion in crown tetrapods. However, our understanding of axial column dynamics in these crown tetrapods is still incomplete and, therefore, a complete understanding of these early tetrapods' locomotor abilities. These locomotor abilities are directly related to paleoecological inquiry like predator-prey interactions in Permian ecosystems. Previous studies have qualitatively investigated spinal mechanics and generated hypotheses about the role of the spinal column in locomotion. To quantitatively investigate the dynamic capabilities of the spinal column in ancient tetrapods, we used Stratasys PolyJet multi-material 3D printing, capturing the range of material stiffness within tetrapod vertebral units to estimate mechanical properties during dynamic bending and twisting. We selected a large crown amniote from the Permian era for this investigation. We estimated the spine's bending stiffness, damping coefficient, and resilience by applying dynamic loads to our 3D printed spines in three anatomical axes and measuring the resulting strain. Subsequently, by systematically taking the spines to the point of mechanical failure, we measured their kinematic limitations. And then by systematically taking the spines to the point of mechanical failure measured their kinematic limitations. We anticipate that

658 Allie Case, Malia Smith, Kathleen Hunt, Janine Brown, Alyson Fleming, Matthew Savoca, John Ososky, Michael McGowen

Relationship of adrenal stress hormones in WWII-era Antarctic blue whales and fin whales

Understanding physiological stress responses remains a challenge in mysticete whales due to the difficult nature of sample collection. Determination of stress-related hormone baselines is particularly challenging since no modern populations of whales are unimpacted by human disturbance. Using museum-housed samples of baleen plates circumnavigates these issues via retrospective analysis of adrenal stress hormones (glucocorticoids; cortisol and corticosterone). Baleen, the filter-feeding apparatus of the mysticetes, accumulates these hormones as it grows, capturing 4-6 years of continuous endocrine history for fin whales (Balaenoptera physalus) and blue whales (Balaenoptera musculus), respectively. Therefore, this unique sample matrix allows an in-depth look into the life history and stress response of an individual whale over several years and may help determine normal baselines of adrenal hormones. In this pilot study, we analyzed glucocorticoids from baleen plates harvested shortly after WWII, capturing a time when human disturbance in their Antarctic ecosystem is believed to have been minimal. The two glucocorticoids were correlated across the entire baleen plate, with higher corticosterone levels compared to cortisol for all four whales (two males of each species). The average corticosterone:cortisol ratio was 3.866. If our continued studies reflect this similar ratio, we may recommend assaying only corticosterone, saving limited sample mass. Additionally, these data are the first endocrinological studies on these endangered Southern Ocean species and may be useful for comparing past to present-day populations.

411 Cailin Casey, Chelsea Heveran, Mark Jankauski

Flying insects with asynchronous muscles have stiffer thoraxes than insects with synchronous muscles

Insects have developed diverse flight actuation mechanisms, including the use of synchronous and asynchronous musculature. Despite known differences between synchronous and asynchronous musculature, there remain questions of how these differences translate into flight performance. In this study, a tethered flight experiment was designed to simultaneously measure the aggregate forces acting at the thorax and the exoskeletal thorax deformation these forces cause using a laser vibrometer and piezoelectric force sensor, respectively. Experiments were conducted on species with asynchronous musculature including Bombus centralis, Xylocopa californica, and Musca domestica and species with synchronous musculature including Manduca Sexta, Helicoverpa zea, and Agrotis ipsilon. Results showed that insects with asynchronous muscle deformed their thorax 48% less and produced 174% greater forces relative to their thorax diameter and body mass, respectively. To better interpret the differences in thorax forces and deformations measured during tethered flight, a second experiment was designed to measure the dorsal-ventral thorax stiffness in insects with synchronous and asynchronous musculature. When accounting for weight and size, the asynchronous thorax was on average six times stiffer than the synchronous thorax in the dorsal-ventral direction. The difference in thorax stiffness led us to hypothesize about differing roles of series and parallel elasticity in the thoraxes of insects with synchronous and asynchronous musculature. Specifically, insects with asynchronous musculature may have a more compliant series element between the thorax and the wing.

920 Eva Castagna, Kenddra Buresch, Charles Chubb, Roger Hanlon

Quantifying cuttlefish camouflage consistency

The key question is: do cuttlefish deploy the same exact camouflage pattern each time they settle on the same background? Previous work in our laboratory has revealed that there is some degree of variability in body pattern response between different cuttlefish placed on the same substrate, whereas individual cuttlefish appear to be relatively consistent in their body pattern response to the same substrate. The purpose of the current study was to quantify the amount of variation in cuttlefish body patterning in response to various substrates, both within and between animals. We took high-resolution images of six cuttlefish, on three different substrates: uniform gray, 8mm black and white checkers and 25mm black and white checkers. Each cuttlefish was tested twice on each substrate. For quantification, we used a MATLAB program designed to analyze the granularity (spatial scale) of the expressed body patterns. Results showed variability in body patterning between animals tested on the same substrate; greater variation was seen in disruptive and mottle patterns, while the uniform pattern response was relatively consistent. Cuttlefish body pattern between trials for each substrate remained relatively consistent, although there was more variability in the mottle and disruptive patterns than the uniform patterns. These results may help refine our understanding of visual perception in cuttlefish; i.e., how they translate visual cues into camouflage patterns in this swift sensorimotor system.

995 Moth Castagna, Jenny Burrow, Ciara Stewart, Avery Russell

Take it or Leaf it: Is Leaf Shape a Reliable Pollinator Learning Cue?

A century of research demonstrates generalist pollinators use diverse floral cues to learn which flower types offer food rewards. While floral cues are often reliable, flowers are not the only possible source of food reward cues for pollinators. Leaf shape also differs reliably among plant species and could potentially be used to discriminate among flower types, especially when flower color is unreliable. Here we tested conditions under which generalist bees (Bombus impatiens) learned to associate two sets of cues (leaf shape versus petal color) with pollen rewarding artificial flowers. We expected bees would learn to use leaf shape when learning petal color was more difficult. We therefore assigned bees to either of two treatment types, differing in terms of whether targets differed greatly or little in petal color. In both treatments, targets differed in leaf shape in the same way. We found that bees learned much faster when petal color differed greatly, verifying that our different treatments did affect the difficulty of learning. Although we expected bees to learn the correct leaf shape and petal color combinations, many individuals learned leaf shape, but not petal color, or vice versa. Analyses are pending for treatment level effects. Our results suggest that leaf features may serve as cues that can be learned by bees to discriminate among flowers.

1585 Nicole Castaneda, Clarissa Starbuck, Diana Hews, Joy O'Keefe

Neutrophil-Lymphocyte ratios correlate with both endo- and ectoparasite loads in Midwestern bats

Bats provide ecosystem services worldwide, but many are threatened or declining. North American bats are understudied. Here we present neutrophil to lymphocyte ratios (N:L ratio), a common measure used as an indicator of infection and stress, and relationships to parasite load, from four bat species. In northeast Missouri bats, we captured Indiana bat (Myotis sodalis, N = 75), big brown bat (Eptesicus fuscus, N = 447), evening bat (Nycticeius humeralis, N = 71), and eastern red bat (Lasiurus borealis, N = 25) in the summer of 2021. We estimated loads for most individuals, and performed blood thin smears for a subsample. Combining all species, juveniles had the highest ectoparasite prevalence and the highest ectoparasite loads (average load is 42 ectoparasites per juvenile, 14 for adults). For endoparasites, we determined fecal egg counts (FEC) from mostly nematodes. The bat species did not differ in prevalence (x = 36%) or loads (x = 6160 parasitic eggs/g dry guano). Opposite to the ectoparasite pattern (higher in juveniles), parasitic egg loads tended to be higher in adults, all species combined. The N:L ratios were relatively low, and, combining all species, the mean N:L ratios was significantly higher in adults compared to juveniles, and lower in males compared to females. Interestingly, both ecto- and endoparasites loads were positively correlated with N:L ratios, indicating that both types of parasites elicit an immune response from these bats.

1446 Alberto Castro, Allyn Nguyen, Theodore Garland, Saad Ahmed, Natalie Holt

Evolution of muscle contractile properties in mice bred for high voluntary wheel-running behavior

For nearly 100 generations, we have used selective breeding with house mice to study coadaptation of morphology and physiology with the evolution of high daily levels of voluntary exercise. Studies measuring muscle contractile properties and muscle-tendon morphometrics can elucidate mechanisms of coadaptation in muscles. At generations 91 and 93, we used in-situ preparations to quantify contractile properties and morphometrics of the triceps surae complex of four replicate high runner (HR) lines and four non-selected control (C) lines. After accounting for body size, mice from HR lines had relatively lighter triceps surae muscles and longer Achilles tendons, but shorter muscles, when compared with C mice. Rates of force development and relaxation were significantly slower in HR mice. HR mice had significantly faster maximal shortening velocities when compared with C mice (LS Means of 2.60 lengths s-1 and 2.16 lengths s-1), and higher endurance (LS means of the slope of the decline in force over a series of 90 tetanic contractions was -0.00704 in HR mice compared to -0.01805 in C mice). Therefore, we show adaptation in muscle and tendon lengths that likely affect contractile velocity, twitch kinetics, and endurance properties. Overall, we demonstrate adaptive changes in muscle-tendon morphology and contractile characteristics due to directional selection on locomotor behavior. Supported by NSF grant IOS-2038528 to TG and NH.

36 Eleanor Caves, Laura Kelley

Bigger is not always better: green swordtails Xiphophorus helleri proportionally process body size

During mate choice, females often assess the magnitude (duration, size, etc.) of male signals that vary along a continuum, with signal variation reflecting variation in male quality. It is often implicitly assumed that signal perception is linear, meaning females perceive and respond to each difference between signalers in signal magnitude. However, many sensory systems adhere to Weber's Law (proportional processing), by which animals discriminate between stimulus magnitudes based on the proportional (relative), rather than absolute, difference between them. We used two-choice tests to examine the preferences of female green swordtails (n = 24), Xiphophorus hellerii, for animations of courting males differing in size, which female X. hellerii assess during mate choice. We found that female preferences for larger males were better predicted by the proportional size difference between two males than the absolute difference. For a given absolute size difference, female preference for the larger male was stronger if both males were small (larger proportional difference) than if both were large (smaller proportional difference). Therefore, despite widespread female preferences for larger male traits, bigger is not always better— at a certain magnitude, the increase in benefits a sender derives from investing in a larger signal will diminish. This is the first demonstration of proportional processing of a visual signal, and suggests an important role for receiver perception as a selective force in signal evolution.

284 Benjamin Cellini, Jean-Michel Mongeau

Hierarchical integration of visual and mechanosensory feedback during control of gaze in Drosophila

Animals often sense information from multiple modalities to guide locomotion, which requires sensory fusion in the nervous system. For instance, the control of gaze in humans is influenced by information from visual and vestibular origins. External sensory information, e.g., the presence of an object, can elicit redirection of gaze. However, this visually driven action concomitantly stimulates the vestibular system. In this context, vestibular feedback is internal, or nested, within the higher-level visual feedback topology. We developed a framework based on control theory to unravel hierarchical (nested) feedback systems in biological systems and applied it to study gaze stabilization in the fruit fly Drosophila. Using virtual reality flight simulators with distinct control topologies, we show that nested body-generated mechanosensory feedback has a significant influence on how flies control head movements. By comparing gaze stabilization responses of body-free and body-fixed flies, we discovered that body visual feedback changed the tuning of head movements to visual motion frequencies from broadband to high-pass. In contrast, nested mechanosensory feedback damped both smooth and saccadic head movements. By comparing head responses to self-generated and externally generated body motion, we revealed that nested mechanosensory feedback is non-linearly gated. Altogether, our findings suggest that nested mechanosensory feedback has a transformative effect on visually elicited head responses. Our control theoretic framework is generalizable to biological and robotic systems relying on hierarchical feedback control.

1387 Henry Cerbone, Michelle Yuen, Perrin Schiebel

Biorobotic study of how basilisk lizard feet mediate reaction forces while running

Some lizards can quickly traverse complex environments by running bipedally on their hind legs, suggesting a robust method of maintaining dynamic stability which contends with unexpected forces. Basilisk lizards, B. basiliscus, can run bipedally both on land and at the air-water interface. Work-to-date has sought to understand the kinematics and force-generation aspects of this ability. Using this work as a starting point, we use the basilisk lizard running rapidly on water (∼7-21 body lengths/second) to explore the role of an extended foot during dynamically stable locomotion in complex environments. We hypothesized that the shape and flexibility of the basilisk lizard foot would offload control from the central nervous system by reducing perturbations transmitted to the lizard's center-of-mass during interaction with water. We used a biorobotic model, cadaveric basilisk lizard feet mounted on a force-sensing robot arm, to measure reaction forces transmitted by the feet. The initial foot trajectory was based on existing kinematic data. By introducing perturbations to this trajectory and observing the resultant changes in the reaction forces, we determined the extent to which passive properties of the foot could minimize deviations in the reaction forces from the base case. Our results allow us to begin understanding whether locomotion in a system that is only dynamically stable could be achieved without feedback through reliance on distal structures to contend with kinematic errors.

790 Alexa Cesari, Jesse Placone, Nicole Ramo, Kavish Saini, Michael Rosario, Danielle Adams, Frank Fish

Biological and Biomechanical Properties of Tendons in the Peduncle of Harbor Porpoise

Harbor porpoises (Phocoena phocoena) rely on the use of their tails for swimming. The tendons located in the caudal peduncle are attached to caudal vertebrae to generate propulsive oscillations. These tendons were not examined fully to understand their function and possible storage of elastic energy during swimming. This research aims to mechanically characterize caudal peduncle tendons, including extensor caudae medialis (ECM), extensor caudae lateralis (ECL), and medial hypaxialis lumborum (MHL). Cyclic and stress relaxation tests were performed on the tendons. Individual tendon fascicles were also tested to failure. Polarized light microscopy was used to visualize the fibril crimp as tensile forces were applied to fascicles. Elastic hysteresis measurements indicated that the caudal peduncle tendons displayed unique energy storage properties during tail beat oscillations. Irrecoverable work of the MHL (0.9 ± 0.41kPa) was lower than the irrecoverable work of the ECM (1.3 ± 0.6kPa) and ECL (2.0 ± 1.4kPa). Stress relaxation measurements indicated that there is no statistical difference between tendon types. Individual fascicles tests resulted in maximum elastic moduli of 591.3MPa, 890.8MPa, and 952.3MPa for ECM, ECL and MHL, respectively. Uncrimping of isolated fascicles was visualized at maximum strain of 1.7% with elastic modulus of 163MPa. The mechanical properties of porpoise tendons indicated that elastic energy could be stored and recovered, indicating that the energy cost of swimming could be decreased.

1134 Jules CHABAIN, Liu Hong, Leonardo Chamorro, Philip Anderson

Influence of serrations on puncture performance in the barbs of stingrays

Many studies across an array of organisms have shown that the ability of a puncture tool (spine, fang, stinger, or other weapons) to fracture and penetrate biological targets successfully is significantly dependent on their shape. However, many puncture tools have surface structures that may aid penetration after the initial puncture. Stingray barbs are known for their distinct and highly variable serrations. In order to assess the influence of these serrations on puncture performance, measured as the depth of penetration and overall damage done, we tested 4 species of stingray's barbs both with serrations and after the serrations were removed. Puncture experiments were performed using a drop-tester with 3D-printed models of spines based on CT scans. We assessed the damage and the serration's influence on penetration using particle tracking velocimetry (PTV) with clear PDMS cubes during dynamic speed experiments filmed with a high-speed camera. Tool models successfully punctured in the majority of tests but also suffered breakage in most tests as well. Our results show that the presence of serrations reduces the extent of tool breakage when making the initial contact with the target. PTV data illustrate the serrations influence deformation and damage patterns during high-speed puncture. Interestingly, there also may be an ecological effect, as the taxon with the highest puncture performance is the only freshwater stingray included: Paratrygon aiereba.

735 Elio Challita, Prateek Sehgal, Pankaj Rohilla, Saad Bhamla

Viscoelastic spitting of conehead termites

Termite soldiers Nasutitermes (Termitidae, Nasutitermitinae) defend their mounds by spraying their larger predators with a jet of viscoelastic fluid through a pointed nozzle at the front of their heads. The defensive behavior of these termites is studied in the Peruvian Amazon rainforest using high-speed imaging and field-designed experiments. Here, we reveal the fluid dynamics of their high-speed jetting mechanism (velocity ~ 0.4 m/s, duration $\sim$250 ms) and the lasso-like viscoelastic jets in the air. Using experiments and theoretical modeling, we show how these termites generate large liquid lassos to trap their larger predators by rapidly moving their heads. We analyze the effect of the geometry of the conical nozzle of three species of termites on the kinematic output of their jets. Understanding the fluid dynamics of these lasso-like jets holds potential for revealing the biophysical limits of the termite's defensive behavior and helps inform the design of extrusion nozzles for 3D printing at the microscale.

428 Mac Chamberlain, Mark Hauber

A systematic review of methodologies to studying behavioral imprinting

Since the classic studies on precocial waterfowl by Lorenz (1935), behavioral imprinting has been described in a large diversity of animal lineages. Due to the wide-range of specific imprinting processes and the diversity of taxa in which they occur, researchers must use an equally diverse variety of methodologies in order to document imprinting. We systematically reviewed the relevant literature to identify and describe the range of behavioral methodologies used to study imprinting across these diverse taxa. After compiling a 100-paper dataset behavioral imprinting-focused papers using a key-word and internal citation driven approach, we categorized each study by the different types of imprinting processes investigated, the focal species used, the ontogenetic stage addressed, and the methods applied for both training and testing. The largest proportion of studies focused on filial imprinting in precocial birds. Non-filial processes, such as sexual imprinting or territorial imprinting, as well as altricial and non-avian study species were present but far less represented. Filial imprinting is thoroughly studied through different sensory modalities and applying artificial stimuli while non-filial imprinting studies mainly used live animals as the stimuli without isolating the relevant sensory modalities. Most studies of filial imprinting employed either spatial proximity, a follow response, or the suppression of alarm calls as a measure for imprinting, whereas most studies of sexual imprinting employed the attempt frequency of sexual behaviors.

1314 Jeremy Chamberlain, Daniel McDermott, Grant Dawson, Lorin Neuman-Lee

Characterization of Snake Immunity for a Novel Animal Model

A challenge with human immune and disease research is the use of genetically inbred animal models maintained in highly controlled environments that do not represent inherent variability in human populations. One way to address this issue is comparatively examining wild, non-traditional vertebrate populations. Additionally, most research has focused on organisms with robust adaptive immune responses, obscuring observation of innate response. Natricine snakes exhibit robust and primarily innate immune responses. Therefore, these common reptiles are a promising vertebrate model for answering questions about variability and diversity in innate immune responses. However, reptilian models are poorly understood in immune research. In order to establish these animals as a model in immune and disease research, we identified, isolated, and quantified different leukocyte subsets of three species of watersnake (Nerodia fasciata, N. rhombifer, N. erythrogaster) from northern and southern Arkansas. We assessed functional immune responses using flow cytometry to determine the make-up of specific immune cell populations in the blood, including lymphocytes, heterophils and azurophils. We quantified baseline cell population frequencies to assess levels of variability between several parameters, including sex, species, and location. Additionally, we examined individual responses to stress. In addition to examining, the immune cell populations, we examined the functionality of the immune system using bacterial killing assays. This research allows us to assess differences in innate immune cell populations and variability in immunocompetence in heterogeneous.

32 Kit Yu Karen Chan, Jeanette Wheeler

Large-scale phenomena arising from small-scale biophysical processes: an introduction

At scales far below what the human eye can see, individual cells organize and behave in ways that can have unexpected and wide-reaching consequences, cascading upward to spatial and temporal scales far beyond the reach of individual cells. The emergence of large-scale patterns from small-scale behavior and physiology is a broad theme of research interest across multiple biological fields. Recent technological advances have made previously inaccessible small-scale systems and processes more transparent than ever. This symposium highlights cross-disciplinary studies on emergent phenomena following three major themes: 1) how small-scale biomechanics shape tissue formation; 2) how small-scale biophysics shape ecological interactions, and 3) how physical forces shape the evolution of early life. We aim to promote the use of mathematics, physics, and engineering tools to address biological problems.

1836 Kit Yu Karen Chan, Jeanette Wheeler

Large-scale phenomena arising from small-scale biophysical processes roundtable

This round table discussion will follow up on common themes identified in the symposium presentations for Large-scale phenomena arising from small-scale biophysical processes. It will permit speakers and audience members to discuss shared techniques and approaches across multiple disciplines and levels of biological organization (from cell to ecosystem). This discussion will provide a venue for speakers and audience members to explore the next big questions in the field.

583 Santhan Chandragiri, Bikram Dhoj Shrestha, Vivek Prakash

Modelling the effects of confinement on fluid dynamics of micro-swimmers

Cilia play a major role in the swimming and feeding of marine invertebrate larvae. Ciliary beating generates fluid vortices around the larvae which in-turn determines their swimming behaviour. Since the marine larvae typically have complex three-dimensional (3D) flow-fields that are very challenging to study both numerically and experimentally, it is often convenient to study them using a two-dimensional (2D) confinement. However, this 2D confinement may induce specific artefacts in the 3D flow-fields of the micro-swimmers, so here our objective is to quantitatively investigate the effects of the 2D confinement. In this work, we numerically study the role of confinements on the fluid flows around a ciliated micro-swimmer. First, the micro-swimmer is modelled as an active particle (squirmer) with a slip velocity on the surface. Second, the fluid dynamics around the squirmer is studied under i) no confinement, ii) weak confinement (confinement is much larger than squirmer size) and iii) strong confinement (confinement is close to the squirmer size). We quantify the effect of the confinement in terms of structure, size and intensity of the fluid vortices around the larvae. We will also compare our simulation results with lab experiments. We will provide guidelines and best practices for 2D confinement, and our results will be broadly applicable to a variety of ciliated micro-swimmers.

661 Karthikeyan Chandrasegaran

Molecular mechanisms mediating larval ecology and mosquito host-seeking behavior

Mosquitoes are important vectors of diseases that claim several million lives every year worldwide. As larvae, they occupy diverse habitats and are influenced by many ecological factors that impact their adult life. Interestingly, the magnitude of these effects differs between males and females. Female mosquitoes show remarkable plasticity of body size in response to environmental variability. Also, body size in females strongly correlates with their adult behavior and reproductive traits. Here, we varied levels of intraspecific competition to quantify how larval conditions impacted olfactory responses of virgin and mated adult females seeking hosts for blood. The preliminary results suggest that host-seeking preferences are strongly linked to variations in female body size and mating status. Analysis of the head transcriptome of the large and small-sized females, both virgin and mated, reveals differences in genes linked to the onset of host-seeking and olfactory sensitivity. In my talk, I will discuss a novel multi-threaded approach that compares the gene transcripts' co-expression levels to identify 'hub genes' whose expression states likely mediate the links between larval ecology and adult host-seeking in mosquitoes. Using results from the transcriptomic analysis, we are pursuing electrophysiological investigations to understand the neural bases of the observed size and mating status-dependent variability in mosquito host-seeking behavior. These results will be discussed in the context of mosquito vector potential and the ensuing disease consequences.

1457 David Chang-van-Oordt, Conor Taff, Daniel Ardia, Maren Vitousek

The effects of developmental cold exposure on nestling thermoregulation in tree swallows

Early breeding in temperate birds is correlated with high reproductive success, but also to higher chances inclement weather —mainly cold snaps— during reproduction. Early developmental exposure to cold temperatures may alter the ability to maintain body temperature. If developmental cold exposure improves the ability to maintain body temperature when environmental temperatures fall, it could facilitate early breeding in the future and set up nestlings for increased reproductive success. We studied the role of cold exposure during incubation on nestling development in Tree Swallows (Tachycineta bicolor), an altricial species. We experimentally reduced the daytime temperature of Tree Swallow nests during incubation and measured the effects on 12–13 day old nestlings, when thermoregulatory ability is similar to that of adults. We looked for differences in thermoregulation and respiratory rate during a cold (10º C) challenge, and compared other phenotypic traits between groups, including mass and bactericidal ability. Preliminary analyses showed that cold exposure during early development did not change the ability to maintain body temperature during the cold challenge, but the variance of body temperature at the end of the trial increased in the control group only. Cold-exposed nestlings were able to thermoregulate more consistently than control nestlings. We also collected data to test the hypothesis that the metabolic cost of maintaining body temperature is lower in developmentally cold-exposed nestlings than in control nestlings.

1226 Isabella Changsut, Haley Womack, Alicia Schickle, Koty Sharp, Lauren Fuess

A comparison of constitutive and induced immune response in coral of variable symbiont densities

Scleractinian corals form the basis of diverse coral reef ecosystems. However, corals are in swift decline globally, in part due to rising disease prevalence. Most corals are dependent on symbiotic interactions with single-celled algae (family Symbiodiniaceae) to meet their nutritional needs. Preliminary evidence suggests that suppression of host immunity may be essential to this relationship. To explore potential immunological consequences of symbiotic relationships in corals, we investigated constitutive and induced immune activity in the facultatively symbiotic coral, Astrangia poculata. Colonies of A. poculata with variable densities of Breviolum psygmophilum (Symbiodiniaceae) were collected from RI. We compared constitutive immune phenotypes and induced immune response in the coral tissue. Symbiont density was strongly correlated to several constitutive immune phenotypes; catalase activity and melanin were significantly positively correlated to symbiont density. A. poculata colonies with variable symbiont densities were exposed to a pathogenic challenge, and differences in constitutive and induced immunity were measured using transcriptomic approaches. Preliminary transcriptomic results indicate significant differences in constitutive immunity and response to immune challenge correlated with symbiont density. Our findings suggest a complex relationship between symbiosis and immunity in cnidarians and highlight the need for nuanced approaches when considering the trade-offs associated with cnidarian symbioses.

666 Daniel Chappell, Daniel Speiser

Contending With Too Much Information: The Visual Neuroethology of Scallops

Of all the sensory modalities, vision is most closely associated with a pair of sensory organs and extensive centralized neural processing. This coevolutionary relationship is found in numerous taxa, but animals with distributed visual systems deviate from this trend by having numerous visual organs dispersed across their body surfaces. Additionally, distributed visual systems are associated with a diversity of neural architectures, and it is largely unknown if these nervous systems process visual information similarly to cephalized visual systems or if they use novel strategies to efficiently integrate, process, and represent visual information. Bay scallops (Argopecten irradians) have distributed visual systems consisting of dozens of complex eyes radially dispersed across their mantle tissues. It was previously thought that scallops downsample the visual information gathered by their high-resolution eyes to ease the burden on their simple nervous systems. However, we found bay scallops demonstrate interactive visual behaviors consistent with preserving visual information. Using a combination of neuroanatomical approaches and visually-mediated behaviors, we explore how scallops can efficiently integrate and process distributed visual information with high signal integrity and use this structured information to guide complex motor behaviors. Scallops serve as a unique model system in which to study the neural basis of distributed vision and to better understand how animals effectively sense, process, and behave using a balance of centralized and distributed network topologies.

544 Corie Charpentier, Danielle Barnes, Saige-Lyn Gidzinski, Heidi Fuchs

Coastal invertebrate larvae vary in their responses to artificial light at night

Light influences the biology of coastal animals by cuing behavior and biological clocks. The nighttime light environment has changed dramatically over the last century due to the increase in artificial light along developed coastlines. Many coastal invertebrates begin life as planktonic larvae in waters exposed to light pollution, but little is known about the impact of artificial light on larval behavior. In a larval crab, barnacle, and oyster, we evaluated directional swimming responses to light sources that mimic moonlight, high-pressure sodium (HPS) streetlights, and LED streetlights. Depth-stratified zooplankton samples were also collected from a coastal lagoon to assess whether light-mediated swimming responses impacted larval depth in the field at two sites: a “dark” site with little artificial light input and a “bright” site where artificial light input was >100x brighter than the dark site. Artificial light induced phototactic behavior and altered nighttime depth. Late-stage crab larvae descended in response to increases in diffuse downwelling light, although more larvae descended in the LED and moonlight treatments than the HPS treatment. Phototactic responses were less dramatic in early-stage crab larvae, barnacle larvae, and oyster larvae. Field collections indicate that depth preferences varied between the dark and bright sites in some crustacean larvae, including caridean shrimp. Overall, responses were most pronounced in crustacean larvae with large compound eyes, although responses varied between taxa and developmental stages.

975 Morgan Chase, Jessica Maisano, Edward Stanley, Amanda Krause, Paul Gignac

Introducing the Non-Clinical Tomography Users Research Network (NoCTURN)

Digital publishing platforms and internet resources allow access to scientific findings and data at scales never before realized. Unfortunately, researchers sometimes embrace lock-in systems for data generation and analysis because meaningful alternatives do not exist or are challenging to implement in current workflows. Scientific advances still take place when this occurs, but they become fragmented with discordant quality control, interoperability, reproducibility, and democratization of access. To maximize the value of these often-publicly-funded resources, disciplines are turning to FAIR Guiding Principles for data stewardship. FAIR (Findability, Accessibility, Interoperability, and Reuse) promotes the additive value of widespread data sharing that is transparent, equitable, and inclusive. Here we present NoCTURN, a recently NSF-funded FAIR Open Science Research Coordination Network for computed tomography users. NoCTURN (the Non-Clinical Tomography Users Research Network) aims to address the fragmentation of tomography toolkits stemming from proprietary software, nonstandard metadata formats, and repeatability limits. In this presentation, we outline how we will achieve this together by: 1) developing a community committed to information sharing; 2) coordinating data analysis, storage, and reporting requirements; 3) highlighting underrepresented voices in the field; 4) organizing standards inclusive of industry, research, education, and outreach stake-holders; and 5) modeling FAIR Open Science strategies for others. NoCTURN is recruiting members, from undergraduates through established investigators, in X-ray-, neutron-, and synchrotron-beam computed tomography communities, including SICB.

463 Payel Chatterjee, Agnish Prusty, Umesh Mohan, Sanjay Sane

Sensory feedback control of head stabilization in hawkmoths

Gaze stabilization is a behavioural reflex that helps in stabilizing rotational optic flow across animal taxa. While most animals stabilize their gaze by eye movements, flying animals like insects and birds minimally move their eyes relative to their heads. In these animals, gaze stabilization is achieved via head movements. The feedback control of gaze stabilization is characterized in great detail in the insect order, Diptera. In them, the reflex is primarily mediated by compound eyes and the mechanosensory halteres. Because halteres are a unique adaptation in Diptera, these findings raise an intriguing question: How is head stabilization, a rapid reflex, achieved in insects other than Diptera? The question is more pertinent in nocturnal insects, where visual transduction is slow. A potential candidate for rapid feedback is the antennal mechanosensor, which is known to play a crucial role in insect flight. We hypothesized that antennal mechanosensors may also be involved in the control of head movements. Using high-speed videography and behavioral measurements, we tested this hypothesis in the nocturnal Oleander hawkmoth, Daphnis nerii. Our results suggest that visual and antennal mechanosensory feedback affect head stabilization in a frequency-dependent way. Additionally, we observed small-amplitude head oscillations. Interestingly, these oscillations also depend on sensory feedback, providing further evidence to our hypothesis. Together, the results contribute to our understanding of the operating principles of multimodal feedback in rapid reflexes.

1293 Raul Chavarria, Frank Smith

Shaggy, a Wnt signaling inhibitor, regulates anteroposterior axis development in tardigrades

The compact body plan of tardigrades is associated with the loss of posterior growth and the intermediate trunk region that develops by this process. However, the mechanisms that regulate the development of this secondarily simplified anteroposterior (AP) axis are not known. In many bilaterians, the canonical Wnt (cWnt) signaling pathway regulates AP axis establishment through antagonistic interactions with inhibitors of cWnt signaling. We investigated the roles of shaggy, an inhibitor of cWnt signaling, in regulating development in the tardigrade Hypsibius exemplaris. Using insitu hybridization chain reaction, we analyzed gene expression patterns of shaggy alongside genetic markers of anterior (six3) and posterior (caudal) identity during early development. Next, with RNA interference, we targeted shaggy. This treatment resulted in embryos with a disrupted AP axis and a variety of anterior defects, including specimens with dual AP axes. Additionally, live imaging experiments revealed that axial elongation is disrupted by this treatment. These data suggest that shaggy regulates AP axis development in H. exemplaris. Therefore, we hypothesize that the compact body plan of tardigrades evolved by conservation of the early acting mechanisms that regulate AP axis establishment in bilaterians, with loss of later acting mechanisms that regulate posterior growth.

321 Maya Cheam, Meghan Brady, Kelly Dawe

Searching for the Striated Gene

Selfish genetic elements (SGE) are parts of the genome that proliferate without regard to fitness. Abnormal chromosome 10 (Ab10), a type of SGE, is a much larger structural variant of normal chromosome 10 (N10) which encodes a meiotic drive system that converts these knobs into centromere-like structures that are preferentially transmitted during female meiosis2,4,6. We found that two different methods of determining the structure of Ab10, terminal deletion and genome assembly, disagreed on the location of a morphological marker Striate 2 (Sr2). Specifically, terminal deletion indicated Sr2 was located in the shared region, but outside of the inverted region while genome assembly fails to show the existence of any such region3. Four candidate genes were identified by aligning the N10 and Ab10 assembly. We identified homozygous mu insertions for three of the four genes, however none of them displayed striated leaves. Our most likely candidate is a RING-CH-type domain-containing protein [Uniprot:A0A3L6G6F7].

1408 Daravuth Cheam, Justin Yeakel, Michele Nishiguchi

Model behavior: Predicting how bacterial biofilms respond to predatory protozoans

Vibrio fischeri are bioluminescent symbiotic bacteria that form cellular aggregate communities known as biofilms both within and outside their hosts. These biofilms are resilient during their symbiotic state inside the light organs of sepiolids squids, but can be susceptible to grazing from protozoans during their free-living cycle outside the host. Long-term grazing effects may be difficult to examine both in the field and experimentally in the lab, but can be estimated using predictive mathematical models. We therefore generated several models to determine whether grazing upon V. fischeri biofilms affected their growth and evolution over multiple generations. The accuracy of these models was tested by comparing their output with results from in-lab experiments. New parameters such as mortality rates were added into an existing model to account for long-term population dynamics. Results indicated that changes to specific parameters have significant effects on certain variables. For example, increasing the growth rate of planktonic cells decreases the size of other variables such as carbon source and biofilm population size. Given our predictions of biofilm modality, models generated from this work provide insight to populations dynamics in V. fischeri biofilms and how they might be affected by protozoan predation, providing the foundation for determining how the environment selects for key attributes used in this beneficial symbiosis.

311 Cathy Chen, Emily Low, Kathleen Lu, Kyra Ricci, Carmela Buono, Elias Miller, Kirsten Prior, Jessica Hua

Citizen science from the perspective of community members and scientists: case study of an EcoBlitz

Citizen science can benefit both community members and scientists, yet deeper understanding of the motivations, perspectives, and experiences of each group remains a current topic of investigation. To better understand both community participants and scientists, we utilized a citizen science EcoBlitz event at Binghamton University. During this event, community members participated in a training event where they learned to collect data on the biodiversity of wildlife in local natural areas using the app iNaturalist. Volunteer scientists were present at the event to discuss the importance of biodiversity and to lead tours of the local nature preserve. After the training event, participants and scientists completed a brief survey about their experiences. Participants and scientists were both primarily motivated to attend the training event by social factors (e.g., to meet people) and for the pursuit of scientific knowledge (e.g., to learn or share knowledge). 65% of community participants reported that the training event positively changed or strengthened their perception of science and/or the natural world, while 64% of scientists reported a positive change or strengthening in their perception of community outreach. These findings suggest that (1) community members and scientists have similar motivations and goals for joining these mutual partnerships, and (2) Community citizen scientist training events can serve to foster positive relationships between communities and scientists by changing the perceptions of each group towards the other.

578 Jian-Liang Chen, Ping-Ying Chen, Fu-Yu Tsai, Dian-Han Kuo

The nervous system and phototactic behavior in Stenostomum (Platyhelminthes: Catenulida

In animals, phototaxis requires detecting not only the presence of light but also the direction from which the light comes. The sense of light direction involves two distinct components in the light-sensing organs, or eyes: photoreceptor cells – which senses the presence of light – and pigment screens – which allows only light from a specific direction to reach the photoreceptor cells. Here we report an unusual case of negative phototaxis in the catenulid flatworm Stenostomum, in which pigmented eyespots and transcripts of genes encoding the photosensing molecules such as opsins and cryptochromes are both missing. We showed that the worms exhibited a well-defined negative phototaxis response by moving away from the light source along the light gradient. Furthermore, the phototaxis exhibited by Stenostomum is spectrum-dependent, as only blue and green light, but not red light, can elicit such behavior. To understand the neural substrate of phototaxis in Stenostomum, we characterize the organization of its nervous system by using immunostaining and whole-mount in situ hybridization to selected neural markers. Our data showed that Stenostomum has a simple nervous system, which contains a small number of neurons. Together, our results suggest that Stenostomum has a nonconventional photosensory system and a simple nervous system, yet it can generate a well-defined phototactic response similar to other aquatic invertebrates, such as planarians.

1752 Yutao Chen, Marianne Alleyne, Elizabeth Bello

Testing the anti-microbial property of cicada wings and wing surface replicates

Biofouling is a prevalent and unwanted phenomenon in medical and industrial settings. In this study, we examine the anti-biofouling property of various polymer and metallic cicada wing replicates using a bioinspired framework. Cicada wings possess many nanoprotrusions which are called nanopillars. They have been found to embue the wings with excellent anti-biofouling properties. In previous work we used a high-fidelity, flexible, and versatile nanoscale replication method to replicate cicada wings. As found in our previous studies, PDMS and copper replicates of cicada wings also possess the same topography. We compared the anti-microbial property of cicada wing replicates with eight different metal and PDMS samples. Both Gram-negative and Gram-positive bacteria were spread onto separate samples, and the survival rate of bacteria was measured over time. After laboratory testing, a field test will be conducted with the same samples in three different locations. The number of bacteria on each sample will be counted and compared. Our study enables the guided design of insect-inspired materials with highly desired functionalities such as bactericidal surfaces. In the future the framework created through this anti-biofouling case-study can be implemented in other bioinspired design projects.

1347 Kathryn Chenard, Goran Dzudza, Emely Inzunza, Ryan Paitz, Renee Duckworth

Maternal stress influences brain structural development and personality in a passerine bird

Early developmental effects induced by maternal stress can influence personality variation in humans and other animals, yet the mechanisms are poorly understood. One relatively unstudied possibility is that variation in offspring behavior results from stress-induced differential allocation of maternal yolk hormones that affect brain development. To test this idea, we investigated the role of maternal stress on brain structural variation of offspring using a passerine bird, the zebra finch. We experimentally manipulated maternal corticosterone (CORT) by dosing pairs with either vehicle or CORT before and during egg laying. We then measured yolk steroids across groups, behavior tested offspring as young adults, and assessed their brain structural variation using magnetic resonance imaging (MRI). We found that CORT treated females produced eggs with higher androgen and glucocorticoid metabolite concentrations compared to control females. Treatment group offspring also differed in behavior, with males responding more strongly than females, as we found that sons from CORT treated mothers showed more fearfulness in a tonic immobility test compared to control sons; yet there was no significant difference among daughters. We will use our MRI data to test the prediction that CORT and control sons differ in key limbic system regions that modulate fearfulness. This research will provide new insight into how variation in brain structure impacts behavioral variation, as well mechanisms by which maternal stress impacts development of these traits.

380 Michael Chiappone, Carlos Rodriguez-Saltos, Lucas Legendre, Zhiheng Li, Julia Clarke

Ostrich syrinx morphology and vocal repertoire: variation across postnatal ontogeny and sex

Evolution of vocal production in birds has been the target of considerable research but has mostly focused on phylogenetically well-nested songbirds. Anatomical description and recordings of paleognaths have often only focused on a single ontogenetic stage or sex. While basic morphology of the vocal organ (syrinx) of ostrich (Palaeognathae, Struthio camelus) has been known since the 1800s, most descriptions of its vocal repertoire and syrinx anatomy since then have been incomplete or inconsistent. New toolkits now enable detailed qualitative description of internal anatomy and meristic data and allow it to be compared to vocal production. Here we describe the anatomy of the syrinx in Struthio camelus for three post-hatching ontogenetic stages and both an adult male and female ($n = 4$) utilizing dissection and x-ray computed tomography (DiceCT). We find changes in ring geometry and spacing through ontogeny. We document a small cartilaginous structure at the tracheobronchial juncture present throughout ontogeny and in both males and females. We also investigate the vocal repertoire of ostriches across ontogeny using a new dataset of 77 recordings, and we identify 4 vocalizations not previously reported in the literature, including the simultaneous production of a hiss and tonal sound. We discuss these results in the context of ancestral syrinx morphology and simultaneous contributions of both syrinx and larynx in vocalization.

1232 Lindsey Chiesl, Heather Mathewson, Gabrielle Names, Britt Heidinger

House Sparrow Parental Provisioning Across Varying Temperature Gradients

Bergmann's Rule states in warm environments individuals with smaller body sizes should be advantageous over larger individuals due to increased ability to dissipate heat. The mechanisms behind this pattern are poorly understood, but one possibility is behavioral differences across temperature gradients. In birds, parental food delivery rates can influence altricial young growth rates resulting in body mass differences when fledging. Environmental variables associated with temperature could alter food delivery rates. Our study evaluates house sparrow (Passer domesticus) feeding rates during the nestling period across temperature and latitudinal gradients from Texas to North Dakota. We hypothesize that ambient temperature influences parental feeding rates and nestling body size. If hot temperatures reduce food availability and increase metabolic demands of adults, then feeding rates should decrease resulting in smaller nestling body sizes. We predict this relationship to be stronger in the southern study sites. We provided nest boxes for house sparrows across our study sites. On day 5 or 7 post-hatching, we recorded parental feeding using video cameras placed approximately 2 m from nest boxes for 4 hours in the morning (0630-1130 hrs). We collected morphological measurements of nestlings on days 2, 4, 6, 8, and 10 post-hatch. This study will increase our understanding of how parental feeding rates are associated with differences in body size and temperature, with implications for how birds might respond to climate.

1210 Tommaso Chiodo, Benjamin Titus, Estefanía Rodríguez

Phylogenomic reconstruction of clownfish-hosting sea anemone clades Stichodactylina and Heteractina.

The clownfish-sea anemone symbiosis has long been considered a model system for understanding mutualism and fundamental evolutionary and ecological processes. Yet the host sea anemones remain poorly studied evolutionarily. Recently, a comprehensive phylogenetic reconstruction of the Order Actiniaria revealed the clownfish hosting anemones belong to three unrelated clades that evolved symbioses with clownfishesindependently. However, the five Sanger loci that were used in this previous study could not resolve species level relationships for the two most specious clades: Stichodactylina and Heteractina. Here, we resolve species level relationships for these clades using bait-capture sequencing targeting ultra-conserved elements and exon loci. Our results finally resolve species level relationships within the genus Stichodactyla and Heteractis, and confirm the Family Thalassianthidae is nested within the Stichodactylina.

237 Ariel Chipman

Serial Homology and Segment Identity in the Arthropod Head

The anterior-most unit of the crown-group arthropod body plan includes three segments, the pre-gnathal segments, that contain three neuromeres that together comprise the brain. Recent work on the development of this anterior region has shown that its three units exhibit many developmental differences to the more posterior segments, to the extent that they should not be considered serial homologs. Building on this revised understanding of the development of the pre-gnathal segments, we suggest a novel scenario for arthropod head evolution. We posit an expansion of an ancestral single-segmented head at the transition from Radiodonta to Deuteropoda in the arthropod stem group. The expanded head subdivided into three segmental units, each maintaining some of the structures of the ancestral head. This scenario is consistent with what we know of head evolution from the fossil record and helps reconcile some of the debates about early arthropod evolution.

508 Wonil Choi, Haruka Wada

Hypoxia induced physical abnormalities in zebra finch embryos

Hypoxia due to either increased temperature or low levels of available oxygen during embryonic development can increase rates of mortality and physical abnormalities in many species. In our previous study where we restricted number of eggshell pores on zebra finch (Taeniopygia guttata) eggs, we observed increased mortality rates as well as detected a physical abnormality in the hind region of their neck (presumably their hatching muscles) within the individuals that failed to hatch. To further investigate heat and hypoxia-associated physical abnormality, the goal of this study was to determine whether this abnormality contributes to mortality by euthanizing the embryos a day before their expected hatch date. We specifically chose this day of euthanasia since most of the embryonic mortality occurred around hatch. As initially predicted, we detected severe physical abnormalities within the individuals that had limited diffusive area (i.e., wax covered eggs), specifically in higher incubation temperatures. Less severe

cases of abnormalities were recorded in embryos incubated at optimal temperature with limited diffusive area. We are currently looking at the histological sections to determine the tissue type of the physical abnormality and understand the cause of this abnormality. We predict that this abnormality is derived by lack of oxygen that resulted in overcompensation of hatching muscle growth.

510 Wonil Choi, Haruka Wada

The role of eggshell pores in thermal tolerance of zebra finch embryos

Rising temperature due to climate change poses a big challenge to the survival of organisms. The oxygen- and capacity- limitation of thermal tolerance (OCLTT) hypothesis posits that oxygen deficiency associated with increased oxygen demand due to high temperature sets the upper thermal tolerance of a species. This hypothesis has been mostly tested in ectothermic species, especially fish and other aquatic species. In contrast, we know little about whether it can be applied to endothermic species and embryos. Here, we tested OCLTT hypothesis in zebra finch (Taeniopygia guttata) embryos, which exhibit ectothermic phenotypes for most of their development. In a 2×2 factorial design, we covered half of the eggs with beeswax at the thirty percent mark to physically elicit hypoxia and incubated these eggs in either optimal or high incubation temperatures. We hypothesized that hypoxia decreases animals' thermal tolerance, thus increase rates of mortality. As expected, we observed lower hatching success rates in wax-treated groups at both incubation temperatures. Specifically, we detected the lowest hatching success rates in the wax-treated group incubated at high incubation temperatures. Furthermore, wax-treated individuals consumed less oxygen and lost less water compared to the control groups regardless of the incubation temperature.

511 Madeline Choi, Kevin Pham, Wonil Choi, Haruka Wada

The effects of nighttime light exposure on avian bacterial killing ability and gut microbiota

With increasing urbanization, organisms in urban areas are exposed to excess levels of artificial light, thereby disrupting circadian rhythms. However, the effects of nighttime light exposure (NLE) on host physiology remain relatively unknown, particularly in avian species. To address this gap, we investigated the effects of NLE on immune function and in gut microbial communities of female zebra finches (Taeniopygia guttata). Specifically, we exposed individuals to constant light (∼160 lux, 24L:0D photoperiod) for 23 days to examine the impacts of circadian rhythm disruption on body mass, bacterial killing ability against Escherichia coli, and gut microbial communities. We did not find an effect of NLE on body mass. However, we found that birds exposed to NLE trended toward higher bacterial killing abilities on both the third and twenty-third day of the experiment. In contrast, we did not find any significant differences in relative abundances in gut microbial communities between treatment groups at the genus level. Put together, these findings suggest that the timing and length of NLE may play an important role in the overall physiology and health of avian species.

1848 Able Chow, Bodo Wilts, Nathan Lord, Ying Xiao

Beetles in Golden Skin: Structural Color in Chrysochroa jewel beetles (Coleoptera: Buprestidae)

Chrysochroa jewel beetles (Coleoptera: Buprestidae) are known for their spectacularly bright, saturated, and diverse coloration, which originates from the selective reflection of light by alternating chitin and melanin layers in the epicuticle. Despite Chrysochroa's widespread popularity among beetle enthusiasts both amateur and professional, the optical properties and mechanisms of their structural color (and Buprestidae structural color in general) has only been investigated in a few select species. Consequently, while many of the most brilliantly colored species have been well represented in entomological arts and collections, the physical and evolutionary origins of their colors have remained unexplored by science. Twenty-eight select taxa representing all 13 Chrysochroa subgenera were investigated to provide an overview of the objective optical properties and underlying mechanisms of their diverse structural color. Optical properties of Chrysochroa structural color were quantified using spectrophotometry. Three major morphological adaptations through which Chrysochroa beetles modify color: cuticle surface sculpture, epicuticle chitin-melanin multilayer organization, and refractive index modification within each layer, were investigated and characterized using Transmission (TEM) and Scanning (SEM) Electron Microscopy, as well as computational modeling via MATLAB. Several previously unknown architectures of multilayer organizations with unique optical properties were discovered. Surface sculpture morphology, an often over overlooked trait in color production, was shown to be critical in the production of super-black and other unique visual effects by controlling the directional reflection of light.

522 Brooke Christensen, Sean Gonzales, Monica Daley

Integrating substrate damping with leg-substrate interaction forces in guinea fowl

Energy dissipating substrates are common in nature and demand rapid and situationally accurate locomotor control. To compensate, animals possess a high degree of neuromuscular and mechanical control versatility. However, as most studies have focused on steady, goal-directed movement, the principles guiding integration of control strategies for non-steady locomotion remain poorly understood. Here, we develop a simple, physical substrate model to mimic linear energy dissipation and investigate the interplay between substrate dissipation and leg-substrate interaction forces in guinea fowl (Numida meleagris). We collected high-speed video and ground force data as birds ($N = 10$) ran across an enclosed trackway under three perturbation conditions: 1) late dissipative, 2) early dissipative, and 3) non-dissipative (control). Based on prior studies of locomotion in uneven terrain, we hypothesized guinea fowl would prioritize load regulation, rather than gait steadiness, when subjected to dissipative substrate perturbations. Preliminary results indicate minimal fluctuations in loading rate and net vertical impulse during stance phases of pre-dissipative and dissipative steps (condition 1). In post-dissipative steps (condition 2), loading rate decreased. Decreased loading rate in the steps following a perturbation suggests context sensitivity of recovery mechanisms, but this finding needs to be confirmed with further analysis. In ongoing work, we are analyzing body, joint and limb dynamics to understand the mechanisms of energy management before, during, and after energy-dissipative substrate perturbations.

299 Brandi Christiano, Michael Ryan

Hungry for pests? The diet diversity of the Brazilian free-tailed bat in Austin, Texas.

The insectivorous Brazilian free-tailed bat (Tadarida brasiliensis) inhabits North, Central and South America and is the most abundant bat species in the Southwest United States. Texas hosts the three largest colonies of T. brasiliensis, with over 30 million individuals foraging in both urban and agricultural environments. The foraging habits in these different environments provide valuable ecological services ranging from consumption of numerous insect pests to pollination of economically important plants. A review of diet studies of this species shows that moths (Lepidoptera) and beetles (Coleoptera) are the two most common food items. Fourteen other orders of insect are commonly identified. These studies mostly relied on visual inspection of fecal samples, which biases identification toward insects with hard shells or scales, and fails to identify soft body insects, such as mosquitoes. A more comprehensive technique, DNA metabarcoding, recovers DNA from any consumed insects and thus overcomes this previous obstacle, revolutionizing studies of animal diets. To better understand the impacts that bats have on the community, we have barcoded and sequenced fecal samples from a local T. brasiliensis population. Using these techniques, we expect to identify disease-carrying pests, like Aedes species in the diet of T. brasiliensis living under the Congress Avenue Bridge in Austin, Texas.

678 Amanda Cicchino, Brenna Forester, Jason Dunham, Cameron Ghalambor, Erin Landguth, Alisha Shah, W. Chris Funk

How a cold-water specialist frog survived a wildfire

Extreme environmental events are becoming more common as a consequence of climate change. Furthermore, they are occurring in environments that were historically unsusceptible to these events, such as wildfires in the old-growth forests of the Pacific Northwest. Understanding the evolutionary outcomes and lasting impacts of fire disturbances on populations is challenging as these inferences require monitoring prior-to and immediately following a fire. Here we report preliminary results of a study that provides a rare opportunity to evaluate responses of a cold-water specialist (tailed frog, Ascaphus truei) to a recent severe wildfire. In 2020, a wildfire devastated over 173,000 acres in the western Cascade Mountains of Oregon, including two populations of tailed frogs that we have been monitoring. To evaluate responses of tailed frogs to this disturbance, we combined pre-fire and post-fire data on stream temperatures, tadpole thermal physiology, and genomics, from both burned and control populations. This allowed us to investigate potential mechanisms (plasticity, adaptation) that facilitated their survival. Following the fire, stream temperatures became significantly warmer, and tadpole upper thermal limits also increased. Targeted sequencing of previously-identified neutral loci and loci associated with thermal tolerance will reveal the underlying mechanism of the observed physiological response. From these results, we will be able to assess the impact of the wildfire on the tailed frog populations as well as on their vulnerability to future environmental changes.

124 Robert Cieri

Locomotor joint moments in Varanid lizards and the scaling of locomotion in sprawling tetrapods

Geometric scaling predicts a major constraint for legged, terrestrial locomotion. Locomotor support requirements at dynamically equivalent speeds scale isometrically with body mass (? M1), while force generation capacity should scale ? M2/3 as it depends on tissue cross-sectional area. Mammals compensate with more upright postures at larger sizes, but it remains unknown how sprawling tetrapods deal with this constraint. Varanid lizards are an ideal group to address this question because they cover an enormous body size range while maintaining similar posture and body proportions. This study reports the scaling of joint moments from the hindlimb and forelimb from varanid species ranging from 7-37,000 g. Joint moments were calculated via inverse kinematics and inverse dynamics in OpenSim using a Varanus varius model scaled to the size of each species. Peak joint moments scale between M1-1.4 in both limbs. Joint moments associated with stance phase (e.g. hip adduction, knee flexion, and ankle plantarflexion) generally scale higher (∼ ? M1.35-1.45) than those associated with swing phase (e.g. knee extension, ankle dorsiflexion) (∼ ? M1.1-1.35 in the hindlimb. Muscle parameters (fascicle length, muscle mass, physiological cross-sectional area, and fibre cross-sectional area) were also found to scale with positive allometry in varanids, suggesting that varanid lizards respond to predicted biomechanical demands of increased body size with both anatomical and kinematic adjustments.

27 Lauren Cirino, Ian Gallagher, Camille Desjonquères, Rafael Rodriguez

Means and opportunity but no motive for mate choice copying

In mate choice, social learning may take the form of mate choice copying or anti-copying, whereby observed mating decisions are either mimicked or avoided. Alternatively, independent mating decisions may be based on innate preferences or early life social learning. While mate choice copying is widespread among some animal taxa, research in arthropods is limited and results are mixed. We tested these hypotheses using Enchenopa treehoppers (Hemiptera: Membracidae). Enchenopa males produce plant-borne vibrational advertisement signals and females express their mate preferences by selectively duetting with males. Individuals on the plant can monitor these public signals during pair formation. We randomly assigned females to treatment duets consisting of either unattractive or attractive male signals, followed by a long (enthusiastic), short (reserved), or no female treatment responses. We described the test females' mating preferences before, after, and during the treatments. We found that female mate preferences were not affected by the treatment duets. Instead, females had consistent individual differences which supports the independent mate choice hypothesis and rejects both social learning hypotheses. Our findings suggest that independent mate choice does not necessarily represent lack of opportunity for social influences from the immediate social context of mate choice.

846 Rebecca Clark, Cassie Smith, Savana Goslovich

Surprising impacts of dietary fiber on leafcutter ant foraging and colony growth

Leafcutter ants have a symbiotic, mutualistic relationship with a fungus garden they maintain and grow. The ants bring leaves to the fungus, which releases enzymes that break down the leaves into nutrients the ants can digest. Fiber consists of carbohydrates which the ants cannot directly digest, but the fungus garden can. We examined colonies of leaf cutter ants (Acromyrmex versicolor) to evaluate the effects of a 50% cellulose fiber diet versus a control cornmeal diet on: food collected, fungus garden growth, waste produced, and the number of ants, dead and alive, across 12 weeks. Although colonies on the 50% fiber diet produced marginally more waste compared to controls, all other measured aspects of colonies remained statistically similar. This was surprising because we expected the high-fiber diet to be difficult for colonies to digest because it contains fewer simple sugars; most herbivorous insects increase food intake in response to high fiber. Even though the ants lack cellulose digestive enzymes, that does not appear to stop them from giving fiber to the fungus, which appears able to readily digest it. There remains much hidden communication between these organisms that we have yet to discover. The current results give more insight into how deeply these two symbiotic partners interact, and the nutritional benefits of this mutualism, even though the ants cannot use the high fiber diet themselves.

987 Thomas Clark, Dillon Monroe, Caitlin Gabor

Effects of chronic exposure to heat on water-borne stress hormones over time in tadpoles

Exposure to elevated temperatures can serve as a chronic stressor in amphibian populations and temperature-induced stressors are becoming more lengthy and common. The glucocorticoid (GC) stress response helps mediate how an individual manages environmental stress. In tadpoles, these hormones can be collected through non-invasive water-borne methods minimizing potential stress introduced through collection. The effect of acute stress on GC levels in tadpoles has been studied but the effect of chronic stress has yet to be explored. We measure the effects of chronic exposure to elevated temperatures on water-borne corticosterone (a GC) release rates in tadpoles and how long corticosterone stays elevated following exposure. We exposed Inciclius nebulifer, Gulf Coast Toad, tadpoles to elevated temperatures (34C) or room temperature (23C) for 7d. We obtained water-borne samples 2hr, 6hr, 28hr, and 5-day post-treatment to explore the persistence of elevated corticosterone levels as individuals returned to homeostasis. Integrated measures of corticosterone may be elevated for days following exposure to chronic stressors, but it is not known how long it may continue to be elevated using this method. Exploring this question will provide the premise for exploring long-term consequences of stressors using this method with natural and laboratory populations as well as through the lens of climate change.

1151 Andrew Clark, Eric Tytell

All turn3D around: a 3-dimensional analysis of turning in bluegill sunfish

All fish turn regularly, yet we know relatively little about how they perform and control this common behavior. Here, we are looking at one aspect of turning: whether fish use a different mechanism to turn quickly than they do to turn more slowly. When using the caudal fin to turn, fish benefit from maximizing the torque produced by the caudal fin by keeping their body (the lever arm) straight, but they also benefit from minimizing their rotational moment of inertia by bending their body in towards the axis of rotation. This sets up a conflict between keeping the body straight to maximize torque and bending the body to minimize moment of inertia. To explore this tradeoff, we use bluegill sunfish (Lepomis macrochirus), and have developed a programmable "car" with an attached chamber that is mounted in a flow tank. The chamber moves forwards and backwards, motivating the bluegill to turn around to keep pace. Initial 2-dimensional evidence of the data has qualitatively suggested that speed of the turn is important, where slow turns are characterized by an initial beating of the tail followed by a bending of the body, whereas fast turns initiate with a body bend before beating the tail. As 2-dimensional analysis has proved insufficient for quantitative analysis, we now present a 3-dimensional quantification to characterize how fish turn at different speeds.

1163 Aubrey Clark, Lauren Simonitis, Tricia Meredith, Marianne Porter

Comparative three-dimensional olfactory morphology of requiem sharks

In sharks, water enters the nasal capsule, and flows through the incurrent and excurrent channels to the olfactory rosettes, which house the sensory epithelium. Rosettes vary in shape and size among species, but the functional consequences of this variation are still unknown. Previous researchers have hypothesized that rosette morphology will impact flow, and perhaps sensitivity and threshold, through the olfactory organs. We hypothesize that channel morphology will also impact these factors. In requiem sharks (family Carcharhinidae, species: Rhizoprionodon terraenovae, Prionace glauca, Negaprion brevirostris, Carcharhinus limbatus, Carcharhinus falciformis, Carcharhinus brevipinna, Carcharhinus plumbeus, Carcharhinus signatus, and Carcharhinus obscurus), we quantified channel and rosette morphology in situ using contrast-enhanced CT, which increases visibility of soft tissues. We stained fixed specimens using 5% phosphomolybdic acid (PMA). We imaged specimens with a Bruker Skyscan 1173 microCT scanner and used SlicerMorph to process data and take measurements: rosette morphology (length, width, fineness ratio [2D shape], raphe width) and channel morphology (incurrent channel diameter, excurrent channel volume) for each individual. This imaging enabled us to visualize the volumes of the incurrent and excurrent channels within the capsule, and in situ olfactory organ positioning. We also created 3D models that will be used in future studies to investigate the effects of morphological variation on hydrodynamics through the shark olfactory system.

1731 Nat Clarke, Christopher Lowe, Laurent Formery

Seeing clearly: visualization of whole, intact organ systems in marine invertebrates

Studies of morphology and pattern in adult stages of many invertebrates are hindered by opaque structures, such as shells, skeletal elements, and pigment granules that block or refract light and necessitate dissection for observation of internal features. An inherent challenge in anatomical studies relying on surgical approaches is that cutting tissue is often semi-destructive, and delicate or fine structures, such as axonal processes within neural networks, can be difficult to reconstruct once they are disrupted. To address this problem, we developed a hydrogel-based tissue clearing approach to render the bodies of opaque and calcified invertebrates optically transparent while preserving their anatomy in an unperturbed state, allowing for observation of intact organ systems. The resulting protocol can clear large (>1 cm3) specimens to enable deep-tissue imaging via confocal microscopy, and is compatible with molecular techniques, such as antibody staining and in situ hybridization to visualize protein and mRNA localization. To test the utility of this method, we performed a comparative microscopy study of intact nervous systems in multiple phyla of marine invertebrates; here, we will present observations on the organization of radial nerve cords and peripheral nervous system between multiple classes of echinoderms. We believe this technique is of broad interest and can allow comparative studies in the evo-devo field to extend further into development by enabling interrogation of structures in juvenile and adult stages.

1754 Nat Clarke, Noah Rose, Vicki Pearse, Dimitri Deheyn

Neon anemones: a fluorescent protein gene encodes a color polymorphism in intertidal Anthopleura spp

In tidepools along the California coast, there is a rare and striking 'neon' green color morph in the Sunburst Anemone, Anthopleura sola. To determine the basis of this coloration, we isolated a pigment enriched in 'neon' individuals and discovered that A. sola produces a GFP-family fluorescent protein in the green-yellow spectrum (530nm emission), which we call 'Anthopleura YFP' (anthoYFP). Population genetics analysis determined that allelic differences in the anthoYFP gene entirely explain the neon phenotype, as only anemones homozygous for a 'neon' allele possess the neon coloration, indicating that this represents a bona fide genetically encoded color polymorphism. Geographic observations uncovered a North-South cline of abundance, suggesting the neon allele is under selection in correlation with a latitudinally graded environmental variable. Using biochemistry, we determined that at the molecular level the 'neon' morph is the result of a single amino acid mutation in the anthoYFP gene that produces a physically brighter fluorescent protein. Further, through comparison to two sympatric Anthopleura species, A. elegantissima and A. xanthogrammica, we determined that anthoYFP is a common trait in this species complex; the physiological function of the anthoYFP protein varies between species, but it has a general role as an antioxidant to buffer against oxidative stress. Together, these observations provide insight into novel functions of fluorescent proteins in intertidal cnidarians as regulators of animal coloration and stress physiology.

1697 Chris Claypool, John Ely, Mary Ann Raghanti, William Hopkins, Patrick Hof, Chet Sherwood, Amy Bauernfeind, Jason Kamilar, Courtney Babbitt

Evolution of gene expression in the primate prefrontal cortex

The prefrontal cortex (PFC), in conjunction with other brain regions, is implicated in higher cognition such as the forethought and complex behaviours observed in great apes. The development of the PFC and its transcriptome is well characterized in humans, but little is known about which PFC traits may be ancestral to primates or derived within the great ape lineage. We used comparative transcriptomics to explore the variation in gene expression in the PFC across 11 species of anthropoid primates. We find that the greatest variation in the dataset is between humans and nonhuman primates, and the second greatest is between chimpanzees and other primates, which suggest that the PFC transcriptome is highly derived in both humans and chimpanzees. After determining which genes are differentially expressed in a species, we test the adjacent genomic loci to determine if there are high rates of sequence evolution indicative of cis-regulatory elements under positive selection. Linking these genes with their ontologies reveals divergences in specific molecular pathways and functions. Phylogenetically aware packages now allow us to test sets of cognition genes for faster rates of evolution in great apes as well as to infer the great ape ancestral transcriptome. This comparative genomics approach adds a new perspective to help us better understand primate PFC evolution and which traits may be adaptive.

469 Ian Clifton, Margaret Duffy, Spencer Hudson, Christopher Robinson, Emily Virign, Susannah French, Kevin McCluney, Jeanine Refsnider

Compensation for exposure to increased temperatures is costly in a montane, desert lizard

Extreme weather events will increase in frequency and intensity with climate change. Physiological and behavioral modulation during these extreme climatic events facilitates persistence of ectothermic species, but these compensatory responses may be costly. We transplanted greater short-horned lizards (Phrynosoma hernandesi) from a cool, high-elevation site to a warm, low-elevation site to quantify their responses to a short-term increase in environmental temperatures. We predicted transplanted lizards would have higher physiological limits after the transplant and exhibit different thermoregulatory behavior than lizards that were not transplanted. We also predicted that transplanted lizards would experience greater maintenance energy costs compared to lizards maintained at the high-elevation site. We found that transplanted lizards spent a lower proportion of time in the sun, but no evidence of changes in physiological limits. Contrary to our predictions, we found no evidence of increased maintenance energy costs. However, transplanted lizards lost more mass, suggesting limitations in energy acquisition that may have been a consequence of thermoregulatory changes. Understanding whole-organism effects of increased temperature is critical for predicting how organisms will be impacted as climate change continues at an unprecedented rate.

1733 Patrick Clouser, Jason Podrabsky

Molecular signatures of anoxia tolerance in embryos of the annual killifish Austrofundulus limnaeus

Annual killifish (Austrofundulus limnaeus) live in ephemeral ponds of Venezuela. They have evolved a life history that includes embryonic diapause; a period of developmental dormancy and metabolic arrest that supports survival during the dry season. These embryos are extremely resistant to environmental stresses; for example, they can survive for months without oxygen (anoxia) as they can spend months buried in anoxic soil during development. I hypothesized that this extreme anoxia tolerance is supported by gene expression networks that characterize specific metabolic and cell physiological responses to anoxia. To evaluate this hypothesis, we used weighted gene correlation network analysis and differential gene expression analysis to evaluate RNAseq data from four different developmental stages that differ in their tolerance of anoxia. Embryos were samples at 4 and 24 hr of anoxia and 2 and 24 hr of recovery from anoxia. Principle component analysis of gene expression patterns suggests unique stage-specific responses to anoxia. These differences are especially pronounced in dormant and actively developing embryos that have similar tolerances of anoxia. Thus, we conclude that even within a single species, there may be multiple molecular programs that can support long-term anoxia tolerance. Understanding how cells can survive without oxygen could lead to critical breakthroughs in medicine and emerging biotechnologies, such as treatments to mitigate damage from heart attacks or strokes.

1469 Anthony Cobos, Natalie Holt

Evidence of elastic energy storage in the Western Fence Lizard (Sceloporus occidentalis)

Locomotion, a behavior closely tied to an animal's survival, often shapes associated morphological and physiological traits. Muscle tendon units (MTUs) are a major contributor to locomotion. Muscles convert chemical energy to mechanical work, and the rate at which this is performed (power) is often used as a performance metric. Muscle power fibers is limited by the observed negative relationship between force production and shortening velocity, and is much reduced at low temperatures. To overcome muscle power limitations, and maintain organismal performance at low temperatures, many ectotherms utilize elastic-recoil mechanisms. A recent study suggested that Sceloporus occidentalis amplified power at the ankle joint during running, producing $\sim$3.79 times more power than predicted from muscle alone, and maintained high performance at low temperatures. Here we test for potential elastic energy storage in the tendon of the gastrocnemius of Sceloporus occidentalis by determining the fixed-end compliance (% shortening of muscle fibers against the tendon) of this MTU. MTUs were excised and attached to a dual-mode servomotor, and markers placed along the axis of the muscle were tracked using high-speed videography during contractions. Preliminary data shows at peak isometric force, fixed-end compliance of the gastrocnemius is relatively low, $\sim$3%, with a $\sim$6.5% tendon strain. Future work will examine whether this relatively small tendon deformation could explain the previously observed power amplification at the ankle in Sceloporus occidentalis.

430 Jamie Cochran, David Buchwalter

Respirometry reveals major differences in aquatic species responses to salinity

All freshwater organisms are challenged to control their internal balance of water and ions in strongly hypotonic environments. However, the relationships between salinity, ion transport rates and metabolism (MO2) remain poorly understood across species. Existing data generally indicate that higher MO2 rates are associated with lower salinities, implying a greater energetic cost of offsetting diffusive ionic losses in progressively dilute situations. Here, we measured the influence of external salinity on the MO2 of three species of aquatic insects, one snail, and one crustacean. Consistent with available literature, we show a clear decrease in MO2 with increasing salinity in the snail (Hydrobiidae sp.) ($r = -0.99$, $p = 0.03$) and crustacean (Gam-

marus sp.) (r = -0.99, p = 0.05). However, we show here for the first time that metabolic rates are unchanged by salinity in aquatic insects, while ion transport rates are positively correlated with higher salinities. In contrast, when we examined the ionic influx rates of Ca and Na in Gammarus sp., we found that Ca uptake rates were highest under the most dilute conditions, while Na uptake rates increased with salinity. This finding potentially implicates the cost of calcium uptake as a driver of increased metabolic rate in Gammarus sp. under dilute conditions and suggests phyletic differences in osmoregulatory physiology, as insects may be energetically challenged by higher salinities, while lower salinities may be more challenging for other freshwater taxa.

1512 Elizabeth Cochrane, Sydney Horan, Matthew Bertone, Mike Butler, Joanna Hubbard, Sarah Knutie

Are invasive house sparrows reservoir hosts of native nest ectoparasites?

Invasive species are a major threat to biodiversity. For example, house sparrows (Passer domesticus) are an invasive bird species in North America that can negatively affect native bird species populations. Most studies have focused on the impact of house sparrow behavior on the health of native species. However, since sparrow nestlings are hosts to nest ectoparasitic taxa, they could serve as reservoir hosts that increase parasite pressure for the offspring of native birds. For our study, we identified and quantified ectoparasitic taxa in house sparrow nests and determined whether their parasite taxa also infested the nests of native bird species in the Eastern United States. Several ectoparasitic taxa were found in the nests of house sparrows, including parasitic mites, fleas, and blowflies. Some of these taxa, such as blowflies Protocalliphora sialia, were found in the nests of native bird species, while others were not. Our study suggests that when managing conservation efforts for native bird species, the role of invasive species as reservoir hosts for nest ectoparasites should be considered.

217 Jeremy Cohen, Brooke Bodensteiner, Diego Ellis-Soto, Shubhi Sharma, Julia Barbosa, Jussi Makinen

Species distribution models are improved by incorporating thermal physiology

Species distribution models are improved by incorporating thermal physiologyTemperature is a critical limiter of species' geographic ranges because increased thermal stress under abnormally warm or cool conditions can reduce the amount of time animals may allocate for growth, reproduction, and food acquisition. Thus, rising temperatures are increasingly disruptive to wildlife populations, resulting in declines of global biodiversity and losses of ecosystem functioning and stability. Forecasting and mitigating the biological impacts of ongoing climate change requires an understanding of how species distributions are shaped by the upper and lower bounds of their thermal tolerances. However, traditional species distribution modeling (SDM) and niche modeling approaches fail to account for lab-derived thermal performance, instead relying on correlational relationships between species occurrence points and meso-scale climate data. Here, we integrate laboratory-derived thermal physiological information as 'offsets' into an SDM framework for species representing diverse lineages from reptiles to amphibians and insects. We find that species-level model predictions improve when accounting for thermal physiological limits. Further, when projecting species distributions under several climate change scenarios, we find that physiologically-informed SDMs suggest greater range loss than traditional correlational models due to the incorporation of upper physiological thermal limits. With one of six species threatened by increasingly warming temperatures, it is crucial to bridge physiology and macroecology to understand how thermal physiology limits the geographic distributions of species.

487 Karly Cohen, Emily Carr, Gareth Fraser

The tale of two jaws – development of the tenaculum in the Spotted Ratfish (Hydrolagus colliei)

Odontodes are a synapomorphy (shared, derived trait) of vertebrates that include teeth, denticles and spines of sharks, armor plates of catfishes, and gar, and the tenaculum (head claspers) on the cranium of male chimeras (Holocephalans). It is hypothesized from fossils that unlike the dermally derived denticles of sharks, tenacula and their associated teeth might originate from oral tissues. We trace the development of the tenaculum and its teeth throughout ontogeny of H. collieli (n = 15) to assess the homology and convergence between this novel craniofacial feature and the oral jaws. Our goals are: 1) to trace the development of the tenaculum, 2) assess if tooth development is more similar to oral teeth or shark denticles, 3) describe when and where tenacula tooth development is initiated, and 4) describe the genes and tissues responsible for tenacula tooth emergence. We found that male chimeras develop a full tenaculum before tooth development is complete and that only fully grown males have toothed tenacula. Teeth develop, replace and emerge from inside the tenaculum rather than from the surrounding epithelium. We suggest the growth of the tenaculum is more similar to the shark oral teeth and jaws than denticles. Our data further suggests that the tenaculum in H. collieli is highly reduced compared to its ancestors and that overtime selection may have acted against having teeth on the forehead.

1004 Whitney Cole, Karen Adolph

Learning to move in a changing body and a changing world

Infants learn to move in a physical, social, and cultural context that shapes their developing motor skills. Seemingly trivial things (e.g., the type of diapers infants wear, the clothes and shoes parents dress them in, and the objects they interact with) alter how infants move. But the context for learning is not static. Rather, infancy is a period of rapid developmental change. Infants must cope with changes in their bodies and environments from day to day and moment to moment. Learning to move is therefore a moving target.Moreover, infants generate their own practice regimen for their developing skills. Although motor skills are traditionally assessed in controlled laboratory tasks, the actual input for learning occurs during everyday spontaneous activity—essentially, during everyday play at home. Infants' self-initiated locomotion generates immense amounts of variable, time-distributed, error-filled practice: Toddlers average 2400 steps and 17 falls per day. More important, experience is highly variable from infants' first steps. Walking infants start and stop, follow twisting paths, and take steps in every direction. The end result of massive variability—some imposed by a changing environment outside infants' control, some self-generated by infants' spontaneous behavior—is a perceptual-motor system adept at change. Infants do not learn fixed facts; instead, they learn how to learn. Such behavioral flexibility makes infants adaptive actors capable of navigating an ever-changing world.

856 Sean Colin, Kakani Katija, Joost Daniels, John Costello, Shirah Strock, Kelly Sutherland, Bradford Gemmell

Behavioral time-series and swimming kinematics of mesopelagic siphonophore jellyfish

Siphonophores are multi-jet jellyfish that are important predators in open ocean ecosystems. They are numerically dominant members of the epipelagic and mesopelagic zones through the worlds oceans. However, due to limited access to them in the field and their delicate morphology few field or laboratory studies have examined their swimming and feeding behavior. Siphonophores comprise of a colony of individuals specialized for either swimming, prey capture, feeding or reproduction. The body plan is divided into two main units, the nectosome (propulsive unit) and the siphosome (feeding and reproductive unit). The nectosome is made up of multiple jetting individuals that move and maneuver the siphonophore. We used remotely operated vehicles (ROVs) to conduct long term (>30 minutes and up to 5 hours) video observations of individual siphonophores to quantify their swimming and feeding behavior. Several species that varied both morphologically and behaviorally were followed and quantified. We found that most species repeat a feeding mode (resting with tentacles extended) and swimming mode (pulsing with tentacles contracted) cycle with different durations of time spent in each mode. We examined how the nectophores coordinate in order to reposition the siphonophore during the swimming mode and how they maneuver the nectosome and siphosome to deploy their complex tentacle arrays.

1106 Alexandra Collias, Natalie Steinel

Schistocephalus solidus modulates stickleback immunity through excretory-secretory products

Helminth parasites can modulate host immunity through excretory-secretory (ES) products. ES products dampen the host immune response, which can ameliorate the severity of some autoimmune diseases but may be harmful during co-infection. The tapeworm Schistocephalus solidus can suppress immunity in its host, threespine stickleback, however it is unclear if this is mediated by ES products. To determine if S. solidus ES products suppress stickleback immune cell viability and the production of reactive oxygen species (ROS), we incubated splenocytes in the presence or absence of S. solidus ES products. While splenocytes in culture medium alone steadily decreased in viability, splenocytes treated with ES products retained viability in an ES product concentration-dependent manner. Cells treated with heat-inactivated ES products showed a similar decrease in viability to control cells, suggesting that changes in splenocyte viability are mediated by proteins that make up the ES products. A parasite population-dependent difference was observed in the viability of ES-treated cells. Similarly, ES products from different S. solidus populations had variable effects on head kidney leukocyte ROS production. These results suggest that S. solidus ES products modulate several measures of stickleback immunity. Furthermore, the variability observed suggests that ability or degree of modulation may be S. solidus population-specific and may provide evidence for host-parasite co-evolution of this pathway.

1558 Sydney Collins, Mihika Kozma, Donald Mykles

A novel model for RTK mediated regulation of the molt cycle in the blackback land crab

Crustaceans molt to grow and regenerate lost limbs. A neuropeptide called molt-inhibiting hormone (MIH) regulates the crustacean molt cycle via inhibition of ecdysteroid synthesis by the Y-organ (YO). Identity of the MIH receptor is yet unknown. Past work on signaling pathways of crustacean molt regulation suggests it may be a class A G protein-coupled receptor (GPCR). In insects, ecdysteroidogenesis is regulated by the prothoracicotropic hormone that binds to receptor tyrosine kinases (RTKs) expressed in the prothoracic gland. Previous studies found differential gene expression in components of the RTK signaling pathway across molt stages of the blackback land crab, Gecarcinus lateralis. This study seeks to characterize the role of RTKs in crab molt regulation by examining the following: 1) Gene expression of RTKs in the YO of G. lateralis across molt stages; 2) Crosstalk between RTK and GPCR signaling pathways by a multimodular protein, Girdin (GIV). GIV can selectively bind to G? subunits and initiate GPCR signal cascades without direct activation of GPCRs. GIV has remained uncharacterized in crustaceans until now. Homologues to GIVs were successfully identified in YO transcriptomes through phylogenetic analyses. An analysis of gene expression of GIV across the molt cycle of G. lateralis is ongoing. Here, we propose a novel model of GIV-mediated RTK/GPCR signaling that provides further insight into the regulation of crustacean molting. Support: NSF (IOS-1922701) and CSU Honors Program.

699 Zuania Colón-Piñeiro, Junangel Aleman-Rios, Laura Reinert, Louise Rollins-Smith, Patricia Burrowes, Ana Longo

Juvenile coqui frogs can mount immune response to chytrid fungus: The key to persistence?

Host susceptibility to diseases is a complex trait that can be influenced by seasonality and ontogeny. Here we focus on Eleutherodactylus coqui, a terrestrial frog that resists fungal infections at certain times of the year as adults, indicating that host immunity is not fully protective. However, we know little about the mechanisms allowing juveniles to survive the infection. Using capture-mark-recapture, we monitored an E. coqui population for more than one year at El Yunque, Puerto Rico to measure Batrachochytrium dendrobatidis (Bd) infections, antimicrobial peptides (AMPs), and skin microbial communities. We hypothesized that if secreted AMPs inhibited Bd growth, individuals with higher concentrations would carry lower infections. We found that earlier life stages usually carried higher pathogen loads and secreted more AMPs per body mass than adults, perhaps allowing them to survive. This finding was unexpected because immune function generally increases with age in amphibians. Preliminary analysis of AMPs released between seasons revealed that uninfected juveniles secreted more peptides than infected individuals only in the warm-wet season. Our findings from terrestrial direct-developing frogs provide support for the idea that juveniles mount immune responses. We discuss the implications of these results in the context of pathogen transmission and microbial assembly, highlighting how the ecological complexity of terrestrial habitats shapes fitness traits in direct-developing frogs.

1452 Stacey Combes, Nicholas Burnett, Susan Gagliardi

Chordwise wing flexibility improves bumblebee stability but inhibits maneuverability during tracking

Insect wings are lightweight structures that bend passively during flight, and past studies show that chordwise flexibility increases force production and, in laminar flow, decreases stability. However, the effects of wing flexibility on other aspects of flight performance, such as stability and maneuverability during different flight challenges, remain unclear. We hypothesized that wing flexibility limits force asymmetries between the wings, as flexible wings passively reconfigure to reduce differences in projected wing area perpendicular to the oncoming flow. This would improve flight stability, but may also limit intentional wing asymmetries that many insects employ to initiate maneuvers. We examined the effects of wing stiffness on bumblebee flight stability and maneuverability by splinting a flexible wing-vein joint on both wings to increase chordwise stiffness. We filmed 19 bees in three flight conditions (laminar flow, unsteady flow, and tracking an oscillating flower) with both experimental and control-splinted wings. Our results show that with stiffened wings, bees were less stable in unsteady flow, displaying increased rates of high-frequency, unintentional body rolling. When tracking a moving flower, however, bees with stiffened wings displayed higher peak rolling rates to initiate turns. Thus, chordwise flexibility in natural wings improves flight stability but reduces bees' ability to initiate maneuvers that rely on wing asymmetry.

696 Kaelin Connolly, Veronica Martinez-Acosta

Neurotransmitter Systems in Lumbriculus variegatus, a regenerating model system

Lumbriculus variegatus, an aquatic oligochaete, undergoes anterior and posterior regeneration. Our lab is particularly interested in regeneration of the nervous system. Lumbriculus' rapid and efficient recovery of function following nerve injury raises questions regarding plasticity at the synaptic level. In this study, we present transmission electron microscopy imaging characterizing synapses that interact with the medial giant fiber, one of the main components of the worm central nervous system. We also present immunohistochemical analysis of neurotransmitter and synaptic proteins in regenerating and non-regenerating worms. Serotonergic neurites are found closely associated with neuronal tracts of the cephalic ganglia and lateral giant fibers, as well as neurites extending into the periphery within specific segments. FMRFamide positive neurons are found primarily within the periphery at places of sensory input and motor output. Lastly, we measure changes in synaptic protein levels associated with the recovery of synaptic function using the antibody, Anti-DSAP 47. DSAP-47 immunoreactivity is most closely associated with the lateral giant fiber system and with axons found within the neuropile of the ventral nerve cord. Changes in expression of DSAP-47 in regenerating worm fragments will provide a better understanding of the contribution of synaptic proteins to the remarkable recovery of function displayed by this regenerating system.

1370 Miranda Contello, Braden Oddo, Brittany Dobbins, Ruben Tovar, Tom Devitt, David Hillis, Dana García

Comparative study of the development of salamanders of the genus Eurycea

Central Texas is home to many salamanders of the genus Eurycea. These salamanders are fully aquatic and retain juvenile features such as gills even as reproductively competent adults. Several of the species live above ground and several live below in caves along the Edwards Aquifer. The species that live below ground exhibit many characteristics typical of cave-dwelling organisms such as reduced pigmentation and reduced eyes. The below ground species we chose to study is the Texas blind salamander, Eurycea rathbuni, which begins to develop eyes in its early stages that degenerate in later stages. We are interested in the evolutionary mechanisms behind eye degeneration in E. rathbuni. To study this, we compared E. rathbuni to two sighted species: the San Marcos salamander (Eurycea nana) and the Barton Springs salamander (Eurycea sosorum). As part of our comparative study, we documented the morphological changes at each stage of development using the Hirox digital microscope. We have created a series of images documenting development of E. rathbuni depicting milestones in early stages such as the development of eyes, limbs and even digits. By comparing these morphological differences, we can more easily see the divergence of features between the sighted and blind species, particularly in the eye development. As our research progresses, we will continue to document development of these three species and others through pictures.

833 Ellen Coombs, Matthew McCurry, Travis Park, Agnese Lanzetti, Andrew Knapp, Rebecca Bennion, Michael McGowen

Functional tradeoffs: Quantifying mandible shape in echolocating whales

Toothed whales (odontocetes) emit high-frequency sounds (echolocate) to sense their prey and environment. A highly specialized mandible (jaw) allows these high-frequency sounds to travel back into the inner ear. The ability to echolocate, albeit rudimentary, is evident in the earliest toothed whales, but little study has been done on mandible form across odontocetes.We scanned 75 mandibles representing $>$ 95% of extant odontocetes and 18 fossil cetaceans ranging from non-echolocating Eocene archaeocetes (early whales) to late-Miocene odontocetes. We used 36 coordinate-based landmarks and 40 curve semi-landmarks to investigate mandibular asymmetry and shape. Finally, we used CT data of a subset of mandibles ($n = 25$) to investigate bone thickness.We found significant asymmetry (p The largest component of mandible variation (PC1 = 51.2%) is the relative length of the mandible followed by mandibular symphysis length (PC2 = 27.3%). Allometry is a small but significant aspect of mandible shape variation ($r2 = 0.10$, p Finally, CT data confirms that the pan bone is the thinnest part of the mandible, specifically the angular process and mandibular foramen region, which is conducive to effective sound transmission. The thickest parts varied by species but are generally the condyles and jaw symphysis. These early results will inform our work on functional tradeoffs between echolocation and bite force.

400 Emma Cooney, Casey Holliday

Jaw muscles and their connections to the TMJ and middle ear of Virginia Opossum

The transformation of the primitive amniote jaw joint into the middle ear of modern mammals remains a rich example of vertebrate evolution. Although we have considerable understanding of the evolution of the bones of jaw and ear, we know less about the musculature involved, and the homology and origin of soft tissue structures like the temporomandibular joint (TMJ) articular disc remain unclear. To test these hypotheses, we used high resolution, diceCT of an adult Virginia opossum (Didelphis virginiana) to explore and identify soft-tissue connections amongst the TMJ and middle ear in a metatherian. We were able to identify a thin layer of connective tissue that corresponds to the TMJ disc. This tissue is continuous with the pterygoideus lateralis tendon rostrally and the discomallear ligament (DML) caudally which then passes through the petrotympanic fissure to attach to the malleus. These topological relationships indicate that opossums have a TMJ articular disc albeit only a membrane. This supports the hypothesis that the TMJ disc is not only a portion of the tendon, or a meniscus of lateral pterygoideus as previously described, but that it can be classified as a sesamoid because of its continuity of connection with the malleus. These findings show that despite major morphological transformation of the cranial skeleton during mammalian evolution, the jaw musculature maintained conserved attachments to its bony insertions to ear ossicles.

1710 Alissa Coonfield, Damian Elias, Ross Hatton, Todd Blackledge

Thread tensioning alters acoustic properties of Argiope trifasciata orb webs

A spider's web functions efficiently as both a snare and sensor. Therefore, the web must be equipped with the mechanical robustness necessary to withstand prey impacts while effectively transmitting relevant vibrational information to the spider. Spiders can "tune" their webs to meet certain physiological needs under given environmental constraints by changing web geometry and thread tension. Previous work demonstrates that increased thread tension in orb webs decreases the time taken by the spider to respond to prey, and modelling suggests that changes in web tension alter the efficiency with which vibrations of certain frequencies can be transmitted. To better understand how changes in thread tension affect spiderweb acoustics, we first use highspeed video vibrometry to determine if the natural frequency of Argiope trifasciata webs increases and decreases with corresponding changes in web tension. We then test the hypothesis that changes in thread tension alter the transmission efficacy of replicated prey signals based on the dominant frequencies of those signals. We couple this with behavioral assays to examine how thread tensioning and the resulting change in acoustics are relevant in prey detection. This project demonstrates how spiders may alter web properties to facilitate the detection of specific vibrational stimuli, leading to more successful and efficient prey capture.

287 Etti Cooper, Ryan Bavis

Critical Thermal Maxima and Plasticity in Metabolic Rates: A Comparison of Two Ant Species

Ants, like other ectotherms, rely on heat from the environment to increase body temperature, and therefore, metabolic rate. However, critical thermal maximum (CTmax) and the capacity to acclimate to high temperatures is highly variable and affected by a variety of biotic and abiotic factors. I gathered CTmax values previously published for 177 United States ant species, and found that CTmax has a statistically significant, though weakly correlated, relationship with latitude. No phylogenetic signal was detected. This suggests that local microclimate may be more influential than latitude in determining thermal tolerance, although it is unclear whether this is due to local adaptation or plasticity. Next, I performed a common garden experiment to elucidate the patterns that determine thermal tolerance at a finer scale. The yellow meadow ant Lasius nearcticus is entirely subterranean, while the invasive pavement ant Tetramorium immigrans is a generalist, mostly foraging aboveground. I hypothesized that T. immigrans would display greater plasticity in response to acclimation at a high temperature as well as a higher CTmax. The mean CTmax value of T. immigrans was 7.4 percent higher than that of L. nearcticus ($p < 0.001$). Phenotypic plasticity was measured by acclimating randomly chosen colonies of each species to 25°C or 30°C conditions for seven days, and then assessing metabolic rate at both acclimation temperatures through respirometry. While the CTmax findings support my hypothesis, the results of the respirometry measurements suggest that L. nearcticus may display greater plasticity, but that this may not be advantageous.

1665 Idelle Cooper

Sexual dimorphism beyond sexual selection: evolution of body and wing color in two damselfly systems

Sexual dimorphism is often presumed to result from sexual selection, particularly involving female choice of male traits. By considering how variation within species may result from other selection pressures, however, we may gain a fuller view of how such variation can evolve. Here I describe our work in two damselfly systems, Hawaiian Megalagrion and North American Calopteryx. Megalagrion calliphya and M. hawaiiense exhibit both between sex and within-female body color dimorphism. We examined the evolution of this color variation using a variety of approaches (behavioral, phylogenetic, physiological), and found support for an ecological selection hypothesis: red coloration in males and in females from high altitudes is an adaptation to ameliorate oxidative stress caused by UV exposure. Sexual dimorphism and within-female dimorphism are simply byproducts of ecological selection in different habitats and gene flow. The Jeweling damselflies, Calopteryx maculata and C. aequabilis, also vary in the degree of sexual dimorphism, primarily because of variation in female wing color. Our mate choice studies indicate that the traditional view of female mate choice may not be the whole story, but that males may also select females to court during species recognition. These examples highlight the variation within and between sexes, the possibility that similar trait patterns can result from multiple different selection pressures, and the potential for sexually dimorphic traits to have roles outside of sexual selection.

1726 Diane Cordero, Alva Mihalik, Lindsey Swierk, Alexandra Martin

Going with the flow and using bubbles to escape threats: Diving preferences of Anolis aquaticus

Diving ectotherms make use of different microhabitat characteristics to maximize predator avoidance. Anolis aquaticus is a semi-aquatic lizard found near tropical streams in Panama and Costa Rica that uses various strategies to avoid predation, such as running away, swimming, and diving into the water. A. aquaticus has been observed “rebreathing” air bubbles attached to their nares while submerged for more than 15 minutes at a time. We collected A. aquaticus at Las Cruces Biological Station in Costa Rica and quantified in the lab how microhabitat variables affect diving behavior. We tested whether A. aquaticus’ dive duration is affected by water flow rate and dissolved oxygen content of water and whether males and females perform differently in these microhabitats, as indicated by dive duration and bubble retention. Our results show that, in faster-flowing water, A. aquaticus had shorter dive durations and higher bubble disruption. Our results also demonstrate that dissolved oxygen had no effect on the dive duration of A. aquaticus, suggesting that oxygen from the water is not diffused into their rebreathing bubble to facilitate longer dives. Additionally, we did not find any significant differences between sexes for dive duration factoring water flow and dissolved oxygen. These results can help us better understand the mechanics of rebreathing behavior and the preferred environmental conditions of A. aquaticus in a rapidly changing global climate.

1132 Rosemary Corkins, Yiheng He, Joshua Martin

Mapping trematode worm infection of the dragonfly brain: Anatomical evidence for parasite control of

Parasites can influence the behavior of the host to facilitate their life cycle. Many parasites of insects modify the animal’s behavior to increase the likelihood they will be eaten by the final host of the parasite. Trematode worms form cysts in the brains of adult dragonflies, causing them to remain on a perch and fail to escape from amphibian or bird predators. Here, we ask whether the location of cysts in the brain can explain the parasite’s influence. We use a common immunofluorescence technique, targeting a synaptic protein to image and create 3D maps of the neuropils of the brains of several species of dragonflies in the family Libellulidae. We then image infected brains in situ using micro-computed tomography (micro-CT) with iodine as a contrast agent, and map the location of the cysts. These cysts were predominantly located the visual system (the medulla and lobula of the optic lobe) and in neuropils associated with sensory-motor systems (periesophageal, ventromedial, and lateral complex neuropils on the ventral surface and the superior neuropils on the rostral surface of the cerebrum). Cysts impacted large portions of a neuropil’s volume and tracts connecting neuropils. Our results suggest that trematode worm infection impacts the visual system, visual navigation, and descending motor control in the dragonfly.

572 Savvy Cornett, Hans Hofmann, Molly Cummings

Sex and food: Reproduction and energy homeostasis in a fish with alternative reproductive tactics

The interplay between multiple hypothalamic neuropeptide systems integrates nutritional status and reproduction across vertebrate, including melanocortin-4 receptor (MC4R) and the gonadotropin-releasing hormone (GnRH) superfamily of hormones, especially GnRH-II. While the GnRHs collectively regulate reproduction and MC4R is critical for energy homeostasis and puberty onset, the relationship between these pathways remains poorly understood. We investigated the physiological and behavioral effects of food restriction in the Pánuco swordtail (Xiphophorus nigrensis), a poeciliid fish with alternative reproductive tactics: large males perform elaborate mating displays, while small males mate coercively. MC4R allelic and gene copy number variation determine at which body size males mature; this predicts a male's reproductive tactic. We compared mating behavior between fed control and food-deprived communities of swordtails (n = 2 females, n = 2 large or small males) for two weeks, using daily 30min video recordings. We then measured courting, coercive, and response behaviors across groups. Compared to fed controls, unfed fish appear to invest less time in mating behaviors, especially the large males. We are now using quantitative real-time PCR to assay the expression of candidate genes involved in GnRH and melanocortin signaling. Morphology was uncorrelated with behavioral changes: standard length did not differ between treatments. Ongoing analyses will reveal how these pathways interact to regulate reproduction in concert with nutritional status. Overall, our study elucidates the functional interactions between the reproductive axis and energy homeostasis.

1397 Mariangel Correa-Orellana, Alice Nguyen, Jess Sterling, Joseph Dubie, Justin Havird

Macro- and micro-ecology of anchialine habitats and adaptation of volcano shrimp to high temperature

Anchialine habitats are defined as landlocked, costal ponds influenced by seawater and freshwater. [JH1] They are often created via volcanism and are most abundant in Hawaii, with about 700 known habitats. Halocaridina rubra (Volcano shrimp) is the most common Hawaiian anchialine species and plays a critical role in anchialine ecology. It is unclear how ecological process at both the macro- and micro- scales develop in newly created anchialine habitats, as their natural formation is seldom observed.[JH2] Here, we measured thermal adaptation of H. rubra in the context of newly created habitats in Hawaii with extremely high temperatures. We also examined bacterial community composition across newly created and established anchialine habitats, as well as gut communities of H. rubra. We examined two different genetic lineages of H. rubra: one from the hot newly created habitats (∼40°C) and one from cooler established habitats (∼30°C). Shrimp kept in the lab were acclimated for a month to 15°C, 25°C, and 30°C. After the shrimps were acclimated, metabolic rate was calculated at each test temperature. CTmax and CTmin of each lineage was also quantified. Metagenomic analysis of the anchialine habitats and gut samples was completed using Qiime2. Shrimps from different genetic lineages reacted differently to acute changes in temperature and there was a high mortality in shrimps acclimated to low temperature transferred to 30°C[JH3] . CTmax was higher in the lineage from the newly created habitats. Metagenomic analysis using QIIME2.

1228 Joshua Corrette-Bennett, Madelyn Scarmack, Caitlyn Mattocks, Allison Sherman

The mechanism of beta-alanine delivery produces opposite affects on axolotl limb regeneration

The Urodele Ambystoma mexicanum (Mexican axolotl) has become one of the more prominent model organisms for studying development because of its exceptional ability to heal wounds and regenerate damaged tissue and severed limbs. While the extent to which axolotls can regenerate tissues and limbs is unique to Urodeles, this organism can still serve as a helpful model for identifying factors that affect wound healing and regeneration of complex tissues in other tetrapods. An increasing number of studies have shown that rates of wound healing and regeneration can be influenced by exposure to various compounds. Preliminary results from our lab suggest that ?-alanine has an effect on the early stages of axolotl limb regenration (wound healing and de-development), but that the mechanism of delivery can significantly alter the outcome. One study looked at regeneration rates when axolotls were bathed in high and low concentrations of ?-alanine, while the second study looked at regenrations rates when axolotls were injected with the same concentrations of ?-alanine. Our results indicate that when the amputated site is bathed in ?-alanine, it has an inhibitory effect on early stages of limb regeneration, but when ?-alanine is delivered via a subcutaneous injection it enhances the rate of limb regenration.

867 John Costello, Sean Colin, Bradford Gemmell, John Dabiri, Eva Kanso

Turning kinematics of the scyphomedusa Aurelia aurita

Scyphomedusae are widespread in the oceans and their swimming has provided valuable insights into the hydrodynamics of animal propulsion. Most of this research has focused on symmetrical, linear swimming. However, in nature, medusae typically swim circuitous, nonlinear paths involving frequent turns. Here we describe swimming turns by the scyphomedusa Aurelia aurita during which asymmetric bell margin motions produce rotation around a linearly translating body centroid. These jellyfish "skid" through turns and the degree of bell margin asymmetry is related to the turn magnitude. We discuss several of the interactions that affect the net outcome of a turn during bell pulsation.

878 Isabel Cote, Anabela Maia

Planktivorous fish in Narragansett Bay exhibit suppressed metabolic rates as temperature increases

Increasing water temperatures have been a worldwide problem for coastal ecosystems. Historical data in Narragansett Bay have shown shifts in fish species composition, likely related to increasing water temperatures. Scup (Stenotomus chrysops) and Atlantic silversides (Menidia menidia) are two common planktivorous fish species found in the Bay, which remain understudied. Fish were acclimated to 18°C over the course of one week and then closed-chambered respirometry experiments were conducted at 18°C and 22°C to test for basal (BMR) and maximum metabolic rates (MMR). After completion of these trials, fish were switched to tanks maintained at 22°C and were again acclimated to this temperature for a period of one week and respirometry experiments repeated. We expected fish to have an increase in metabolic rate with increased temperature. It was also expected that fish acclimated to testing conditions would have higher metabolic rates at higher temperatures. If these species are unable to thrive at elevated temperatures, we would expect metabolic rates to be suppressed. Our results thus far do not support an increase in metabolic rate with temperature. Basal and maximum metabolic rates and aerobic scope stayed relatively constant with increased temperature and there was no statistical difference between those acclimated and non-acclimated to the testing temperature. At the predicted increased temperature for the Bay, we would expect these species to be displaced by other planktivorous species.

1449 Braden Cote, Mark Jankauski

Experimental Evaluation of Wing Hinge Mechanics in Bumblebees

Many flying insects use indirect actuation to realize flight. Within indirect actuation, the insect's flight muscles attach to the interior walls of the thorax exoskeleton rather than the wing base. Small thorax deformations caused by muscle contraction are amplified into large wing rotation via an elaborate linkage mechanism called the wing hinge. Relatively little is known about the mechanics of the wing hinge despite the critical role it plays in insect flight. In this research, we seek to answer the question: does the wing hinge behave as a static or dynamic transmission between the insect thorax and flapping wing? To assess this, we developed an experiment to simultaneously measure the wing rotation and thorax deformation in tethered bumble bees. We performed this experiment on bees with intact wings and bees with wings clipped to understand how changes in wing mass and aerodynamic loading influence thorax motion and/or wing rotation amplitude. Preliminary results ($n = 5$) indicate that after clipping, there is a 32% average reduction in thorax displacement. Of these subjects, an increase in wingbeat amplitude of 5% to 9% was shown. A larger wing rotation combined with a decrease in thorax displacement indicates compliance within the wing hinge and thus a dynamic mapping between the thorax and the wings.

375 Victoria Coutts, Haruka Wada

Food restriction during development and its impact on physiology in the zebra finch

The developmental environment is critical and can cause permanent changes in physiology and morphology. Importantly, when organisms are exposed to changes in their environment, the release of glucocorticoids from the hypothalamic-pituitary-adrenal (HPA) axis facilitate adjusting to those changes by redirecting resources, such as an increase in blood glucose. However, relatively little is known about the impact of caloric restriction on the HPA axis and downstream glucose response. To address this gap, zebra finches (Taeniopygia guttata) were exposed to a restricted or control diet throughout the nestling and juvenile periods and baseline and restraint-induced level of corticosterone and glucose were measured at post-fledging, nutritional independence, later juvenile period, and adulthood. Current data show that food-restricted offspring have marginally lower mass during the juvenile period, significantly less furculum fat shortly after treatment commenced (10 dph) and marginally less furculum fat in adulthood, as well as marginally higher baseline glucose compared to controls. We are currently completing a corticosterone ELISA to elucidate the relationship between corticosterone and glucose levels under caloric restriction. We predict that nutritionally stressed individuals will have higher baseline corticosterone, but a lower response to restraint stress. These preliminary data showed that offspring adjust to food restriction by storing less fat without negatively impacting mass growth, but consequently have higher blood glucose circulating as available energy.

1345 Toby Covill, Catherine Wagner, Sean Harrington, William Rosenthal

Predator Diversion Adaptation in Juveniles of Plestiodon multivirgatus, the Many-Lined Skink

Plestiodon multivirgatus, commonly known as the many-lined skink, possesses a blue tail as a juvenile that it loses as it matures. The trait is believed to serve as a predator diversion tactic but this hypothesis has not been tested in this species. We used a clay model predation experiment to examine the effects of the trait on avian predation. We found that the presence of a blue tail significantly increased the average distance of avian attack towards the tail of the model and altered the distribution of attacks on the body and tail. Blue-tailed models were also found to be attacked less than black-tailed ones. These results suggest that the blue tails do serve to aid in evading predation, and additionally suggest an aposematic function as well. The second conclusion contradicts previous experiments examining similar traits, opening new avenues for future research into this understudied species.

39 Jonathan Cowart, Danielle Collins, Daniel Stanton, Gerhard van-der-Horst, Iskande Larkin

Structural components lend insight into the form and function of Florida manatee sperm

Sperm morphology is highly variable across mammalian taxa with sexual selective pressures regarded as the primary driving forces of sperm diversity. The morphological and structural organization of the spermatozoon provides essential information about: (1) the functional roles of each spermatozoal component, (2) their potential relationship with reproductive success, and (3) the evolutionary influence of sexual selective pressures on sperm morphology. To better understand how a multi-partner mating system may influence sperm form and function in Florida manatees (Trichechus manatus latirostris), we investigated the morphometry and ultrastructure of sperm retrieved postmortem from the vas deferens of nine recently deceased Florida manatees. Sperm were analyzed by automated sperm morphometry analysis (ASMA) and electron microscopy (EM). Preliminary measurements of midpiece volume correlated closely with midpiece volume measurements in other species that exhibit a multi-partner mating system. Additionally, there was distinct enlargement of outer dense fibers (ODFs) 1,5,6, and 9, which were uniquely elongated and rectangular in shape. The enlargement of four ODFs may function to better stabilize the sperm flagellum and enhance sperm velocity within the female reproductive tract. This study provides new insights on the potential link between form and function of Florida manatee sperm, which further supports the occurrence of sperm competition within this polygynandrous species.

502 Christian Cox, Ian Clifton, Noah Gripshover, Agnelly Amador, Wilfredo Aquino, Jonathan Fernandez, Maddyson Mathieu, Amanda Menendez, Camila Quintana, Stefan Rhoades, Guillermo Suarez

More bark than bite: behavioral interactions between bark anoles and brown anoles

Understanding behavioral interactions among closely related species can reveal mechanisms underlying biodiversity in communities. Previous research has focused on understanding interactions among members of stable communities, or responses of native members of a community to invaders. However, biological communities have become increasingly homogenized as the result of human activities, such that many biological communities have multiple non-native species. One excellent example of this phenomenon is the non-native anole lizards in south Florida. We studied behavioral responses of the most abundant anole, the brown anole, and the second-most abundant anole, the bark anole, to intruders of the more abundant brown anole of both sexes. We found that brown anoles were more likely to attack an intruder, while bark anoles were more likely to flee. Males of both species were more likely to attack when presented with an intruder that was a male, while females were more likely to flee when presented with a male. Male bark anoles were more likely to flee from the intruder male than male brown anoles. Our research determined that the behavioral response to a brown anole intruder was species-specific, and that both intra- and interspecific interactions are sex-specific in nature. These results imply that agonistic interactions could structure assemblages of non-native species.

1398 Breonna Cox, Sarah Foltz

Frequency of the use of garbage in nest construction by cavity-nesting bird species and correlations

Human-caused pollution is a major threat to global biodiversity and avian species are not exempt from its impacts. The nests of many species are often made of a subset of materials readily available in the local environment, such as grass and twigs. However, the development of urban areas alters the types of nesting materials that birds breeding near humans have access to. This is leading to common natural nesting materials being replaced with plastics, paper, and other forms of garbage in the nests of some species. Here we study the prevalence and types of man-made garbage used in nest construction by three cavity-nesting species that readily breed in artificial nest boxes in southwest Virginia, USA: eastern bluebirds (Sialia sialis), tree swallows (Tachycineta bicolor), and house sparrows (Passer domesticus). Number eggs and/or nestlings was recorded during box checks conduced four times per week throughout the 2022 breeding season, and completed nests were assessed for nest materials and the presence of mites and blowfly larvae. We predict that species will vary significantly in their use of garbage as a building material and in the types of garbage used, and that nest failure and parasite presence will be positively correlated with garbage use. Data analysis is ongoing, but will provide insight into both the potential effects of urban-associated pollutants on avian species and species' variation.

1642 James Crall, August Easton-Calabria, Matthew Smith, Olivia Bernauer

Toward automated monitoring of plant-pollinator interactions

Interactions between plants and pollinators vary in space and time. Recent work has shown, for example, that plant pollinator networks show significant flexibility over rapid time scales (e.g. days or weeks), with important implications for the structure, function, and dynamics of these critically important ecological networks. However, 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. Our system uses deep-learning-based detection to perform real-time monitoring of floral visitation and is implemented on low-cost, open-source, field-deployable hardware. We demonstrate the potential of this approach in both natural meadows and agricultural ecosystems using dozens of cameras monitoring floral visitation over several months. Combined with high-resolution mapping of dynamic changes in floral resources using drone imagery, we use this approach to describe fine-scale spatial and temporal variation in plant-pollinator interactions and quantify the effects of spatial heterogeneity of floral resources, fluctuating weather, and species response diversity. Finally, we assess the potential for using rapidly emerging tools in deep learning, computer vision, and open-source hardware to improve our understanding of the structure and function of plant-pollinator interaction networks.

981 Rachel Crane, Christofer Brothers, Paul Leary, Stacey Combes

Dragonfly pursuit of artificial prey with biologically relevant flight behaviors

As efficient generalist predators that execute rapid aerial pursuits to capture prey, dragonflies are an ideal model for studying 3D interception of dynamic targets. Because prey behavior is variable and hard to control, previous studies have employed various methods of moving "artificial prey" (beads) above perched dragonflies to elicit pursuits. We developed a flexible system for presenting artificial prey to wild-caught dragonflies in a mesh tent in the field that can mimic many aspects of the flight dynamics of live prey. Our Arduino-controlled pulley system moves artificial prey on fishing line in predetermined and replicable patterns, encompassing non-linear trajectories and steady or varying velocities and accelerations. To determine whether this system elicits dragonfly pursuit behaviors similar to those seen with live prey, we presented blue dashers (Pachydiplax longipennis) with artificial prey moving at a range of constant, biologically relevant speeds (~0.5-2.5 m/s). We filmed predation attempts with two high-speed cameras, then digitized bead and predator trajectories. Dragonflies scaled peak velocity linearly with prey velocity, moving ~1 m/s faster than their prey, as has previously been observed with live prey. When unsuccessful, dragonflies either quickly abandoned pursuit or attempted but failed to intercept the target. Using this system to experimentally isolate aspects of prey movement (e.g., flight speed variability, turning maneuver magnitude) we can determine whether dragonflies tailor their pursuit to particular aspects of prey behavior.

322 Ondi Crino, Dan Noble

How do developmental conditions affect mitochondrial function?

The developmental enivronment can have powerful and sustained effects on animal morphology, physiology, behavior, and performance. Given that the developmental environment affects a range of phenotypic traits, it has been proposed that developmental conditions are modulated through cellular mechanisms that are shared across cell and tissue types. Exposure to adverse developmental conditions can have sustained effects on mitochondria. It is currently unknown if these effects are widespread across taxonomic groups and which components of mitochondrial function are most likely to be affected by developmental conditions. Here, we present results from experimental work that examines how exposure to glucocorticoids during development affects adult mitochondrial function. We also discuss results from a systematic reveiw that examines the effects of developmental conditions on mitochondrial function across taxonomic groups.

1407 Andrew Cronin, Judith Smit, Wouter Halfwerk, Jacintha Ellers

Effects of urbanization on early life stages and potential for local adaptation

Urbanization is rapidly altering landscapes across the globe. Persistent populations in urban environments experience a range of novel stressors and selection pressures. Due to these shifted ecological contexts, urban and non-urban populations have been shown to differ in a range of morphological, physiological, and behavioral traits. In species with multiple life stages, early life stages are characterized by high mortality rates and strong selective pressures, which may differ between urban and non-urban populations. Additionally, changes in selection pressures early in development likely contribute to phenotypic divergence in adults. Despite the high potential for differences in selection pressures and potential ramifications for later life stages, the effects of urbanization on larval stages remain largely unknown. We examined morphological and behavioral differences between urban and forest tadpoles in the túngara frog, Engystomops pustolosus. Additionally, we conducted a reciprocal transplant experiment between urban and non-urban tadpoles to examine the role of behavioral plasticity in response to urban environmental conditions. We also sought to experimentally test for indications of local adaptation in urban and non-urban populations of this species. Determining how urban conditions affect early life stages provides a more comprehensive understanding of the implications of urbanization on persistent populations. Furthermore, by examining phenotypic changes and their fitness consequences in frogs in early life stages in response to urbanization, we provide novel insights into the potential for urban evolution.

791 David Cuban, Steve Johnson, Alejandro Rico-Guevara

Sunbird drinking: unexpected nectar feeding mechanics despite morphological convergence

Sunbirds rely heavily on nectar to survive, yet very little research has been conducted on how they are able to drink the floral reward efficiently. Through high-speed videography of a variety of sunbird species with contrasting bill morphologies feeding on nectar at artificial flowers, we elucidate the short-timescale mechanics allowing their feeding apparatus to extract nectar rapidly. Contrary to expectations based on morphological similarities, we reveal that sunbirds use hitherto undescribed feeding mechanisms while drinking nectar. We contextualize these findings within a wide survey of the literature on avian nectar drinking biomechanics that we recently performed. Our findings show how convergent evolution driven by nectarivory as a life-style has led to remarkably similar feeding apparatus morphologies, however, these superficially similar structures are used in surprisingly distinct modes of acquiring the cornerstone of their diet. This study reinforces cautionary tales about inferences of function based purely on morphology, and the need to expand our investigations of drinking biomechanics, and its implications on behavioral choices, ecological determinants, and coevolutionary trends.

710 Yuhe Cui, Valeria Saro-Cortes, Brooke Flammang, Aimy Wissa, Jose Yañez-Salas

A Flying Fish Robotic Model Organism: Designing a biologically relevant caudal fin

Flying fish exhibit multi-medium locomotion in water and air. The caudal fin plays an important role in the movement by generating thrust during swimming and in transition to flight. In this talk, we present the characterization, design, and fabrication of a biologically relevant flying fish caudal fin. Previous research, by the co-authors, presented a mechanism for actuating a flying fish-inspired caudal fin based on the kinematic properties of the fish. However, the fin design was not biologically relevant as it lacked proper material and stiffness considerations. To increase the biological relevance of the fin design, a museum sample of Exocoetus volitans was studied and the biological properties of the caudal fin were acquired by analyzing CT scans of the sample. The flexural rigidity of the fin rays in the dorsal and ventral lobes was calculated based on the fin ray's geometric and material properties. A mechanical fin was then designed with a similar stiffness distribution. The fin model was then fabricated and evaluated experimentally to explore the influence of the stiffness of rays of the caudal fin on thrust generation. The caudal fin is used to test biological hypotheses about the role of the caudal fin in the flying fish locomotion and provides insight into the design of a bio-inspired unmanned underwater-aerial vehicles for marine surveying and exploration of the littoral zone.

837 Jackie Culotta, Marie Ervin, Brooke Vetter, Allen Mensinger

Integrating Sensory Physiology and Behavioral Conditioning to Influence Fish Movement

Invasive bighead carp (Hypophthalmichthys nobilis) cause ecological and economic damage in their introduced range of the Mississippi River Basin and continue to spread. One tool to protect the connected Laurentian Great Lakes is broadband acoustic deterrents which deter carp from passing through channels, although fish habituate to the stimulus after repeated playback. These nonphysical deterrents allow vessels to pass through locks while reducing carp migration. Carp also exhibit aversion behaviors to carbon dioxide, suggesting that combining these two stimuli into one deterrent system could reduce habituation and increase nonphysical barrier efficacy. In this study, bighead carp (N = 10) were conditioned to associate recorded boat noise (0.06 – 10 kHz, 155 dB re 1 ?Pa) with CO2 (∼35,000 ppm). Behavioral phonotaxis responses were compared between fish conditioned with CO2, or with air as a control (N = 10). Phonotaxis trials were conducted over seven days with sound played from one side of a two-choice shuttle tank, allowing fish to choose between a loud and quiet chamber. Carp conditioned with CO2 are hypothesized to exhibit more negative phonotaxis behaviors than fish trained with air, with shorter latency to move away from a sound deterrent, quicker velocities when exiting, and fewer returns to the sound chamber. Findings could be applied to increase nonphysical barrier effectiveness at lock gates along the Mississippi River and help protect the Laurentian Great Lakes from invasion.

1205 Patrick Cunningham, Mahita Shankar, Sarah Kienle

Variation in North American Canis skull and musculoskeletal morphology

In North America, wild Canis species—coyotes, gray wolves, and red wolves—serve important ecological roles as apex and mesopredators. Individuals are diverse, occupying habitats ranging from marine to mountainous, and exhibit high inter- and intraspecific variation in behavioral, ecological, and morphological traits. Here, our objectives are to compare craniofacial musculoskeletal adaptations across the genus and assess interspecific variation in skull morphology in the coyote, the most ubiquitous species. We perform detailed anatomical dissections and quantify skull shape using 3D geometric morphometrics. We describe 33 craniofacial muscles in the Canis genus and document interspecific variation in muscle number, size, and shape. For instance, coyotes and red wolves have a reduced, or absent, levator anguli oculi lateralis and retractor anguli oculi medialis compared to the domestic dog. Among coyotes, we showcase high intraspecific differences in skull size and shape. Southeastern coyotes have a skull shape more similar to western coyotes, characterized by smaller attachment areas for the temporalis and masseter; this differs from previous work where southeastern coyotes were thought to be an intermediate phenotype between western and northeastern coyotes. Overall, our preliminary results highlight high levels of morphological variation in wild Canis species, which likely contributes to the high phenotypic diversity exhibited by this clade. Our next steps are to compare how genetic and ecological traits further shape ecomorphological diversity in these widespread terrestrial.

1102 Michael Curran, Christopher Anderson

Locomotor kinematics and performance among syntopic but spatially divergent chameleon congeners

Chameleons have evolved numerous specializations associated with arboreality, including pincer-like feet and prehensile tails to help navigate narrow branches. Locomotion in chameleons has been well studied in the veiled chameleon (Chamaeleo calyptratus), but comparative studies, particularly among closely related species inhabiting different environments, have been limited. The Jackson's chameleon (Trioceros j. jacksonii) and high-casqued chameleon (Trioceros hoehnelii) are syntopic congeners inhabiting different parts of the same habitat. Both are arboreal, however T. j. jacksonii are found higher in the trees than T. hoehnelii, which are typically found on low shrubs and brushes. We performed locomotor trials with adult T. j. jacksonii and T. hoehnelii walking on meter long wooden dowels of different (0.125in, 0.25in, 0.5in, 0.75in) diameters. We quantified the morphology and kinematic and performance variables, including velocity, joint angles of forelimb and hindlimbs, stride length, stride frequency, and limb extension, from biplanar high-speed video of locomotor trials for each species. Our results provide insight into how differing arboreal distributions and degrees of arboreality impact locomotor patterns and performance on substrates of differing diameter. Further, these results help illustrate how closely related syntopic species are able to spatially separate themselves and fill different ecological niches within the same habitat.

1369 Jacob Daane, H. William Detrich, Matthew Harris, Andres Aguilar, Michael Sandel

Using 'replicate' radiations of perciform fishes to understand the genetic basis of trait evolution

Central to adaptative radiation is the origin of traits that facilitate access to novel niches, yet the genetic and developmental mechanisms underlying the appearance of these traits are poorly understood. Over the last 100 million years, perciform fishes have undergone multiple independent adaptive radiations in response to similar ecological and environmental opportunities. Can such 'replicate' radiations help us to disentangle lineage-specific signals from more universal mechanisms of trait evolution? Here, we discuss comparative genomics in two perciform radiations – the marine Antarctic notothenioids and the freshwater sculpins of Lake Baikal. For both radiations, the main axis of ecological diversification has been the water column, from shallow benthic ancestors into deep-water and pelagic lineages. The pelagic lineages of both radiations have evolved despite the absence of a swim bladder, the buoyancy organ of most fishes. Instead, both clades have evolved improved buoyancy through reduction in skeletal density and accumulation of corporeal lipids. Using whole genome and targeted sequencing approaches, we have assembled genomic data from 44 notothenioid species, 24 Baikal sculpins and several outgroup lineages, which enable us to track macroevolutionary trends and to discover patterns of protein coding and gene regulatory evolution. We will compare the two radiations and describe genetic signatures underlying buoyancy adaptations and their implications for understanding human diseases. Supported by US NSF 1955368 (JMD/HWD), 2001584 (MPH) and 1557147 (AA/MS).

168 Jason Dallas, Robin Warne

Early-life Manipulations of the Gut Microbiota in a Vertebrate Ectotherm Affect their Heat Tolerance

The gut microbiota has been tightly linked with numerous physiological functions of its host, but one function that has only recently begun receiving attention is how host thermal tolerance in ectothermic vertebrates is affected by changes in the gut microbiota. Here, we examined how early-life manipulations of the gut microbiota in larval amphibians influenced their critical thermal maximum (CTmax). We removed the bacterial community on the outside of wild-caught wood frog (Lithobates sylvaticus) egg masses via an antibiotic wash, and then either maintained eggs without a microbiota or inoculated eggs with the intestinal microbiota of the more thermally tolerant green frog (L. clamitans) or pond water containing wood frog egg masses. We tested the heat tolerance at two different acclimation temperatures (15° and 23°C) following a three-day acclimation period to examine if CTmax was influenced by a potential interaction between gut microbiota and environmental temperatures. Wood frog larvae that received no microbiota inoculation had the lowest CTmax among all treatments, and those that were inoculated with larval green frog microbiota had the highest CTmax. There was also a significant effect of short-term temperature acclimation on CTmax, highlighting the plasticity of this trait. Our results are the first to identify that cross-species microbiota transplantation increases thermal tolerance of an ectothermic vertebrate, further highlighting the importance of the microbiota.

966 Chris Dallmann, John Tuthill

Context-dependent modulation of leg proprioception in Drosophila

To effectively control arms and legs, motor circuits rely on feedback from proprioceptive mechanosensory neurons. However, how particular proprioceptive neurons contribute to control remains poorly understood, in part because little is known about their activity during behavior. Here, we address this question in Drosophila, focussing on proprioceptive neurons from the femoral chordotonal organ (FeCO), the largest proprioceptor in the fly leg. To study the activity of FeCO axons in walking and grooming flies, we developed a setup for two-photon calcium imaging of neural activity in the ventral nerve cord and automated markerless tracking of leg movements. To identify whether FeCO axons are modulated in a context-dependent manner, we compared our measurements with predictions from computational models that replicate proprioceptor responses to imposed leg movements. We found that position-tuned FeCO axons are active across behaviors as predicted, whereas movement-tuned FeCO axons are much less active during walking and grooming. Using circuit reconstruction in an electron microscopy volume of the Drosophila ventral nerve cord, we found that the FeCO subtypes receive distinct presynaptic input, suggesting that synaptic release from their axons may be independently modulated. We propose that the function of this modulation could be to suppress expected proprioceptive feedback caused by the fly's own movement to increase sensitivity to unexpected external perturbations.

1383 Hannah Daly, Jacob Lasala, Kristen Mazzarella, Theodora Pinou

Spatial diversity of barnacles on nesting turtles on the Gulf of Mexico

Marine turtles play a vital role in hosting the most abundant and diverse communities of epibionts, including parasites, mutualists, or commensals. Epibiotic communities can range in quantity and location over a sea turtle's body. This variation can be due to desiccation, food accessibility, and abrasion from contact with the turtle's flippers or other hard objects encountered during the turtle's lifetime. Previous studies have focused on the epibiotic distribution on sea turtles in the Pacific Ocean and in the Atlantic Ocean, but little is known about the distribution on sea turtles in the Gulf of Mexico. Barnacles are a common epibiont on sea turtles, and their relationship is neither beneficial nor determinative to the turtle. We hypothesized that the distribution of barnacles is uniform across the carapace, neck, and front flippers. Furthermore, we examined if there was a direct relationship between barnacle abundance and sea turtle size. We documented barnacle presence, abundance, and classification on 37 loggerheads (Caretta caretta) and 17 green sea turtles (Chelonia mydas). For loggerheads, the majority of barnacles cluster in the vertebral region of the carapace, including the neck/flippers; while the majority of barnacles on green sea turtles cluster on the neck/flippers. Patterns noted on loggerhead turtles may be due to preferential flow rates over the vertebral region. These patterns may also infer foraging activity for the two species.

1588 Tyler Daly, Christine Ramsay

Predicting the spread of an invasive marine fouling organism via physiological temperature tolerance

While invasion biology has become a prominent area in global change biology, relatively little is known about the early stages of an invasion and the initial spread in recipient communities. The geographic extent of any invasion is first determined by an abiotic filter and the physiological tolerances of the species itself. Tricellaria inopinata, a marine bryozoan which fouls natural and anthropogenic coastal structures, was first reported in the western Atlantic as an invader in 2010 in Massachusetts. To predict the spread of this invasion, we examined the temperature tolerances of T. inopinata in laboratory mesocosm experiments over a range of temperatures representative of habitats along the western Atlantic coast and paired our results with field surveys and previous reports of this invader. Our ex situ results show T. inopinata can withstand temperatures between 40C to 200C. This temperature tolerance allows it to potentially spread north and south of its initial invasion in southern New England, where it has been reported as far north as Casco Bay, ME. A newly established southern range was visually confirmed through field sampling in 2018, where T. inopinata was found as far south as Cape May, NJ. With this physiological tolerance data, we can begin to predict how far these invasive organisms can spread in non-native ranges, to prevent and prepare to mitigate the impacts of these non-native organisms.

742 Andrew Dang

Characterizing the molecular basis of red-green color vision in Heliconius butterflies

Red filtering pigments (RFPs) are responsible for red-green color vision in many butterfly species, such as some members of Heliconius. RFPs are able to extend the archetypal insect trichromatic color vision of UV-, blue-, and green-sensitive photoreceptors by redshifting a number of green-sensitive photoreceptors to red-sensitive ones. Despite knowing the existence and effects of RFPs, little is known about the evolutionary processes and molecular background of RFPs. Here we investigate RFPs using phylogenetic reconstruction, gene expression, immunohistochemistry, and confocal microscopy. Through phylogenetic reconstruction, we discovered a novel gene family found only in Lepidoptera. Using RNA-seq data and Kallisto RNA quantification, we determined a candidate gene from this family that expressed in butterfly head tissue (brain and eyes) of Heliconius species known to possess RFPs. We created an antibody for the gene and used immunohistochemistry to link the molecular expression of this protein to where RFPs express in Heliconius melpomene ommatidia. We will continue using microscopy techniques to further characterize the mRNA expression of this gene in H. melpomene via in situ hybridization. In addition, we will investigate the role other members of this gene family may have in butterfly vision. As this novel gene family is found only in Lepidoptera, red-green color vision in butterflies evolved independently from other insect groups and these findings are an important step in characterizing red-color vision evoution in insects.

1549 Lindsey Daniel, Warren Burggren

Genetics and Environment Regulate Zebrafish Embryo Division Rates and Subsequent Survival

Variation in the timing of emergence of developmental phenotypes is common, rather than the exception, both within and between species, potential obfuscating experimental developmental studies. Here we tracked early embryonic cell stages (fertilization - 64 cells) of two developing zebrafish strains - AB Wild Type and NHGRI-1 (low heterozygosity). O2 consumption ($\dot{M}$O2) was measured in each of these groups in both strains. We exposed slow, medium, and fast group embryos to anoxic, hypoxic, normoxic and hyperoxic E3 media. Developmental rates from 1cell-64 cells for the three groups were: slow = 75±; medium = 60±3, and fast = 38 ±3 (min/cleavage). Two-way ANOVA indicated a statistically significant difference in cell cleavage rate both within strains ($P = 0.019$) and between strains (P = < 0 .001). $\dot{M}$O2 increased with increasing cell numbers in all embryo groups, as expected. However, $\dot{M}$O2 at any given embryo cell number was also significantly affected by both division rate group and zebrafish strain (P = < 0 .001). The slow groups (both strains) had the lowest $\dot{M}$O2. Day 14 survival was 43%, 36% and 58% for fast, medium and slow groups, respectively (n = 6, P < 0 .004). Heart rates between groups and under four exposures are significantly different (P = < 0.001). In conclusion, alterations in rate of cell division in early development should be accounted for when designing developmental studies and in the interpretation of resultant data.

1338 Andy Danison, Oliver Demuth, Heinrich Mallison, Eric Snively

Atlas of Skeletal Muscle Morphology and Force-Generating Capabilities in Tyrannosaurus rex

Feeding and locomotor biomechanics of Tyrannosaurus rex have been copiously investigated. However, there has yet been no consolidated reconstruction of its skeletal muscles for calculating the forces behind full-body movements. Here we estimate muscle forces with a new full-body model derived from skeletal photogrammetry and regional muscle reconstructions. This restoration includes muscle groups not previously modeled in rigorous detail for Tyrannosaurus, including the back and abdominal musculature. Longitudinal midlines of muscle surfaces were measured and averaged as baseline dimensions for fiber lengths. Variable fiber lengths and modeled muscle volumes were used to calculate ranges of physiological-cross sectional area and isometric force. Estimated force for musculus adductor mandibulae externus superficialis was between 3,232 and 9,235 N, close to previous estimates of 4,574 N and 3,343 N. Similarly, the neck muscle m. complexus could exert a force between 3,731 N and 10,660 N, previously estimated at 7,776 N. The proximity of our estimates to previous works suggests that this model yields accurate results. The force of m. pectoralis was estimated at 3,856 to 11,017 N and that of m. latissimus dorsi was estimated at 3,768 to 10,767 N. These muscles have never been modeled before and agree with previous literature indicating that Tyrannosaurus had powerful forelimb musculature. In addition to isometric force calculations, we visually present a comprehensive anatomical atlas of musculature for adult Tyrannosaurus rex.

1732 Hannah Darcy, Philip Anderson

Consequences of the land-to-water transition on skull morphology and performance in salamanders

Land-to-water transitions are major evolutionary events and introduce new constraints to tetrapod morphology. Two North American salamander groups have recolonized aquatic habitats: mole salamanders (Ambystomatidae) and lungless salamanders (Spelerpini; Plethodontidae). We sought to understand the morphological and biomechanical consequences of this transition using a comparative approach. First, we tested the hypothesis that aquatic species have convergent skull morphologies, given the different developmental pathways followed by the two groups. Using 3D microCT scan data from online repositories and museum specimens, we performed a geometric morphometric analysis on skull shape and plotted a phylomorphospace. Second, we performed nanoindentation tests on cartilage and bone from dissected Ambystoma to determine if Young's modulus differed significantly between aquatic and terrestrial taxa, and to determine the difference in magnitude between cartilage and bone. Finally, we used the morphological and material property data as inputs for a biomechanical model. We tested the importance of skull shape in resisting forces simulating prey-capture by holding shape volume and material properties constant in a Finite Element Model. Our hypothesis was that shifting to suction feeding underwater relaxed constraints on bite force, resulting in skull shapes less suited to resisting forces. The results of these three studies can be used to build a performance landscape: an algorithmically generated plot predicting "ideal" areas of morphospace for a given function, which can suggest hypotheses for future experimental work.

1094 M. Zachary Darnell

Environmental and social context influences decisions associated with fiddler crab burrow retreats

Behavioral thermoregulation can ameliorate thermal stress but is costly. For species that court in a thermally stressful microhabitat, sexual selection via endurance rivalry favors individuals that are able and willing to endure harsh conditions in the courtship habitat, as retreats to a thermal refuge will reduce mating opportunities. The relative costs and benefits of refuge use vs. continued courtship in the face of thermal risk, which vary across abiotic and biotic contexts, determine the optimal behavioral strategy. We examined the social and abiotic factors driving behavioral decisions related to thermoregulatory retreat in several species of fiddler crabs (Decapoda: Ocypodidae). Male fiddler crabs perform a courtship display on the thermally stressful intertidal sediment surface. Time on the surface, and thus time available for display, is limited by high temperature; as temperature increases, surface time decreases. The strength of this environmental constraint varies across thermal regimes and is modulated by social context, including the presence and number of females (potential mates) and males (potential competitors). Our results demonstrate that behavioral decisions related to thermal retreat depend both on the abiotic conditions that influence the degree of thermal stress and on the social conditions that influence the reproductive prospects of the individual.

1645 Ashley Darst, Lindsey Kemmerling, Emiliee Snell-Rood

Variation across butterfly species in tolerance to heavy metal pollution

The Twin Cities metropolitan region, like many urban environments, has a history of heavy metal pollution from sources such as leaded gasoline and paint, in addition to continued inputs from industry and transportation. Urban metal pollution contributes to elevated childhood blood lead levels and less explored impacts on the urban ecosystem. The Minneapolis-St. Paul Long Term Ecological Research Program seeks to investigate these impacts and to understand why some organisms tolerate exposure to heavy metals better than others. We are testing the hypothesis that evolutionary histories with environmental toxins have pre-adapted certain organisms to anthropogenic pollutants, such as heavy metals. Butterflies are a good system to investigate this question because closely related species vary widely in host plant chemistry, and we can quantify their evolutionary history with mutagenic host plant defensives. We collected 20 species representing independent larval diet shifts from across a gradient of pollution in the Twin Cities, using wing size and egg counts as proxies for performance. We predict that in the face of metal exposure, species which are less tolerant to heavy metals will have relatively smaller wings and fewer mature eggs. We expect that butterfly species which evolved with more mutagenic host plant families (e.g., Pieris rapae) will show higher tolerance to anthropogenic heavy metal pollution than butterfly species that evolved with less mutagenic host plant families (e.g., Colias spp.).

1344 Stephanie Davidson, Gregory Kasriel, Davida Smyth

Use of S. aureus to study airflow and filtration in a collegiate environment

As SARS-CoV-2 continues to mutate and spread, it is imperative that the scientific community continue research on reducing exposure and transmission in the general public. The Centers for Disease Control and Prevention (CDC) have clear guidelines for vaccines, masks, social distancing, and personal hygiene. Unfortunately, the guidelines regarding air filtration are not as expounded upon. Staphylococcus Aureus behaves similarly to SARS-CoV-2 in the air and can be utilized as a safe means of implementing testing in real world applications, as roughly 30% of the population at any given time has S. aureus in their nasal passage. Undergraduates on the A&M San Antonio campus are using air sampling instrumentation to ultimately correlate time in location, occupancy of location, and activity in location to determine whether current air filtration systems are sufficiently removing S. aureus in the air, or whether updated systems and protocols are required. A protocol was developed, and baseline unoccupied data was collected, to begin the study. Environmental factors including humidity, temperature, and CO2 levels were collected as well as they provide valuable information pertaining to occupancy and S. aureus behavior in the air. This research is expected to highlight and stress the importance of looking at HEPA filtration systems and protocols, and possibly expanding on current CDC guidelines to include time, occupancy, and activity in tandem, and its application to SARS-CoV-2.

1809 Lance Davidson

Invasive or adaptive? Robust development in the face of extreme temperatures.

As a cold-blooded organism, the aquatic frog Xenopus laevis can maintain robust morphogenesis over a broad range of temperatures. Developmental rates from egg to tadpole follow the Q10 of simple chemical reactions increasing 7-fold from 14 to 30°C. How do developmental mechanics change over this range? and how are deformation rates accommodated without compromising the integrity of ultrasoft embryonic tissues? One possible solution to the last question may lie in a closed-loop feedback circuit we recently uncovered in the Xenopus epithelium that appears to function as a mechanical governor during the most rapid phases of gastrulation and neurulation. High heterogeneous strains in the embryonic epithelium drive release of extracellular ATP that activates contractility in the surrounding tissues to slow morphogenesis. The operation of such a mechanism in Xenopus may underlie its fitness as an invasive species, enabling these frogs to expand their populations at the margins of their native ranges and establish new non-indigenous colonies.

107 Jordan Davidson-Frazier, Courtney Miller, Rachel Menegaz

Mechanical Advantage of Jaw Muscles in a Mouse with Facial Shortening

The primary organic component of bone is type 1 collagen (Col1). A genetic disorder involving Col1 is osteogenesis imperfecta (OI), or brittle bone disease. Human patients with severe OI have increased skeletal fractures, weaker muscles, and craniofacial abnormalities, including midfacial shortening. This project aims to investigate the effects of Col1 mutations on the morphology of the skeletal attachment sites for the muscles of mastication.OIM mice with a mutation in the

COL1A2 gene (B6C3Fe a/a-Col1a2oim/oim, n = 8) were compared to their unaffected wild-type littermates (n = 11). All animals were micro-CT scanned at week 16 (skeletal maturity). 125 digital morphological landmarks, collected in 3D Slicer, were used to calculate bite force outlever and muscle inlever distances. The geomorph package (RStudio) was used to conduct geometric morphometric analyses. Mechanical advantage was calculated as inlever/outlever for the temporalis, superficial masseter, and anterior/posterior deep masseter. Results show considerable differences in muscle attachment morphology between OIM and WT mice ($p = 0.042$). When compared to WT mice, OIM mice have considerably lower mechanical advantage in the superficial and posterior deep masseters ($p>0.001$). These findings suggest that Col1 mutations significantly alter muscle-bone structure and performance. Nevertheless, OIM mice still produce bite forces capable of causing facial fractures. More work is needed to understand how decreasing muscle mechanical advtantage affects feeding performance in OIM mice.

528 Sarah Davies, Maria Ingersoll, Niharika Desai, Kate Mansfield, Phillip Cleves, Hanny Rivera, Leah Williams, Rachel Wright, Thomas Gilmore

Interactions between symbiosis and innate immunity in cnidarians

Many cnidarians, including reef-building corals, establish symbiotic relationships with photosynthetic algae in the family Symbiodiniaceae. These partnerships are sensitive to temperature anomalies, which cause symbiont loss and increased mortality. Previous studies have implicated host innate immunity as playing a role in the maintenance of cnidarian-algal symbiosis and it has been shown that establishing symbiosis with different genera of algal symbionts modulates thermal tolerance. Over the last several years our group has further investigated the interactions between symbiotic state, algal symbiont type, innate immunity and thermal tolerance across different life history stages in the anemone Exaiptasia pallida (Aiptasia) and corals Orbicella faveolata, Astrangia poculata, and Oculina arbuscula. Using experimental, molecular genetic, and transcriptomic approaches, our results demonstrate that host innate immunity is modulated by symbiotic state in Aiptasia larvae and adults, adult O. arbuscula, and O. faveolata recruits. We also show that establishing symbiosis- especially with specific algal strains- modulates host innate immunity, and these specific host-algal pairings may result in differences in thermal tolerance and responses to microbial challenge in the lab. Overall, this presentation will integrate results from several studies that provide further support for the role of host immunity in the maintenance of cnidarian-Symbiodiniaceae partnerships and shed light on how different symbiont genera can modulate this immunity and ultimately influence host resistance to pathogens and bleaching.

374 Johnny Davila-Sandoval, Allan Carrillo-Baltodano, Néva Meyer

VNC tweaks: ventral nerve cord specification in the annelid Capitella teleta

Development of a central nervous system (CNS) is tightly linked with dorsal-ventral (D-V) axis formation in vertebrates and insects, but evidence for spiralian taxa remains unknown. The CNS in Capitella teleta (Spiralia: Annelida) includes a ventral nerve cord (VNC) formed by the animal micromere 2d at the 16-cell stage. Previous studies determined that 2d can form neural tissue in isolation, but not in the presence of other animal micromeres. To provide insight into nervous system evolution, we studied VNC and D-V axis specification in C. teleta via blastomere isolations on early-stage embryos. We examined the pan-neuronal marker elav1 in mid-stage larvae after blastomere isolation and found that one vegetal macromere at the 16-cell stage (2A, 2B, 2C or 2D) was sufficient to rescue the formation of the VNC. However, VNC was formed when vegetal macromeres were removed at the 32-cell stage, suggesting that the pro-neural signal from vegetal macromeres has already occurred by that stage. We also examined the markers foxA (foregut), pax3/7 (ventrolateral ectoderm) and gataB1 (endoderm) after removal of the macromeres at the 16-cell stage. foxA maintained its ventral expression domain, pax3/7 expanded throughout the trunk and gataB1 was absent, suggesting the presence of a D-V axis, expansion of non-neural ectoderm and loss of endoderm. For future directions, we will use transcriptomics to identify the signaling pathways underlying VNC specification in C. teleta.

449 Allison Davis, Michael Ryan

Cooperation in an asexual-sexual fish system

Gynogenetic species are asexual species that rely on sperm of closely related sexual species to develop embryos, despite no transfer of sperm DNA. This poses a perplexing problem for gynogenetic species: they must compete for resources with closely related sexual species but cannot outcompete them without causing their own demise. Such is the case for the Amazon molly (Poecilia formosa). However, unlike some gynogenetic species that experience less competition due to niche partitioning, the Amazon molly appears to occupy a nearly identical niche to their sexual counterpart, the sailfin molly (P. latipinna). Here, we explore whether behavioral differences in cooperation play a role in maintaining the Amazon-sailfin system; specifically, cooperation between two or more individuals that will decrease the cost of predation on any one individual. As kin theory suggests, cooperation increases with relatedness; given their clonal reproduction asexual individuals in the population are expected on average to be more closely related than are individual sailfin mollies. By performing paired predator inspections, we compared the level of cooperation among both species by quantifying the proximity to the predator and the number of cooperative swimming bouts. In addition, we assayed boldness and neophobia to determine if predator inspection was driven by risk-taking or exploratory behavior rather than cooperation. Understanding the dynamics of cooperation may enhance our understanding of how this asexual-sexual system is maintained.

443 Xavier Dawkins, Matthew Fuxjager, Doris Preninger

Camouflage in juvenile Wallace tree frogs: the disguise of bird droppings

Adaptations for crypsis and camouflage depend on an organism's interactions with the natural environment, which can change ontogenetically. Wallace tree frogs (Rhacophorus nigropalmatus) are normally bright green, but during their juvenile stage, individuals are bright red with white spots. This coloration is thought to be a mimicry strategy that helps frogs appear as bird droppings. To test this idea, we created different paraffin wax frog models—bright red with white spots, bright red without white spots, green, and unpainted—and placed them in equal numbers within a 1,000 m2 rainforest house at the Vienna Zoo. This environment closely resembles the Bornean rainforest, in which the Wallace tree frog is endemic. It includes several free-living avian predators of the frog, and other free-living species of bats, rodents, and amphibians. Each morning, the models were collected, checked for attack marks from avian predators, and replaced with new models. We ran the experiment for 10 days and observed a hit rate of 15.47%. The odds of attack were significantly greater for red and green frog models and exceptionally low for red models with white dots. The data therefore supports the hypothesis that being bright red with white dots likely acts as a camouflage strategy by disguising frogs as conspicuous, inanimate parts of the environment.

1531 Lainy Day, Derrick Thornton

Relative Sexual Size Dimorphism, Endocranial Volume, and Display in Manakins (Aves, Pipridae.

For males of 13 manakin species, we found acrobatic display complexity predicts increases in brain and body mass, and tarsus length. Others have shown that aerial display increases when male body mass is low relative to females. Male body and brain mass does not predict aerial display for our 13 species studied (8/22 same as aerial study). To investigate whether studies differed due to species used or due to a focus on males alone vs. dimorphism, we first estimated endocranial volume using museum specimens; which could allow us to relate brain size to suites of display elements (e.g. aerial, high-speed, forceful) in both sexes of all (∼56) manakin species. Thus far, we have evaluated two methods in 9 species (7/9 both sexes). Estimates are highly correlated with tarsus length and body mass, suggesting accuracy. Endocranial estimates were negativly correlated with aerial and total display elements for males and females. We are now calculating relative body size sexual dimorphism across species to compare with previous studies, further evaluate endocranial estimation methods, and ascertain how sexual selection differently impacts brain and body size in manakin sexes.

854 Ornela De-Gasperin, Pierre Blacher, Guglielmo Grasso, Solenn Sarton-Loheac, Roxane Allemann, Michel Chapuisat

Cryptic mutation load in a supergene controlling social organization in ants

Supergenes are clusters of linked loci that control compound phenotypes, such as social organization in ants. Explaining their long-term maintenance is challenging, particularly when the mutant supergene haplotype causes selfish gene drive and might thus go to fixation. In many supergenes, the driven or positively selected mutant haplotype accumulated deleterious mutations and became lethal in homozygotes, which contributes to stabilize the genetic polymorphism. In the Alpine silver ant, Formica selysi, a large social supergene with two haplotypes, M and P, controls colony social organization. Single-queen colonies contain only MM females, while MP and PP are frequent in multi-queen colonies. The P haplotype associated with multi-queen colonies distorts transmission, and population genetics models showed that a stable social polymorphism can be maintained under partial assortative mating by social form, provided PP queens have low fitness. With a combination of field and laboratory experiments, we show that the P haplotype carries a severe load of deleterious mutations. This load decreases the survival, fertility, and fecundity of PP queens, and causes early death of most PP workers. Our results provide empirical evidence that deleterious mutations have accumulated in the P haplotype, despite recombination in viable PP homozygotes. We discuss how this cryptic load contributes to stabilize this ancient polymorphism.

279 Jordan De-Padova, Doris Preninger, Nigel Anderson, Matthew Fuxjager

Behavioral ventilation in the aquatic Lake Titicaca frog

Respiration is key to animal life, with most species evolving adaptations that optimize respiratory performance in their environment. We study one such adaptation in the Lake Titicaca frog (Telmatobius culeus), an endangered fully aquatic frog endemic to the high-altitude Andean lake from which the species gets its name. This frog is unique among amphibians due to its ability to respire through its wrinkly skin. Anecdotal accounts suggest that, when submerged in deoxygenated water, the Lake Titicaca frog performs "bobbing" behavior, during which it propels its body off of the substrate using its legs and floats back down in an effort to ventilate its skin. To test this idea, we submerged adult male and female Lake Titicaca frogs in aquaria with either dissolved oxygen content at atmospheric levels or dissolved oxygen content at half the atmospheric level. Each frog was submerged for 20 minutes, and both the frequency and duration of its locomotory behavior were recorded. Compared to control frogs, we found that individuals in low oxygen environments perform more "bobbing" behavior, which likely increases water flow on their skin to enhance cutaneous respiration. Other measures of behavior, including overall activity, were indistinguishable between groups. These findings suggest that one respiratory adaptation may be behavior itself, such that individuals execute a series of complex behavioral programs to help enhance ventilation at low environmental oxygen levels.

1394 Eve Dean, Mia Poulsen, Elijah Wostl, Darren Proppe, Matt Steffenson

Comparing arthropod communities across seasonal temperature variation

Arthropods are a highly diverse group of organisms that perform essential ecosystem roles, including pollination and decomposition. However, arthropod lifecycles and distribution are highly dependent on conditions like temperature and humidity, which vary seasonally and spatially. Any changes in phenology or distribution caused by climate change could have cascading effects on the ecosystem as a result of changes in populations or trophic mismatch. The goal of this project was to determine how species richness and diversity varies seasonally across three representative sites at Wild Basin Wilderness Preserve to determine how temperature and climate change may affect species distributions. Arthropod samples were collected from three sites across Wild Basin, a wilderness preserve in the Texas Hill Country. Invertebrate samples were collected using malaise and pitfall traps at a ridge, midslope, and riparian site across the preserve in both October and December to model temperature and humidity effects of seasonality on arthropod distribution. Temperature and humidity values were captured continuously at each site using iButtons. Preserved samples were identified to the family level. Data analysis is ongoing, but preliminary data indicate that arthropod abundance and richness are higher in warmer seasons, with most significant declines in Lepidoptera and Hymenoptera.

866 Ross DeAngelis, Hans Hofmann

Probing the motivational state of parents by integrating snRNA-seq and spatial transcriptomics

The social relationships formed between individuals, and the dynamics of those interactions, can have remarkable effects on the brain. For example, the onset of parenthood dramatically changes how individuals behave in diverse social contexts due to the strong motivation of maximizing offspring survival. Here, we ask how constitutive and dynamic neural components generate and maintain the motivational state of being a parent compared to non-parental individuals. More specifically, to what extent do behaviors with shared motivational states (e.g., offspring defense vs. offspring provisioning) rely on shared cell type specific activity patterns? The monogamous convict cichlid (Amatitlania nigrofasciata) is an ideal model system to examine these questions. Males and females of this species cooperate as they jointly provision their offspring and vigorously defend them against predators. We first show that the behavioral profile of a pair depends on a combination of offspring state and environmental conditions. Next, using immunohistochemistry, we examine the activity of dopaminergic neurons in key nodes of the social decision-making network. We then integrate single nuclei RNA-sequencing with spatial transcriptomics to identify type and location of behaviorally responsive cells throughout the fore- and midbrain. Our results show how a multifaceted motivational social state such as parenting relies on the integration of molecules, cells, and brain regions. Overall, this work broadens our understanding of how motivational states are generated and maintained within the brain.

1815 Melissa DeBiasse, Claire Olson, Alyssa Pfitzer-Price, Lauren Samaniego, Morgan Kelly, Amber Stubler

The impacts of biotic and abiotic stressors on sponge erosion of oyster reefs

Oyster reefs, one of the most important economic and ecological habitats in the U.S., have suffered major losses due to declining water quality, overharvesting, and disease. To better understand and protect these ecosystems, we investigate the breakdown (erosion) processes occurring in areas where oysters are found. Erosion facilitated by living organisms (called bioerosion), such as boring sponges, is problematic for oyster aquaculture and restoration efforts, yet little is known about the processes that influence the rates of sponge bioerosion on oyster reefs. To address this knowledge gap, we are evaluating two factors thought to affect sponge bioerosion rates: the presence of nudibranchs that prey on boring sponges and ocean acidification. Our methods include manipulative experiments and the collection of sequence data to 1) determine the ways that Atlantic and Pacific boring sponge species respond to predators under different ocean acidification conditions, and 2) compare the short- and long-term effects of predator presence and acidification on sponge bioerosion rates of oyster reefs. The experimental data we collect will be used to model bioerosion on simulated oyster reefs to better understand how these two factors influence overall oyster reef carbonate changes. This work will improve management practices for controlling sponge bioerosion for oyster growers and restoration programs, and our understanding of how biotic and abiotic stressors act individually and together to alter sponge bioerosion behavior.

1800 Dina Dechmann, Lara Keicher

Energy saving strategies in common noctule bats

Torpor is one of the most efficient energy saving strategies and often associated with cold temperatures. In the last decades more diverse and flexible forms of torpor have been described. For example, tropical bat species can reduced their metabolism and heart rate at high ambient and body temperatures. We investigated whether noctule bats (Nyctalus noctula) from temperate Europe also use torpor at high ambient and body temperatures, and how and when reproductive female and male noctule bats use torpor. We measured metabolic rate, heart rate, and skin temperature at a range of ambient temperatures in the lab and found that, similar to tropical bat species, noctule bats can have a reduced metabolism and heart rate, while body temperature and ambient temperatures are high, irrespective of reproductive status. Using heart rate telemetry, we then monitored torpor use of free-ranging noctule bats and found laboratory and natural behavior to differ. By implementing both approaches we reveal complex torpor use strategies of noctule bats and identify possible limitations of eco-physiological laboratory studies. We suggest that the capability to flexibly save energy across a range of ambient temperatures within and between reproductive states may be an important ability of temperate zone bats and propose that that heart rate telemetry opens new possibilities to investigate more complex energy saving strategies also in other temperate-zone heterotherms.

1178 Aimee Deconinck, Olivia Madalone, Christopher Willett

Take My Breath Away: Mitonuclear mismatch disrupts hypoxia tolerance in Tigriopus californicus

During low oxygen conditions, the nuclear genome must coordinate with the mitochondria to avoid redox imbalance. Consequently, mismatch between the nuclear and mitochondrial genomes should decrease coordination of the response to hypoxia which could result in lower tolerance for the whole organism. We explored this hypothesis with first generation (F1) hybrids of Tigriopus californicus. T. californicus is an intertidal copepod with a broad geographic distribution and high mitochondrial diversity. We generated reciprocal crosses from four populations with distinct mitochondrial haplotypes and measured their survival after 20 hours of anoxia and 10 hours of reoxygenation. We then amplified population-specific regions of the mitochondrial Cyt-B gene to verify the identity of the mitochondrial haplotype present in the individuals. Our findings support the hypothesis that mitonuclear incompatibilities reduce the ability of the whole organism to tolerate hypoxia.

598 Noah DeFino, Goggy Davidowitz

Crop-emptying rate and nectar resource allocation of a nectivorous pollinator

Moth and butterfly (Lepidoptera) adults store consumed floral nectar in an organ called the crop. Access to these nutrients is therefore delayed until crop contents are emptied into the gut and is then allocated to functions such as flight, maintenance, and reproduction. Crop-emptying rate could influence future foraging behavior, affecting Lepidoptera nutrient acquisition and plant pollination, as it does in flies and hummingbirds. Moths are important pollinators for wild flowers as well as various crops. In this study, the crop-emptying rate of a single nectar meal and the timing of its allocation to flight muscle and fat body was determined for the hawkmoth Manduca sexta. Manduca sexta are the primary pollinator of Datura wrightii, a plant with historical and cultural importance to indigenous nations in SW United States. We found a portion of nectar completely bypasses the crop and most moths empty their crops by 24 hours after consumption while at rest. Both males and females preferentially allocate nectar sugars to fat body over flight muscles while at rest. Peak assimilation of nectar sugars in the fat body occurs by one hour after feeding in females and 36 hours after feeding in males.

1759 Kaylah Del-Simone, Skye Cameron, Christofer Clemente, Joshua Gaschk, Taylor Dick, Robbie Wilson

Lifestyles of the small and reckless: Using accelerometers to assess behaviour of threatened animals

Australia is a global leader in mammal extinctions. This is primarily due to the impact of invasive predators. Discovering how animals behave in their environment could provide insights into the mechanisms driving their vulnerability, but continuous observations of most animals in the wild is difficult or even impossible. In this study, we used accelerometers to continuously monitor behaviour for two populations of northern brown bandicoot (Isoodon macrourus). This species is a part of the Peramelidae family, a group of small marsupials vulnerable to introduced predators. First, we trained a machine learning algorithm using footage from individuals in a semi-natural setting to accurately categorise 8 different behaviours, including foraging, vigilance, digging, walking, and bounding in the wild. We then deployed accelerometers on 20 individuals in the wild to record activity. Based on 2033 hours of data, we were able to determine temporal activity patterns, energy expenditure and wild locomotor speeds. Using overall dynamic body acceleration as a proxy for energy expenditure, we found that while activity budgets were different, energy expenditure similar between populations. Bandicoots were also found to shift temporal activity, with peak activity times between populations being significantly different (7pm-3am versus 2pm-12am). Our data can be used to assess how varying degrees of habitat variation, urbanization, or predation risk, can drive the activity of certain species, especially those that are vulnerable to extinction.

1763 Kaylah Del-Simone, Rebecca Wheatley, Theordore Pavlic, Robbie Wilson

Performance ecology & conservation: Modelling the effect of habitat change on predator-prey dynamics

Restorative thinning is a practice often used in densely regrown habitat where succession has been halted by an overabundance of young trees. These stands often have low complexity, little understory development, smaller tree height and diameter. By decreasing the stem density, intraspecific competition is reduced and stand development is accelerated. While the effects of thinning on forest structure are well understood, the effects on forest fauna are less known, especially within Australia. The removal of cover in the short term, can increase small mammal detectability and reduce refugia quantity, making them more susceptible to predation. We addressed this question using an agent-based model. With these models, we were able to simulate mobile agents interacting with each other and their environment thousands of times. To assess the survivability of a small mammal densely regrown and thinned habitats, we used the northern brown bandicoot (Isoodon macrourus) as a study species as this small marsupial is vulnerable to predation. Predator agents were represented by either a cat (Felis catus), fox (Vulpes vulpes) or dog (Canis familiaris). Our model predicted overall survivability of the bandicoot agent was highest in remnant habitats, with dense regrowth having the least. Bandicoot agents parametrized with higher agility had the greatest chance of escape in all scenarios and survivability was further increased with the introduction of artificial refugia, especially in thinned environments.

875 Pablo Delclos, Richard Meisel

Regulation of an odorant binding protein by a proto-Y chromosome affects male house fly courtship

Y chromosomes have male-limited inheritance, which is predicted to favor the fixation of male-beneficial alleles. Consistent with this, previously characterized Y chromosomes harbor genes necessary for male-specific traits, but determining how Y-linked genes affect specific male phenotypes has been a challenge. In the house fly, Musca domestica, two young Y chromosomes (YM and IIIM) segregate as stable polymorphisms in natural populations, and they differentially affect multiple traits, including male courtship performance. To identify the genetic mechanism underlying this effect, we performed a meta-analysis of RNA-seq data and identified genes encoding odorant binding proteins (in the Obp56h family) as differentially expressed between males carrying the IIIM and YM chromosomes. Differences in copulation latency between YM and IIIM house fly males is consistent with differences in Obp56h expression and copulation latency previously observed in Drosophila melanogaster. However, Obp56h is not found on either the YM or IIIM chromosomes, suggesting that it is regulated in trans by one of the house fly sex chromosomes. Using a network analysis and allele-specific expression measurements, we found multiple genes on the house fly IIIM chromosome that could serve as trans inhibitors of Obp56h expression. We also find evidence that this regulatory architecture controlling copulation latency is conserved between house fly and D. melanogaster.

370 Sage DeLong, Lauren Cirino, Rafael Rodriguez

Vibrational signals in mating and fighting behaviors in the red milkweed beetle

Vibrational communication is ecologically important to insects. Substrate-borne vibrations are commonly used by herbivorous insects to communicate species-specific information. Here, we describe the substrate-borne vibrational signals associated withmating and fighting behaviors of the herbivorous red milkweed beetle (Tetraopes tetraphthalmus). Males dorsally mount females and begin copulation in less than five minutes. Prior to and during copulation, males can produce vibrational signals with their abdomens that females likely perceive as contact courtship. Males also engage in intraspecific competition for females and can use vibrations in their fighting repertoire. These vibrations are either airborne squeaks or substrate-borne vibrations that intensify as fighting behavior intensifies. We discuss the function and importance of these vibrational behaviors in a social context.

1358 Rémy Delplanche, Ruowen Tu, Henry Sodano, Daniel Inman, Bret Tobalske

Strain and vibration of selected wing feathers during different flight modes in doves

Real-world airflow is complex, and any flying organism or miniature autonomous vehicle (MAV) must be able to accommodate perturbations. Providing sensory feedback for control is a major goal of new MAV design. Deformations of flexible feathers in avian flight may mitigate perturbations due to turbulence. To test whether feather sensors may serve in feedback control and gust mitigation in gliding birds, we printed 3D feather sensors, modeled after the 9th primary (P9) and 3rd secondary (S3) of the Barbary Dove (Streptopelia risoria) and instrumented with strain gauges and piezoelectric transducers to quantify the deformations and vibrations. We imped the sensors into the feather shafts of dried, spread wings and live doves. We obtained measures for glide polars including vertical gust perturbation and during different modes of flight. P9 strain tracked lift until the wing experienced stall, after which it tracked the total pressure. S3 strain did not correlate with the total or component wing forces. The piezoelectric transducers revealed vibration intensity was least at low angles of attack (0 - 20 degrees) and elevated at negative angles and higher positive angles of attack. Our results show that 3D printed sensors can potentially provide information on aerodynamic forces to central processors. Additionally, our results demonstrate functional differences between primary and secondary feathers in the avian wing. NSF EFRI 1935216.

822 Joe DeMarchi, Mark Wilber

Do Bd infected green frogs (R. clamitans) act as competent hosts?

A fundamental goal of disease ecology is to understand when, where, and who drives pathogen persistence. Within communities not all species are equally susceptible to pathogen infection. Hosts have species-specific responses to infection that range from resistant to highly susceptible suggesting that certain hosts competence can disproportionately affect pathogen spread and disease transmission. However, very little is known about how competency relates to host identity through mechanisms such as susceptibility and pathogen shedding rates in the field or lab. Here we investigated the competency of a highly abundant and wide-ranging adult amphibian species, Rana clamitans infected with a local strain of Batrachochytrium dendrobatidis. We performed dose-dependent challenge assays utilizing four different zoospore doses (1×104, 1×105, 1×106, 1×107) and estimated host susceptibility and shedding rates given infection. Given low observed Bd prevalence and intensity in the field, we hypothesized that R. clamitans adults would be relatively incompetent hosts. However, we found that despite low infection intensity and a relatively weak Bd strain, 25% of individuals maintained infection longer than 40 days. This result emphasizes that the relationship between the duration of infection and infection intensity is critical for quantifying host competency.

1372 James deMayo, Joseph Tucker, Jenna Tomkinson, Lahari Gadey, Phillip Freda, Jantina Toxopeus, Gregory Ragland

Life stage and transcriptional dynamics affect differential gene expression during thermal stress

Climate change is increasing the mean and variability of environmental temperature across seasons. In metazoans, environmental variation within a life cycle can impose fluctuating selection across developmental stages creating development X environment interactions on phenotypes. We evaluated transcriptional plasticity in response to thermal (cold) stress across life stages (larvae and adult) using the model fruit fly, Drosophila melanogaster. We measured differential gene expression at temperatures above, equal to, and below the critical thermal minimum (CTmin) of D. melanogaster to understand how transcriptional responses vary across this ecologically important threshold. While whole adults exhibit muted differential expression patterns across the thermal gradient, whole larvae differentially express large numbers of genes even below CTmin. Overall, larvae express mostly distinct genes in a different time course compared to adults, even when expression was measured in the same (gut) tissue. Thus, responses to cold environments appear to be highly independent at a physiological level, corroborating previous observations that they are decoupled at the genetic level. These development X environment interactions illustrate the importance of ecophysiological models incorporating variation across the life cycle. We will also discuss current work evaluating the role of the thermal sensitivity of transcription itself in the plasticity of gene expression by isolating nascent transcripts. Understanding how transcription behaves with changing temperatures is crucial for predicting the physiological response mechanisms of metazoans to changing climate.

327 Alp Demirel, Ismail Uyanik

Dynamic sensory reweighting in weakly electric fish in relation to sensory salience

Animals routinely integrate multisensory information while controlling their movement. This is accomplished by integrating information from multiple sensory modalities within the CNS. To improve sensory performance, animals dynamically tune the contributions of each sensory modality. Our goal is to reveal how the weights associated with different sensory organs change in relation to salience of the sensory information. We built an experimental setup to separately identify the weights assigned to visual and electrosensory information by weakly electric fish, Eigenmannia virescens and Apteronotus albifrons, during their refuge tracking behavior. Specifically, we built a transparent refuge attached to a linear actuator. In the dark, this refuge is invisible to the fish, but its movements stimulate electrosensory receptors of the fish. We mounted a projector on the linear actuator to project a pattern of vertical stripes onto the refuge, generating visual cues. The refuge is sufficiently translucent so that the fish can see projected stripes from inside the refuge. The key feature is that visual and electrosensory cues can be controlled independently. We modified the sensory salience by changing brightness and sharpness of the projected light stripes and length of the refuge. We conducted experiments with $N = 6$ fish under different sensory conditions and identified the associated sensory weights. We currently investigate models that capture the dynamics of sensory reweighting in relation to sensory salience.

402 Ryleigh Dennis, Andrew Anderson, Suzy Renn

Sex Role Plasticity and Aggression in the Cichlid Fish Julidochromis marlieri

Sexually dimorphic, or sex-baised behavior is often linked to gonadal sex; however, the ecological or social environment can induce behavioral plasticity. In pair bonded organisms, one individual often specializes in territory defense while the other specializes in nest care. Julidochromis marlieri are African cichlid fish which display behavioral plasticity in sex-biased behaviors; in the wild, J. marlieri form pairs in which the female is larger and more aggressive than the male, but in laboratories, "reversed" pairs can be formed in which the male is relatively larger. Under these conditions, sex-biased behaviors are reversed. We investigated how the social environment may influence behavior by observing how the sex of a conspecific intruder affects the behavior of this mating system. Conspecific intruders were introduced to both male-larger and female-larger pair types and behaviors were recorded and analyzed. We examined behavioral responses to three factors and their interactions: sex and relative size of the subject and the sex of the intruder. Our findings confirm larger females are more aggressive towards intruders than smaller females are. Male-larger pairs are more sensitive to the sex of the intruder than female-larger pairs, with both males and females in male-larger pairs showing more aggression towards male intruders. Our results support the role of social environment, including the sex of conspecific intruders, as a contributing factor in the expression of sex-biased parental behavior.

1122 Kathryn Denny, Steve Huskey, Christopher Anderson, Michael Smith

Communication via biotremors in the veiled chameleon (Chamaeleo calyptratus)

While substrate-borne vibrations are utilized by different reptile species, true conspecific communication via biotremors has not yet been demonstrated in lizards We tested chameleon behavioral sensitivity to vibrations by placing them on a dowel attached to a shaker, emitting vibrations of 25, 50, 150, 300, and 600 Hz and then measured their changes in locomotory velocity before and after the stimulus. We then paired chameleons in various social contexts [anthropogenic disturbance (human disruption of animal); dominance (male-male; female-female C. calyptratus); courtship (male-female C. calyptratus); heterospecific (C. calyptratus + C. gracilis); and predator-prey (adult + juvenile C. calyptratus)] and used simultaneous video and accelerometers to record their behavior and biotremors. This study demonstrated that C. calyptratus is sensitive to and produce biotremors in a context-dependent manner which are elicited by visual and/or physical contact with another conspecific or heterospecific. Biotremors were produced in anthropogenic disturbance, conspecific dominance, and courtship contexts. Overall, two classes of biotremors were identified, “hoots” and “rumbles”, which differed significantly in mean ($\pm$ SE) dominant frequency (142.1 ± 7.0 and 110.7 ± 8.5 Hz, respectively). Juvenile chameleons two months of age were able to produce biotremors, suggesting this behavior may serve a wide range of ecological functions throughout ontogeny. Overall, the data suggest that the veiled chameleon utilizes substrate-borne vibrational communication during conspecific interactions.

959 Randi Depp, Rachel Oslon

Sex Differences in Cross-sectional Geometry of Adult Human Ribs

Despite advancements in safety features in motor vehicles, rib fractures remain one of the leading injuries in motor vehicle accidents (MVAs). Thoracic injuries sustained during MVAs disproportionately affect females and the disparity is even greater in older age cohorts. Models generated for injury biomechanics research often simplify the cross-sectional geometry of ribs, which affects the accuracy of the model predictions for rib fractures. Additional research is needed to better capture morphological variation in human ribs between sexes in order to generate more realistic trauma models and refine the current understanding of the effect of cross-sectional parameters on rib stiffness. Whole body computed tomography scans from 20 deceased adult humans (10 males, 10 females), ages 60 and over were obtained. Right ribs 1-10 from each individual were segmented and transverse sections perpendicular to the rib surface at 10% intervals along the rib length were exported. Cortical thickness was quantified using a specialized algorithm to improve accuracy. Other measures of cross-sectional geometry were also quantified, including cortical and endosteal areas, and area moment of inertia in the y- and z-axes. All measures were normalized by rib span length to account for scale differences. These results will demonstrate differences in cross-sectional geometry between males and females of an older age cohort. Such findings are vital to improving sex- and age-specific trauma models.

1673 Mikayla DeSaye, Alyssa Stark, Stephen Yanoviak

Blowin' in the Wind: The Effect of Wind on Ant Behavior, Locomotion, and Adhesion

Many organisms rely on adhesive structures to maintain contact with substrates in their environment. Ants rely on adhesive tarsal pads, curved tarsal claws, and a multicomponent secretion to cling to diverse substrates they encounter while foraging. Several environmental factors (e.g., rain, temperature) can impede ant adhesive performance, which may result in poor locomotor performance, abnormal behavior, and even falling. One environmental factor that has not been well studied is wind. Previous work shows that wind slows small organisms like ants and can cause them to be blown off their trail, however, these studies did not test ants actively using an adhesive system. The primary goal of our work is to test for an effect of wind on running speed and behavior of large ants (i.e., above surface-level boundary layer) when challenged to run on low and high adhesion substrates (i.e., glass and sandpaper, respectively). We exposed C. pennsylvanicus workers to a range of experimental wind from an air compressor (approximate velocity 5-22 mph). All ants exhibited conspicuous changes in walking behavior (e.g., crouching), decreased running speed, and adhesive failure (e.g., falling) on a low adhesive surface. These findings will improve our understanding of how common environmental features such as wind impact the behavior, performance, and survivability of small, wingless, cursorial organisms, like ants, who are critical ecosystem engineers.

530 Sarah Detmering, Robyn Crook, Jonathan Shia, Skyler Deutsch

Identifying Analgesics for Hummingbird Bobtail Squid (Euprymna berryi) to Improve Cephalopod Welfare

Cephalopods' remarkable intelligence, unique behavior, and complex neurobiology have made them one of the most promising organismal models for research. But this increasing demand from research labs as well as zoos and aquariums can only be met ethically if proper welfare practices can be followed. These practices include the use of effective analgesics. Although the effects of analgesics in vertebrates are well understood, there is currently no research on the efficacy of common veterinary analgesics on cephalopods. Here we show how different analgesic classes affect hummingbird bobtail squid (Euprymna berryi) during a series of behavioral and peripheral nervous system assays. In behavioral assays, acetaminophen and aspirin had no effect on nociceptive thresholds, however, buprenorphine and ketorolac showed promising results. In tests of peripheral nervous system excitability, buprenorphine was the only analgesic producing slight decreases in the evoked firing of action potentials. Our preliminary results indicate that effective analgesia for Euprymna berryi may be affected via drug combinations of opioids and NSAIDs. Ongoing studies are investigating different dosages of drugs and drug combinations.

1530 Michael Deutsch, David Adams, Lorin Neuman-Lee, Matthew Gifford

Abiotic and biotic stressors influence physiological and life history traits in a lizard

In response to energetic challenges, activation of the hypothalamic-pituitary-adrenal (HPA) axis elicits the secretion of glucocorticoids, potentially driving alterations of growth, reproductive investment, immune function, thermoregulation, and behavior. Repeated activation of the HPA axis is hypothesized to lead to measurable changes in life history traits due to the continual reallocation of energetic reserves. Yet, physiological mechanisms driving life history variation in response to environmental stressors are often conflicting or unresolved. To address both abiotic (thermal environment) and biotic stressors (predator presence) influencing life history and organismal physiology, we sampled Sceloporus consobrinus populations inhabiting forest and xeric glade habitat, allopatric and sympatric to Crotaphytus collaris (a known predator of S. consobrinus). We collected glucose, corticosterone, and body temperature immediately following capture, and 30 minutes post-capture to measure stress axis reactivity. To address reproductive trade-offs, we determined maternal fat content, clutch characteristics, and offspring morphology. Results suggest the presence of a predator is associated with elevated baseline glucocorticoid concentration in gravid females. Additionally, S. consobrinus in glade habitats without the predator have elevated circulating glucose concentrations, higher activity body temperature, and smaller body size, which might indicate energetic trade-offs.

569 Jalyn Devereaux, Jessica Karr, Thomas Hahn, Jamie Cornelius

Impact of winter weather on stress and reproductive physiology in captive red crossbills

Animals cope with seasonal changes in weather by scheduling life history stages to maximize fitness, but trade-offs may arise. Physiological preparations for cold temperate winters, for example, may limit the ability to breed – even if food remains abundant. We explore relationships between changing weather, reproductive and stress physiology in an opportunistic breeder, the red crossbill (Loxia curvirostra), by manipulating temperature, rain, and latitude (daylength) in a controlled setting from November through February. Birds were divided into 6 treatment groups and experienced 30 minutes of rain per day in either cold (6oC) or warm (18-22oC) temperatures and on natural photoperiod consistent with either high (58o N) or low temperate latitudes (44o N). Controls experienced dry conditions at these same temperatures and photoperiods. Blood samples were obtained at three sampling periods throughout the experiment, including: early-mid November, late December/early January, and mid-February. We compare baseline and stress-induced corticosterone levels with reproductive physiology across the fall to winter transition. This research will help determine how weather parameters may interact with hormonal control mechanisms of breeding in a reproductive opportunist with high degrees of flexibility in timing. Animals cope with seasonal changes in weather by scheduling life history stages to maximize fitness, but trade-offs may arise. Physiological preparations for cold temperate winters, for example, may limit the ability to breed – even if food remains abundant. We explore.

599 Charlotte Devitz

Where the pavement ends: Breaking barriers to accessibility in the field

Approximately 15% of the worlds' population is identified as having some form of a disability, but as few as 2% of scientists in different STEM fields are disabled. This disparity reflects heavily on not only barriers to access in the academic and scientific communities, but on the perspectives on what disabled individuals have to offer. This talk focuses on identifying challenges and solutions around disability and inclusivity in field biology. Field science is often immediately written off for people with disabilities given that it is frequently fast paced, physically demanding, and taking place in largely inaccessible places. Little infrastructure is in place to accommodate disabilities in nearly all field settings and obtaining accommodations can therefore be intimidating in this context. Still, creating a more accessible and inclusive future for field biology will require more than just eliminating physical barriers to access; Instead, it will necessitate widespread efforts to change perspectives on disability, accessibility, and accommodations and their place in our scientific spaces and practices. Drawing on personal experiences as a disabled scientist, this talk will explore the disabled experience in field biology and offer a range of solutions moving forward, ranging from small interventions such as building in consistent field support to more systemic change, such as establishing programs in universities to provide adaptive field equipment.

1739 Sneha Dharwadkar, Guinevere Wogan

Biogeography of genus Nilssonia in the Indian subcontinent: past inferences and future predictions

The genus Nilssonia consists of five medium to large riverine softshell turtle species distributed across the different regions within the Indian subcontinent. These species are known to occur in large river systems and reservoirs, and are currently threatened by dams and hydropower projects, sand mining, water pollution and large-scale illegal poaching. Using phylogenetic niche modelling, we estimated the historical biogeography of the genus Nilssonia and predicted the ancestral distribution of the genus. We further explored phyloclimatic overlap among species to establish the role of climate in driving historical biogeographic patterns. Lastly we projected niches forward under anticipated future climate change to assess the probability of occurrences. Our results showed that precipitation and temperature were the most important variables affecting the distribution of the species across their ranges. Our preliminary results of the forward projected niches indicate considerable reduction in the ranges of all the species, especially impacting the Nilssonia leithii with over 50% reduction in its currently known range.

1336 Valentina Di-Santo

Ontogenetic shifts in swimming performance in forage fish under climate change

Fishes are the only vertebrate group in which an individual, across its life history, may have body masses ranging several orders of magnitude. High rates of mortality in larval fishes under ocean acidification and warming may be partially owing to a limited swimming performance. Fishes undergo rapid morphological and behavioral shifts as they develop from larvae into juveniles. While adult fishes are effective acid-base regulators, larvae may be more vulnerable to climate stressors. In this study, I present data on the effect of ocean acidification and warming on swimming performance of sand smelt, Atherina presbyter, across ontogeny. Embryos of sand smelt were raised under current and future levels of CO2 (approx. 400 μatm and 2000 μatm) and temperature (17 and 21°C) in a full factorial experimental design. I used high speed cameras and respirometry to quantify the effect of ocean acidification and warming on ontogenetic shifts in swimming biomechanics, metabolic rates, and behavioral milestones, such as the onset of schooling, of sand smelt across the larval period and as they transitioned into juveniles. Results from this study show that ocean warming and acidification have an interacting and complex effect on larval fish locomotion causing a reduction in swimming endurance, an increase in the costs of locomotion, and alteration in kinematics during solitary and collective swimming.

655 Terry Dial, Ashley Heers, Mark Mainwaring

The impact of early life conditions on performance during adulthood: past, present and future

Organisms experience considerable variation in the conditions to which they are exposed during the early stages of life as a result of environmental conditions, evolutionary selection pressures and conditional effects on genetic inheritance / expression. Such variable experiences during early life have long-lasting effects through to adulthood and can also be passed onto offspring via transgenerational effects, thereby influencing the fitness of successive generations. We begin this introductory paper by describing the history of the topic and outline how our acquisition of knowledge has increased over time from a range of vertebrate and invertebrate taxa. We then describe how links between early life conditions and performance during adulthood are now ubiquitously influenced by anthropogenic activities, such as habitat alteration and climatic changes. Meanwhile, the use of increasingly sophisticated technology - such as the attachment of miniature tags, -

have provided many new and important insights, and we outline how such approaches are central to many of the papers in this issue. Finally, we outline a “horizon scan” of the topic in which we asked experts to define which questions were most in need of research attention in the next decade, thus shaping the future directions in which the topic should proceed. In this way, we describe the past, present and future of links between early life conditions and performance during adulthood.

841 Julia Diamandi, Troy Shirangi

Cis-element analysis of the dissatisfaction gene identifies neurons for Drosophila female courtship

In Drosophila, virgin females carrying mutations in the dissatisfaction gene (dsf) are delayed inmating with males and exhibit deficits in opening their vaginal plates during courtship. Dsfcontributes to female behavior in part by functioning in a sexually dimorphic population ofinterneurons in the abdominal ganglion called the DDAG neurons. The DDAG neurons infemales are composed of a variety of neuroanatomical subtypes, but which subtypes matterfor female behavior is unknown. Here, we screened seven cis-regulatory fragments from thedsf gene for reporter expression in dsf-expressing neurons in the adult central nervoussystem. We find that most of dsf’s expression in the central nervous system is driven bycis-regulatory sequences within dsf’s third intron. Using these fragments, we identified asubpopulation of local female-specific DDAG interneurons that is sufficient for the opening ofthe vaginal plates in virgin females during courtship. The regulatory fragments targeting thissubpopulation of neurons contain putative binding sites to proteins encoded by the sexdetermination gene, doublesex, suggesting that doublesex may directly regulate dsfexpression in a subset of DDAG neurons. Our results provide new insights into the neuralcircuits that mediate the opening of the vaginal plates and the mechanisms that regulate dsfexpression in the central nervous system.

813 Kelly Diamond, Clarie Olson, Kaera Utsumi, Maria Eifler, Douglas Eifler

Allometry of size and performance in the desert horned lizard (Phrynosoma platyrhinos)

As animals develop, demands on their physical form often change in response to ecological pressures. One area where this is particularly evident is in structures associated with locomotion. Due to their smaller size, juvenile animals often need to evade a larger and more diverse set of predators. In this study we examined the allometric relationships between body shape, size, and sprint performance in the desert horned lizard, Phrynosoma platyrhinos. We anticipated a positive allometric relationship for body size and mass as adult Phrynosoma lizards use a dorsoventral “shielding” as an antipredator strategy. We predicted a negative allometric relationship between body mass and sprint speed, as juvenile lizards are under stronger selection to run away from predators. We collected 35 lizards in the Alvord Desert in southeastern Oregon, ranging in size from 27-83mm snout vent length. We measured sprint speeds, collected morphological measurements, and recorded the habitat in which each lizard was found. Preliminary results support our prediction that larger lizards have disproportionally lower peak sprint speeds ($R2 = 0.895$, $F = 271.8$, $p < 0$ .001), but the relationship between mass and body length is more isometric ($R2 = 0.977$, $F = 1359$, $p < 0$ .001). These results suggest that the puffing antipredator strategy may constrain juvenile performance. However, other morphological components, besides body length, such as leg length or muscle composition may be responsible for observed differences in performance.

606 Danae Diaz, Sönke Johnsen, Steve Nowicki

Can you judge a bird by its cap? Assessing the link between cap color and cognition in a songbird

Individuals may benefit from mating with cognitively superior mates but are rarely able to observe cognitive abilities of potential mates directly. Melanin-based feather pigmentation could serve as a reliable signal of cognition because melanin production competes for resources (e.g., cysteine) needed for central nervous system (CNS) development. This relationship, thus, suggests that more colorful individuals may be cognitively superior. We investigated the relationship between pheomelanin-based cap coloration and cognitive traits in male swamp sparrows (Melospiza georgiana). We used spectral reflectance measurements ($\lambda = 400$-800 nm) to calculate “redness” by averaging nominal red (600-700 nm) and green (500-600 nm) channels and then calculating (red-green)/(red+green). We also measured the total area of the pigmented region because swamp sparrow head caps vary in not only redness but also the amount of redness, as some patches have patterns that disrupt the coloration. Males were then tested on a battery of cognitive tasks. We assessed the relationship between cap redness and area as a signal of each cognitive task independently and assessed correlations on performance between tasks. Our results suggest that cap color correlates positively with a spatial memory task. Additionally, individual performance on a color association task correlated positively with performance on a color reversal task. These results suggest that feather coloration may serve as a signal of spatial cognitive ability.

891 Candido Diaz, John Long

Behavior and Bioadhesives: How Bolas Spiders, Mastophora hutchinsoni, Catch Moths

Spiders use various combinations of silks, adhesives, and behaviors to ensnare and trap prey. A common but difficult to catch prey in most spider habitats are moths. They easily escape typical orb-webs because their bodies are covered in sacrificial scales that flake off when in contact with the web's adhesives. This defense is defeated by spiders of the sub-family of Cyrtarachninae, moth-catching specialists who combine changes in orb-web structure, predatory behavior, and chemistry of the aggregate glue placed in those webs. The most extreme changes in web structure are shown by bolas spiders, who create a solitary capture strand containing only one or two glue droplets at the end of a single thread. They prey on male moths by releasing pheromones to draw them within range of their bolas, which they flick to ensnare the moth. We use a high-speed video camera to observe the capture behavior of the bolas spider Mastophora hutchinsoni. We use kinematics of spiders and moths in the wild to begin to quantify and model the physical and mechanical properties of the bolas during prey capture, the behavior of the moth, and how these factors lead to successful prey capture. We then create a numerical model to explain the unique behavior of the bolas silk– stretcheing and retracting during prey capture. Research supported by NSF, project #2031962 to CD and JHL.

1606 Kelimar Diaz, Steven Tarr, Baxi Zhong, Daniel Goldman

Water surface swimming via continuous contact in a centipede

The ability for animals to locomote on water has emerged across scales (Bush and Hu, Annu. Rev. Fluid Mech., 2006). Previous studies on locomotors at the interface focused on discrete environmental contacts, where propulsion emerges from limb-surface interactions. Less is known about how animals locomote via continuous contact (i.e., body-surface interactions). Here, we discovered that a centipede, L. forficatus ($N = 8$, $L = 2.3 \pm 0.3$ cm, 14 leg pairs), uses body-surface interactions to locomote at the water surface. The centipede locomoted via waves of body curvature that traveled with the direction of motion (direct). In contrast, amphibious centipedes (Yasui et al., Sci. Rep., 2019) fold their limbs towards their body and propagate waves opposite to the direction of motion (retrograde). Schlieren wave reconstruction suggests L. forficatus relies on constant self-deformation for locomotion, similar to animals in non-inertial regimes (e.g., sand swimming lizards). We posit propulsion via direct waves is achieved non-inertially due to the animal's ratio of local perpendicular to parallel forces (drag anisotropy) generated by extended limbs. To test this, we performed drag experiments at the interface and varied the attack angle and drag speed. Drag experiments revealed that for the centipede's morphology (slender body with limbs perpendicular to the body axis) drag anisotropy was ≤ 1. Resistive force theory simulations with experimentally resolved forces suggest the animals locomote using the maximum achievable bends without introducing undesirable limb-body collisions.

1324 Sofia Diaz-de-Villegas, Lauren Fuess

Investigating the effects of bleaching on host disease susceptibility in a model Cnidarian

Corals reefs support immense marine biodiversity and provide key ecosystem services like coastal protection and fisheries resources. Unfortunately, scleractinian corals, which form the structural basis of these ecosystems, are increasingly threatened by a variety of anthropogenic stressors. Of particular significance are bleaching events and disease outbreaks, both of which are becoming more frequent and more severe, often leading to mass mortality. Ecological data suggests these phenomena are often intricately linked, with disease outbreaks following thermal stress. To better understand the mechanisms linking bleaching and disease, we conducted a multi-stressor experiment. Exaiptasia diaphana from two genetically distinct clonal lines were exposed to a thermal stress (34C for 5 days). Then, at one and three weeks following the end of thermal stress, anemones were exposed to the known coral pathogen, Vibrio coralliilyticus. We tracked mortality for the duration of the experiment. Tissue samples were preserved for symbiont density counts as well as protein, carbohydrate, and lipid analysis. Variation in constitutive and induced immunity across groups was measured using biochemical immune assays, while variation in energetic reserves was quantified with enzymatic carbohydrate and lipid assays. The resulting data will provide new insight regarding the complex relationship between bleaching and disease and contribute to improved coral reef management under future climate change scenarios.

1114 Meron Dibia, Hunter King

The termite mound as passive, sorbent-based, vapor harvesting device

Many fungus-harvesting termite species that build large, closed-chimney mounds also live in areas that are dry and hot for much of the year. The water cost of building and repairing of the mound structure, as well as cultivating fungus within is very high, and little is understood about how the system maintains its water budget. Here, we explore a possibility by which the termite mound operates as passive, sorbent-based, vapor harvesting device. As such, it uses: naturally-sorbent building materials to temporarily store and release vapor between day and night phases, facilitating periodic states of high internal humidity; architecture to passively drive transport of moist air toward condensing elements coupled to its underground heatsink; and the daily oscillations in temperature and humidity as its external driver. To evaluate this potential function, we continuously measure soil moisture and temperature over day-night cycles in different sections of the Odontotermes obesus species mounds in South India. Preliminary data offer some tell-tale signs of this potential vapor harvesting activity, notably in the phase shift between internal and external humidity patterns. Further confirmation would cast the termite mound as a very unusual example of animal-engineered thermal device.

1381 Kord Dicke, Dhruba Naug

Slow-fast differences in physiology, behavior, and life history in honeybees

The metabolic rate of an organism, which determines the rate of all biological processes, has been strongly linked to explaining behavioral differences at the individual level. This applies to the pace-of-life model which places individuals within a species on a slow-fast continuum that is composed of correlated differences in behavior, physiology, and life history traits. While these correlations might impose some constraints at the individual level, the consequences of such constraints can be potentially relaxed in animals living in social groups where the social phenotype is an emergent outcome of the individual phenotypes that constitute the group. Using honeybees as a model, we measured metabolic rate and a number of physiological, behavioral and life history parameters in individual bees to test for these correlations that constitute the slow-fast axis. Our results show a complex interrelationship across these parameters that show consistent but mixed support for metabolic rate being a fundamental driver of slow-fast phenotypes in support of the pace-of-life theory in the social context.

1053 Bradley Dickerson, Noah Cowan, Andrea Gaede, Auke Ijspeert

Feedforward and feedback control architectures for locomotion using mechanosensory input

Feedback is critical to nervous systems as it ensures accurate, fine-scale control so that animals can attain their next meal or successfully navigate complex, unpredictable terrain. Tools from a field of engineering known as control theory allow us to quantitatively describe feedback-driven systems and predict their behavior to novel stimuli. A common control architecture is the so-called PID (proportional, integral, derivative) controller has helped us understand problems such as the circuit dynamics of sensory systems informing task-driven locomotor behaviors. PID controllers allow a system to correct for the current strength of a perturbation (P), predict its future value (D), and account for any past error (I). Such architectures are of particular importance in situations where the timing of a corrective response is critical to maintain stability. However, despite feedback (and feedforward) control being an essential concept in both engineered and biological systems, the words mean entirely different things to different communities. Here, we first clarify this terminology and apply it to different experimental topologies. We then use this framework to interpret animal behavior and explore feedforward/feedback scaling relationships across taxa.

1145 Edwin Dickinson, Aleksandra Ratkiewicz, Michael Granatosky, Julia Molnar, Adam Hartstone-Rose

Algorithmic reconstruction of in situ muscle fascicles across a range of body sizes

Muscle architectural properties determine both the force-generating and excursion potential of skeletal muscle, and thus represent a critical means of assessing functional performance. Such data have been traditionally collected via gross dissection, but this destructive process cannot be used with rare specimens and sacrifices important spatial data regarding the three-dimensional orientation and relationships of fascicles. In the past few years, advancements in tissue staining and imaging modalities have facilitated the tomographic study of muscle microarchitecture, using either manual or algorithmic approaches to reconstruct muscle fascicles in situ. Here, we present quantitative comparisons of several techniques (including gross dissection, manual fascicle segmentation, and fully automated fascicular reconstruction) for the reconstruction of fascicles in the mammalian masticatory apparatus, a complex system comprising several multipennate muscles. We demonstrate, across a wide range of specimen sizes, that automated approaches achieve results roughly concordant (± 15%) with manual approaches, but generally skew towards greater fascicle lengths. Automated approaches offer numerous advantages, including the ability to quantify a larger number of fascicles from each muscle, and the removal of user subjectivity from the process of fascicle identification, boosting replicability. We also highlight the value of data on fascicle tortuosity (i.e., compression, calculated as the difference between arc and chord lengths) and its potential relationship with each muscle's length-tension curve.

1153 Edwin Dickinson, Melody Young, David DeLeon, Burcak Bas, Bettina Zou, Aleksandra Ratkiewicz, Brian Beatty, Michael Granatosky

What makes a climbing tail? Morphology and material properties of tail feathers across birds.

Climbing birds use their tail feathers as a compressive brace when scaling vertical surfaces, supporting 10-50% of body weight. This application likely exerts significant mechanical demands, and indeed an increase in tail stiffness among certain climbing lineages (e.g., woodpeckers) is considered a classic example of biomechanical adaptation. However, the morphology and material properties of these feathers compared to those of non-climbing birds has yet to be empirically assessed. We present data on the form and mechanical strength of tail feathers across a broad range of avian taxa to test the impact of tail-use during climbing. Using phylogenetic generalized least squares, we demonstrate that while tail feather length scales isometrically with body size across avians as a whole, this relationship is positively allometric among tail-climbing birds (i.e., tail-climbing birds have relatively longer tails for their body mass). Shaft widths were also relatively greater among tail-climbing birds. However, elastic modulus was equivalent across groups, suggesting that climbing birds alter the morphology, but not the intrinsic material properties, of their tail feathers to facilitate this behavior. Our findings shed new light on form-function relationships within the avian tail and provide novel data to address long-standing biomechanical questions as to the impact of vertical ascent upon the anatomy of climbing birds.

1155 Jeremy Didion, Jessica Fox

Central complex neuron responses to haltere input from multiple behaviors in Sarcophaga bullata

Though much is known about how some sensory systems adapt to contextual changes, like photoreceptors adjusting to ambient light levels, little is known about how proprioceptive neurons change their function to match behavioral context. In true flies, reduced hindwings known as halteres act as proprioceptors to detect forces caused by body rotations. In quiescent flies, experimental oscillation of the halteres changes the firing rate of some neurons in the central complex (CX). We measured the activity of neurons receiving self-generated haltere input (as observed with high-speed videography) as the fly alternated between standing and walking behavior on a floating ball. Preliminary results show that at the onset of walking, the two halteres oscillate asynchronously and eventually synchronize their oscillation. Continuous haltere oscillation during walking decreases the firing rate of some CX neurons located in the lateral accessory lobe, and modulates firing rates in neurons in other CX locations. By comparing CX responses to haltere oscillations from both active and quiescent animals, we can measure the influence of behavioral state on neural activity in a proprioceptive circuit.

1305 Wesley Dillard, Gareth Fraser

Evolution of the Dermatoskeleton: Insights from Odontode Scute Development in Armored Catfish

Due to the morphological disparity between extant lineages the developmental origin of dermal skeletal tissues in the vertebrate trunk remains a contentious issue. Although stem vertebrates possessed heavily mineralized dermal armor partitioned into scale subunits across both the head and trunk, elements of this scale unit have been lost or reduced in most extant vertebrates. Cartilaginous fishes have retained the dental and enameloid components of their dermal skeleton in the form of odontode denticles, while most bony fishes have retained only a bony component, if any at all. Previous characterizations of trunk dermoskeletal development have addressed the contribution of neural crest cells and mesodermal tissue to developing armor, but have only done so in groups that do not display all components of the ancestral vertebrate scale and with conflicting results. In this study we investigate the development of the bony and dental components of the scutes of Ancistrus armored catfishes, a group of teleost fishes that have re-evolved both bony armor and odontode denticles despite having descended from a scaleless ancestor. We use a combination of techniques to chart the development and molecular contribution to these tissues, including cell lineage tracing, immunohistochemistry and Computed Tomography (CT). Understanding the complex interactions of these tissue components of the dermatoskeleton in this highly-derived group of teleost fishes can contribute important insights to the evolution of tooth-like scales.

1437 Michael Dillon

Into the cold: unearthing the physiology of dormant queen bumble bees

Bumble bees are critical pollinators with population declines on multiple continents linked to changing climates. A growing body of work has documented effects of extreme temperatures on workers during the growing season; but we have comparatively little information effects of temperature on queen bumble bees, which emerge in fall, mate, and overwinter prior to starting new colonies in the spring. This annual life cycle (workers, males, and old queens die in fall) means that population persistence depends on success of fall queens. Here, I'll discuss our work investigating effects of temperature on queens across Fall, Winter, and Spring. Queens survived an early fall snowstorm by retreating to buffered microclimates. Cooling temperatures appear to be the primary cue for overwintering, and queens show suppressed metabolism only after prolonged exposure to cold ($< 4^{\circ}$C) temperatures. Yet, even after 6+ weeks below 4°C, queens are still responsive, capable of rapid return to normal activity. Both modeling approaches and empirical data suggest that suppressed metabolism is likely critical for minimizing use of fixed energy stores over winter.

1637 Giulia DiRaimo, Carla Narvaez-Diaz, Stephanie Crofts

Aristotle's Lantern and Soft Tissue Anatomy in Burrowing and Non-Burrowing Sea Urchin

Previous work has described how the purple sea urchin (Strongylocentrotus purpuratus) is capable of burrowing into a range of different rocky substrates. To excavate burrows, the urchins mainly use their teeth to scrape-away at the substrate, though spines may also be used to wear-down the substrate in addition to bracing in the burrow. Different populations of purple urchins show a great deal of phenotypic plasticity, and differential burrowing ability is correlated to the specific substrate associated with each population. In this study, we quantified and compared differences in the Aristotle's Lantern, a complex tool used for feeding and excavation, and associated soft tissues in urchins that burrow and those that do not. We compared purple urchins found inside and outside of burrows, as well as with closely related non-burrowing species from the same range. To visualize soft tissue anatomy, we used 3D slicer to isolate and measure structures of interest in contrast-stained CT urchin scans. Our findings indicate that the relative size of the Aristotle's Lantern is preserved in different populations and species of urchins, but proportions vary. We also found differences in the protractor and retractor muscles of the Aristotle's Lantern.

267 Calvin Dirickson, Ian Curnutt, Devaleena Pradhan, Heather Ray

Ovarian Follicular Development and AMH Distribution in a hermaphroditic fish Lythrypnus dalli

The ovarian cycle of females has distinct stages indicating oocyte development and maturation; however, the cellular mechanisms regulating this process and morphology of these stages are relatively unknown. The Blue Banded Goby, (Lythrypnus dalli), is a bidirectionally hermaphroditic fish that can be used to study mechanisms pertaining to oogenesis in adult females and during the process of adult sex change. As a first step, we characterized the ovarian cycle by sectioning and staining ovaries from naturally cycling wild-collected adults. We separated the ovary into 4 phases and characterized five follicle stages. The early phases (1-2) were categorized by early-stage follicles (1-3) while later phases (3-4) were dominated by late-stage follicles (4-5). There were notable differences in interstitial space between phases two and three. We are currently evaluating the distribution of the glycoprotein Anti-Mullerian Hormone (AMH) during these ovarian phases and follicular stages. During development, AMH plays a role in determining sex by removing the Mullerian ducts, thus promoting male development. AMH has also been linked to participate in follicle maturation in adult female ovaries. We predict that the distribution of AMH will be higher in early-stage follicles and lower in more developed follicles based on data from other species that larger follicles produce less AMH. This study will be foundational for future studies that will investigate the function and distribution of AMH during sex change.

130 Scott Dixon, Simon Walker

The Neuromuscular Control of Blowfly Flight

The flight machinery of insects is highly specialised, permitting the aerial agility and fine motor control that has allowed insects to exploit habitats across the globe. The primary power-producing flight muscles, the dorso-ventral and dorso-longitudinal muscles, power the upstroke and downstroke respectively, by causing cyclical deformations of the thorax. The physiology of these muscles is well-understood; however, they are not responsible for the asymmetric flight manoeuvres that insects perform. Such finer alterations to wing kinematics are controlled by several smaller muscles, known as steering muscles, which attach to cuticular invaginations known as sclerites. However, the complexity of the arrangement of these muscles makes it difficult to infer their function purely based on where they insert. Previous studies utilising electrophysiology, and more recently calcium imaging, have explored the role that these muscles play in flight kinematics, however, the picture remains incomplete. For example, practically nothing is known about how these muscles are involved with wing initiation at take-off, or how they control the wing pitch angle. This study combined thin-wire electromyography with high-resolution, high-speed filming of Calliphora vicina blowflies using four cameras simultaneously. Both take-off and in-flight manoeuvres were recorded, the latter being induced by wide-field pitch, roll and yaw visual stimuli. The activity of individual muscles and the role they play in controlling wing kinematics on a stroke-by-stroke basis could therefore be fully assessed.

132 Scott Dixon, Simon Walker

Using the Optomotor Response to Determine the Flicker-Fusion Frequency of Insects

Visual feedback acts as an important control mechanism during insect flight, enabling a spatiotemporal analysis of the environment. For this to be possible during high-speed traversal, insects must possess sufficient temporal acuity, often measured by their critical flicker-fusion frequency, the maximum frequency of stimulation that the eye can discern as discontinuous. Using simple flickering light, several species have had this value determined electrophysiologically. However, psychophysical experiments in vertebrates imply that animals cannot discern the flicker of complex stimuli to the same extent. In this study, we therefore set out to determine the flicker-fusion frequency of three common laboratory insects, Calliphora vicina, Drosophila melanogaster and Bombus terrestris using behavioural assessment. Insects were presented with a variety of optic flow stimuli mimicking yaw, roll and pitch perturbations that triggered their well-studied optomotor response. Stimuli were composed of several frames and projected at a range of refresh rates, based on the prediction that only projection frequencies above the species' flicker-fusion threshold would be perceived as continuous motion and therefore elicit a stereotypical behavioural response. By analysing wingtip kinematics, we found no changes in behaviour until projection frequencies increased to 40-70 Hz, far below the previously reported critical flicker-fusion frequencies for these genera (Bombus: 130 Hz, Calliphora: 240 Hz, Drosophila: 200 Hz). Further testing indicated how this threshold was affected by the physical characteristics of the visual stimulus.

1508 Brittany Dobbins, Maia Rogers, Ruben Tovar, Tom Devitt, Dana García, David Hillis

Expansion of the Lateral Line System Among Blind Salamanders of the Genus Eurycea

Selective pressures of extreme environments can drastically alter the phenotype of an organism. Inhabitants of the subterranean Edwards-Trinity aquifer system, like the Texas Blind salamander (Eurycea rathbuni) and cave-dwelling populations of the Cascade Caverns salamander (E. latitans), must navigate these waterways in total darkness. Unlike their surface relatives (E. nana and E. sosorum), these subterranean salamanders have highly reduced eyes. All four species are aquatic throughout their lives. Based on research in Mexican blind cavefish, we hypothesize that subterranean salamanders have more lateral line receptors (neuromasts) compared to surface salamanders to compensate for reduced vision. To test this hypothesis, we mapped and quantified neuromasts of the anterior lateral line (ALL) of E. nana, E. sosorum, E. rathbuni, and a cave population of E. latitans using diffusible iodine-enhanced computed tomography scans of three individuals per species. A one-way ANOVA showed significant difference in the number of ALL neuromasts among these species ($F(3,8) = 15.45$, $p = 0.001$). Tukey's HSD Test for multiple comparisons indicated the mean number of ALL neuromasts in E. rathbuni and E. latitans was significantly higher than E. nana and E. sosorum (p-value < 0.05). Our results highlight the potential of this system for studying the parallel evolution of sensory modalities and lay the groundwork for further analysis associating spatial distribution of ALL neuromasts with specific environments and ecosystems.

474 Whitney Dobbyn, Bret Tobalske, Donald Powers

Body Plumage as a Barrier to Heat Dissipation in Southeastern Arizona Hummingbirds

Thermoregulation contributes substantially to daily energy expenditure in endotherms due to the high cost of body temperature (Tb) maintenance. During flight, extra heat produced by flight muscles must be dissipated to maintain Tb. An important mechanism for regulating Tb are thermal gradients to passively dissipate heat. However, passive heat dissipation is complicated during flight due to the insulative properties of plumage. Prior work has looked at heat transfer through plumage to body surfaces, but heat transfer from skin through plumage during flight is unstudied. We used thermal pit tags and infrared thermography to study heat transfer from skin surfaces to plumage exterior in flying and perching Blue-Throated Mountain Gems (Lampornis clemenciae) and Rivoli's Hummingbirds (Eugenes fulgens). We hypothesized heat gained during flight would be dissipated after perching, when skin surfaces could be easily exposed. Skin surface temperature (Ts) was 6.8°C warmer than plumage during flight and 6.5°C warmer after perching. After perching > 8 minutes, the difference lowered to 5.5°C. Both skin and plumage Ts increased 0.6-4.3°C within 15 seconds after perching. This could be due to increased skin circulation post flight or convective cooling during flight. Regardless, skin and external plumage Ts were correlated, suggesting exterior plumage Ts is influenced by Tb . Because plumage tracks lower than skin Ts, it does provide some resistance to heat loss.

1030 Molly Dobrow, Laura Habegger, Mason Dean, Stephen Stagon

The mechanics of energy dissipation of tessellated cartilage in sharks

A unique component of the skeletons of elasmobranchs is a tessellated mineralized shell surrounding the unmineralized cartilaginous core. A variety of functions have been proposed for this unique skeletal armoring; however, the potential for the tessellated layer to act as an energy dissipator has barely been explored. Although previous studies have attempted to analyze the stress-relaxation behavior of this material, the local variation in material properties (a function of fine-scale microstructure and compositional variability) has made examination of the mechanics of the tessellated layer difficult. This study develops a 3D printed tesserae model using additive manufacturing that aims to replicate material gradients seen in situ, to analyze the structural mechanism by which energy could be dissipated in this system. Nano-CT scans of tessellated mineralized cartilage from the jaw of blacktip reefshark (Carcharhinus limbatus) are used to develop a composite resin 3D printed model using a Stratasys J35 Polyjet printer. The use of ultra-high-resolution imaging and multimaterial printing allows us to mimic the observed variation in mineral density with high precision. By performing compression testing on this model, we evaluate stress-flow and strain distribution through tesserae, allowing us to test the effect of material gradients on load and strain distribution.

1852 Adi Domer, Yariv Brotman, Ofer Ovadia

Plasma metabolome of migrating passerines: Novel insights into flight metabolism and avian insulin-resistance

Migrating birds alternate between fasting during endurance flights and extensively feeding during stopovers. Weexamined the plasma metabolome of two autumn migrating passerines prior to their crossing the Sahara Desert. The birds were sampled at two stopover sites populated by Pistacia trees, bearing fat-rich fruits during autumn, and at an additional site dominated by autumn-blooming Eucalyptus trees. Both the polar and lipophilic metabolites varied significantly among sites. The inter-site dissimilarity in the polar metabolites was mainly generated by ten metabolites. This dissimilarity can be principally attributed to inter-site variation in the physiological state of the birds (freshly landed vs. rested). The inter-site dissimilarity in the lipophilic profile of rested birds is suggested to be attributed to the inter-site variation in their primary food source type (fat-rich fruits vs. nectar). Our findings reveal metabolic pathways activated during stopovers, indicating an urgent need for flight recovery, and suggesting that cycling glucose, derived from protein catabolism, plays a vital role in this recovery process. This novel perspective, conducted on free-ranging birds, may indicate that similar to trauma recovery in other animals, avian insulin-resistance and hyperglycemia have evolved due to endurance exercise, prolonged fasting, and preference towards fatty acid oxidation associated with bird migration.

131 Natalie Doody, Scott Dixon, Graham Askew, Simon Walker

Muscle strain patterns and mechanical power output of blowfly flight muscles

Dipteran flies are capable of producing intricate asymmetric flight manoeuvres. Large power muscles drive the wingbeat through cyclical thorax deformations, however, they lack the capacity to create asymmetric wing motion. The steering muscles, despite only accounting for < 3% of flight muscle mass, can rapidly actuate subtle mechanical changes at the wing hinge to induce asymmetric flight manoeuvres. In order to understand how this is achieved and fully elucidate steering muscle function, analyses of muscle strain, activation, and stress, need to be conducted. To visualise the steering muscles of blowflies (Calliphora vicina), time-resolved synchrotron X-ray computed microtomography was used to produce three-dimensional videos of the thorax during tethered flight. Strain patterns were calculated using Amira software to manually track the movement of the steering muscle attachment sites throughout the wingbeat. Muscle strain patterns were then correlated with wingbeat kinematics through linear modelling techniques. In a separate cohort of blowflies, the mechanical power output of the asynchronous (power) and synchronous (steering) muscles was quantified utilising the work loop technique. In addition to quantifying mechanical power output throughout sinusoidal length changes and different phases of activation, work loops were generated using physiologically relevant muscle strain data (Amira) and muscle activation patterns derived from electromyography during tethered flight. These experiments provide a holistic view of steering muscle function which can underpin the design of micro air vehicles.

1222 Kelly Dorgan, Sanjay Arwade, Arghavan Louhghalam, Xuejing Wang

How the worm turns: impacts of geotechnical properties on burrower navigation

Burrows are extended through muddy sediments by fracture, and the behaviors of burrowers depend on sediment properties, specifically the fracture toughness and stiffness of elastic muds. Cracks propagate in the direction of least resistance. Sediments are heterogeneous materials in which fracture toughness and stiffness vary on scales and amounts that are poorly understood. We suggest that crack branching or microcracking at the tips of burrows are important ways in which particles can be freed from the matrix to be consumed or transported to create burrow structures and mix sediments. We use modeling to explore how burrower behaviors and variability in sediment properties affect crack propagation direction and branching. Modeling results indicate that neither variability in stiffness nor varying “behaviors” or model worms are likely to result in crack steering. Sharp gradients and small-scale variability in fracture toughness contribute to tortuosity in crack paths and potential branching. Rather than steering burrows through asymmetrical stresses, our model results suggest that worms navigate on small scales by creating crack branches and selecting a branch to follow. Burrow paths in natural sediments show generally straight paths with occasional branching, consistent with model results. Ongoing work is exploring the energetics of fracture in heterogeneous materials to better understand how and where crack branching occurs and how easily worms can initiate branching events to better steer in heterogeneous muds.

439 Daniel Doucet, Juan Daza

The neglected system of squamate reptiles provides clues to higher relationships of Lepidosaurians

The integumentary system, largely accountable for the names Lepidosauria and Squamata have not been explored to understand the higher-level relationships of these clades. While keratinized scales are often used in taxonomic studies to diagnose new species, the overall variation of these structures has not been implemented in a large-scale study of scales. Here we present preliminary results of the 139 specimens representing 12 major lepidosaurian clades, further subdivided into 70 squamate families. In this study we used 180 binary characters to produce a multiple correspondence analysis. Our results recovered a morphospace that is highly congruent with current hypothesis of relationships. Amphisbaenians were recovered in a unique area of the morphospace, while snakes were found sharing an area with anguimorphs and some skinks. The two groups of iguanians (Pleurodonta and Acrodonta) also are near to one another, but the acrodonts are in the periphery of their joined area. Although other major clades have a large area of overlap, the analyses could discriminate close groups such as lacertids and teiids. Morphological variation of scales has the potential to inform relationships of these reptiles, which have a longstanding debate about their molecular and morphological topologies. Fossil lizards with well preserved integument were a key case study for applying this dataset, and are useful in resolving some amber specimen inferences.

543 Nine Doutreloux, Michel Marengo, Dimitri Theuerkauff, Martial Laurans, Michela Patrissi, Pierre Lejeune, Martin Laporte, Patrick Berrebi

Genetic structure of Corsican spiny lobsters, a matter of irregular annual recruitment?

The spiny lobster (Palinurus elephas, Fabricius 1787) is one of the most important economic marine resources of Mediterranean Sea, and also a coastal marine endangered species due to overfishing. To increase the biological knowledge of this species in order to harmonize fishing and conservation, a genetic study has been programmed on the Corsica Island populations (France, Mediterranean Sea). For this, five samples totaling 85 lobsters were taken all around the island from fishermen's brotherhoods. They were genotyped at twenty-one microsatellite loci, adding 15 Atlantic individuals more from Brittany (France) which serve as outgroup. Statistical analyses of genotypes showed slight differentiation between samples but no clear geographic structure. No isolation by distance was detected around the island. Surprisingly, the Atlantic sample is not particularly different from the Mediterranean ones. However, the generalized deviation from panmixia is highly significant and variation partitioning of redundancy analyses point out irregular annual recruitment, probably from several breeding gatherings, inducing inter-localities and inter-cohorts slight genetic differentiation.

654 Cynthia Downs, Ryan McMinds, Rays Jiang, Swamy Adapa, Emily Cornelius-Ruhs, Rachel Munds, Lynn Martin

Bacterial sepsis triggers elevated immune transcriptomic responses in larger primates

Why are some species more susceptible to and more likely to act as reservoirs for parasites whereas others are resistant? We explored body size's role in shaping vertebrates' immune defenses. The Safety Factor Hypothesis posits that large animals should have disproportionately stronger immune defenses because of their disproportionately greater risk of exposure to infectious organisms and disproportionately slower ability to keep pace with pathogen replication. We queried the effects of body size of six species of primates on the innate immune regulatory architecture of the blood. We had three significant findings using novel comparative transcriptomic approaches in which we induced simulated bacterial infections in live blood samples by challenging fresh blood samples with lipopolysaccharide (LPS). First, the overall transcriptional response to infection was stronger in larger species. Second, larger primates disproportionately prioritized innate immune gene expression over non-immune genes during infection relative to smaller primates. Third, genes that were constitutively under- or over-expressed by large species generally had compensatory changes in expression during an LPS response. That is, genes with lower constitutive expression in larger primates tended to also have more positive changes in expression during infection, and genes with higher constitutive expression tended to have more negative changes. Together, these results support the Safety Factor Hypothesis and indicate that body size even impinges on the regulation of immune responses to bacterial infections.

1455 Marie Drozda, Karen Maruska, Emily Ray

Variations in Sex-Steroid Receptor Levels in the Jaw Muscle of a Mouthbrooding African Cichlids

Parental care is crucial across vertebrates to ensure offspring survival and species persistence. Mouthbrooding is an extreme form of parental care that involves carrying developing young in the mouth for protection, which is associated with dramatic changes in jaw morphology to accommodate the growing offspring. Females of the mouthbrooding African cichlid fish Astatotilapia burtoni brood developing young in their mouths for 14 days, however, the mechanisms that regulate prolonged muscle contraction and jaw expansion to support brood activities are unknown. Sex-steroid hormones such as progestins, androgens, and estrogens impact a wide variety of physiological and behavioral processes across vertebrates, including modulation of skeletal muscle function, and we hypothesized their involvement in jaw muscle plasticity in the brooding cichlid. We compared the levels of sex-steroid receptors in the sternohyoideus jaw muscle of gravid (receptive), brooding, and recovering female A. burtoni using qPCR. Brooding females have higher expression of progesterone receptor mRNA in the jaw muscle compared to gravid and recovering females, suggesting the importance of progesterone in brooding-related jaw activity. We find evidence to support a role for sex-steroids in jaw muscle plasticity across the reproductive cycle of a model cichlid fish. Because fishes are the oldest and most diverse group of vertebrates, this research in A. burtoni provides insights towards better understanding the evolutionary mechanisms that mediate sex-steroid-mediated muscle plasticity across vertebrate taxa.

665 Smith Drupa, Cassandra Donatelli, Adam Summers, Jonathan Huie, Karly Cohen

The Hardest Part is Letting Go: Shear Adhesion in the Northern Clingfish

The northern clingfish, Gobiesox maeandricus, has a ventral suction cup composed of modified fins capable of adhering to rough substrates in the tumultuous intertidal. This disc is lined with papillae that may improve adhesion on irregular surfaces. Regardless of substrate roughness the pull off strength is the same up to a critical roughness. Clingfish are likely to encounter shear forces in nature, leading us to ask whether testing in shear would result in the same roughness-strength relationship. We expected the relationship between roughness and break-away force to be similar, but the force magnitude to be smaller in shear. To test this, we attached clingfish (n = 12, length = 53-114mm) to vertical panels of varying roughnesses (0-127μm) and recorded pull-off force. Between trials, we used ultraviolet light to image the papillae on the disc and record damage. We found a strong relationship between disc area and shear strength, and medium-roughness surfaces required the highest force to dislodge. Partial or full papillae loss only impacted adhesion on the smoothest substrate. These results are different from previous orthogonal tests, where pull-off force was similar on all rough surfaces with successful adhesion, and papillae loss did not impact performance. These results point out the importance of testing animal performance in biologically relevant scenarios.

1341 Joseph Dubie, Ki'Brianna Carthen, Justin Havird

Role of homeostatic processes in balancing selective pressures on mitotypes in C. elegans

Mitochondrial genomes have unique intraindividual dynamics that result in different selective pressures acting on them at various levels of organization. At the organismal level, selection favors mitotypes that contribute to bioenergetic homeostasis and high individual host fitness. However, within individuals, selection favors drive through increased replication and transmission. The balance between these conflicting selective pressures is further complicated by mitochondria being dynamic organelles that fuse, divide, replicate, and degrade in response to intracellular state. These homeostatic processes are thought to affect the balance between intraindividual and interindividual selective pressures by either exposing or masking the phenotypic consequences of mitotypes. To better understand how these homeostatic processes influence selection balance, we used Caenorhabditis elegans bearing a heteroplasmic mitotype, uaDf5, with a 3.1 kb deletion known to exhibit an intraindividual competitive advantage over wild-type mitotypes. We then created four lines bearing heteroplasmic uaDf5 mitotypes and a nuclear mutation that disrupted a mitochondrial regulatory process: 1) drp-1(tm1108), which disrupts mitochondrial fission; 2) eat-3(ad426), which disrupts mitochondrial inner membrane fusion; 3) fzo-1(tm1133), which disrupts mitochondrial outer membrane fusion; and 4) dct-1(luc194), which reduces protease binding efficiency during mitophagy. We hypothesize that these mutations will play a role in either the selective removal or the maintenance of the udDf5 mitotype within these lines. This research will provide insight into the evolutionary fate of new mitochondrial variation.

1701 Jessica Dudley, Marilyn Renfree, Oliver Griffith

The evolution of extended pregnancy involves taming inflammation; evidence from the tammar wallaby

In the first live-bearing mammals, pregnancy was short with only a brief period of maternal-fetal attachment. This period of attachment is characterised by a maternal immune response, which is conserved in marsupials and eutherians. While inflammation is key to successful implantation in eutherians, one key innovation in eutherians is the ability to switch off this inflammation after it has been initiated. This extended period, where inflammation is suppressed, likely allowed for an extended period of placentation, which is a key difference between marsupial and eutherian reproduction. One lineage of marsupials, macropods (wallabies and kangaroos), has also managed to extend placentation beyond the 2-3 days seen in other taxa. We examined endometrial gene expression in the tammar wallaby (Notamacropus eugenii) at various stages through pregnancy to identify how inflammation was regulated throughout gestation. We show that some inflammatory genes are expressed at key time points of gestation, including IL6, prior to attachment, IL12A and LIF throughout the period of placentation and PTGS2 prior to birth. However, we did not see evidence of a complete inflammatory response at any time point. These results are consistent with specific inflammatory genes being co-opted into important aspects of tammar pregnancy, while a generalised inflammatory response is being suppressed or moderated. We argue that modulation of inflammation is a key innovation that allows for the extension of pregnancy in mammals.

1477 Margaret Duerwachter, Jerry Husak

Cardiovascular traits, metabolic rates, and performance of green anoles along a latitudinal gradient

Survival in novel environments and effective colonization often depends on temperature. Reptiles, as ectotherms, are particularly sensitive to temperature changes, yet many species have been able to colonize environments vastly different from a given point of origin. However, the physiological adaptations that allow for survival and persistence in colder climates and their effects on performance characteristics are poorly understood. Oxygen limitation is likely a driving force behind many of these physiological changes; as oxygen supply decreases in cooler temperatures, organisms must either increase oxygen supply by altering the cardiovascular system, decrease demand by lowering metabolic rates, or both. Changes to oxygen availability are also likely to impact whole-organism performance characteristics that are important for survival. Using green anole (Anolis carolinensis) lizards from four locations along a latitudinal gradient, we examined several potential cold-adapted traits, including critical thermal minimum (CTmin), standard metabolic rate (SMR), heart ventricle size, and hematocrit, and their effects on sprint speed and endurance. We found significant population differences in CTmin, heart size, and hematocrit but not SMR, suggesting that changes in oxygen levels are largely managed by increasing supply rather than decreasing demand. Endurance performance was significantly higher in more northern populations, while the opposite pattern was observed for sprint speed.

360 Joseph Duke

Impact of preterm birth on respiratory and cardiopulmonary function in adult humans

Preterm birth results in underdeveloped respiratory and cardiopulmonary systems, which causes challenges to neonatal life and impairments that persist into adulthood. The impairments in function lead to lesser respiratory and cardiopulmonary function at rest and a lower aerobic exercise capacity compared to their term born counterparts. The precise underlying cause(s) of impaired respiratory function at rest and a lower aerobic exercise capacity in adults born preterm is not entirely known, but could be a number of interrelated parameters including mechanical ventilatory constraints, impaired pulmonary gas exchange efficiency, and excessive cardiopulmonary pressures. Whether or not all or some of these aspects are present in adults born preterm and precisely how they may contribute to the lower aerobic exercise capacity is only beginning to be systematically explored. Thus, the purpose of this presentation will be to outline what is currently known about the respiratory and cardiopulmonary limitations at rest and during exercise in adults born preterm. Where possible I will highlight similarities and differences between obstructive lung disease resulting from preterm birth and chronic obstructive pulmonary disease (COPD) as the pathophysiology of these conditions may not be identical. Finally, I will speculate on how respiratory and cardiopulmonary impairments resulting from preterm birth may accelerate the normal age-associated decline in aerobic exercise capacity via an accelerated decline in respiratory and cardiopulmonary function.

1684 Anastasia Dulskiy, Nicola Kriefall, Sarah Davies, Koty Sharp, Karl Castillo

Drivers of microbial diversity in the temperate coral Oculina arbuscula

Disruption of the coral-algal symbiosis (bleaching) in response to anthropogenic stressors, such as warming and nutrient pollution, represents the most significant threat to coral reefs worldwide. Corals are complex meta-organisms ("holobionts") that house a variety of microbes, and recent evidence supports the role of bacteria in facilitating coral acclimatization to environmental stressors. To explore potential microbial underpinnings sustaining the coral-algal symbiosis, we investigated bacterial and Symbiodiniaceae communities in the temperate, facultatively symbiotic coral Oculina arbuscula. In July and November 2021, we collected samples from brown (symbiotic) and white (aposymbiotic) colonies of O. arbuscula at three sites along an inshore-offshore water quality gradient in North Carolina's White Oak River Basin. Coral-associated bacterial and Symbiodiniaceae communities were characterized using 16S and ITS2 metabarcoding, respectively. Additionally, to better understand environmental influences on the coral microbiome, we collected sediment and seawater samples during each sampling event for 16S sequencing. We hypothesize that 1) corals with higher Symbiodiniaceae densities will associate with more diverse microbial communities; 2) coral microbiome composition will differ between sites, with inshore coral microbiomes displaying greater richness, but lower evenness; and 3) microbiome composition will differ across seasons. This study highlights the importance of O. arbuscula as a model to improve our understanding of the coral-algal symbiosis, and underscores the need to better understand the microbial ecology of this abundant, yet understudied, coral.

313 Fernanda Duque, Carlos Rodriguez-Saltos, Kathleen Lynch

Comparative studies using mesotocin in parental and non-parental blackbird species

Parental care is present across all vertebrate taxa, but in some clades, species evolved brood parasitism, relying on females of other species for egg incubation and offspring rearing. The neural substrates that have been modified in brood parasites resulting in the loss of parental care are not well understood, but comparative studies offer the opportunity to unveil such evolutionary changes. While previous studies showed differences in prolactin receptor abundance in the preoptic area in brood parasites compared to closely related parental species, less is known about neural differences in other social-related neuropeptides and their potential consequences on behavior. Here, we conducted a study investigating the effects of mesotocin (MT), homologous to oxytocin in mammals, on the preferences and brain of brown-headed cowbird females and their parental counterparts, red-winged blackbirds. Birds were allowed to explore a nest with eggs paired with dove coos and a nest with a dummy nestling paired with begging calls. We measured female preferences for spending time near/on either nest and their interactions with nest contents. Then, using qPCR we measured transcript abundance of different peptides in brain regions involved in modulating maternal care. This study will show whether MT has differential effects in the brain and behavior of parental and non-parental females. It will also identify nodes in the social behavior network that were modified during the evolution of brood parasitism.

1346 Elena Duran, Jacquelyn Grace, Susan Heath, J Jill Heatley

An investigation into a novel health condition of an iconic shorebird

Birds are important sentinels of environmental change and degradation. Anomalous health conditions of birds are therefore important to document and investigate, as declining health of birds may represent a greater threat to ecological, and even human, health. Here, I discuss the findings of a two year-long investigation into the status of black skimmer chick health on the east Texas Gulf Coast. Black skimmers are iconic coastal birds which, like many avian species, are experiencing population declines and are in need of conservation intervention. In the summers of 2018 and 2020, biologists from the Gulf Coast Bird Observatory documented an unusual health condition appearing in black skimmer chicks, which involved the growth of torsional primary wing feathers, followed by the chicks' inability to fledge. In the summer of 2022, this condition occurred again in conjunction with die-offs of chicks and fledglings, and we began an investigation into the cause. We present the results from that investigation, as well as baseline health data for the establishment of reference intervals for plasma chemistry and complete blood count values for this species. We discuss these results within the broader context of emerging zoonotic diseases and coastal bird species management.

1157 Kristin Dyer, Lauren Lock, Brock Fenton, Nancy Simmons, Daniel Becker

Cellular immunity and hemoparasite prevalence in a fragmented Neotropical bat community

Anthropogenic habitat fragmentation impacts biodiversity, overall ecosystem health, and risk of emerging infectious diseases (EIDs). Ecological disturbances can expose wildlife to chronic stressors, which may affect a host's cellular immunity, susceptibility to pathogens, and ultimately survival and fitness. Neotropical bats are an ideal community to investigate the relationship between habitat disturbances and cellular immunity, as they are linked to numerous EIDs, have high species richness, and are broadly diverse in ecological roles. We sampled a bat community representing an array of ecological niches from both intact and fragmented habitats in northern Belize, a country that supports high bat diversity and is under intense land use change. To explore whether cellular immunity responses to habitat fragmentation are consistent across species or shaped by aspects of host ecology, we will create generalized linear mixed effects models incorporating bat species, dietary niche, and habitat fragmentation. To investigate the role of parasite prevalence, we will conduct microscopy surveys for hemoparasites such as microfilariae and Bartonella spp. We predict the relationship between habitat fragmentation and host cellular immunity will be moderated by bat dietary niche, taxonomy, and/or body mass. We anticipate hemoparasite prevalence will also vary with habitat fragmentation. This study will provide insight into risk factors for EIDs by improving our understanding of physiological stress, cellular immune function, and parasite prevalence in response to habitat fragmentation.

632 Maia Dykstra

Heavy Metal Hyperaccumulation and Physiological Stress in Ulva fenestrata

Ulva fenestrata is a green macroalgae known for its hardiness and rapid growth rate. It is consumed globally and is grown commercially in some areas of the world. It has also been strongly considered as a bioremediation solution due to its capacity to hyperaccumulate contaminants. We investigated the accumulation of chromium and cadmium in U. fenestrata after short-term exposure to ambient metal contamination levels ranging from no contamination to 26 times the maximum level of contamination measured in the Salish Sea. We also observed the effects of physiological stress in the algae under contaminated conditions. We found that U. fenestrata continues to efficiently accumulate chromium

at high contamination levels, but cadmium accumulation loses efficiency with increased contamination. Photosynthetic efficiency and dimethylsulfoniopropionate (DMSP) levels were greatly reduced in individuals exposed to high levels of metal contamination. These results have implications for the use of U. fenestrata as a bioremediator and for informing the placement of Ulva farms in the Salish Sea.

1194 Erich Eberts, Kenneth Welch

Torpor Use in Ruby-Throated Hummingbirds: Energy Stores, Seasonality, Temperature, and Age-Sex Class

Animals utilize various behavioral and physiological strategies to maximize energy gain and minimize energy expenditure despite seasonally changing environmental and ecological constraints. We investigated torpor in ruby-throated hummingbirds (Archilochus colubris) by evaluating how the relationship between endogenous energy stores and torpor use differs with respect to evening foraging, life history stage, nighttime air temperature, and age-sex class. First, hummingbirds that perform evening hyperphagia quickly convert this meal to fat which they subsequently use to fuel their metabolism; thus, torpor use is likely sensitive to endogenous fat stores. Second, in the summer breeding period, birds use torpor to survive energy emergencies when their fat levels reach a critically low threshold, but shift to a routine fat-sparing strategy in the fall migratory period. Thirdly, on colder nights, birds enter torpor more often and at higher fat levels in the summer; however, in the winter, they use torpor frequently, irrespective of fat level and air temperature. Finally, birds experiencing natural daytime conditions in the summer use torpor more when leaner, and developing juveniles use torpor less often than adults. Overall, these findings suggest that seasonal shifts in hummingbird torpor use are governed by an adipostat mechanism that initiates torpor when endogenous energy stores approach levels that are insufficient for immediate survival (energy emergency), or when excess fat stores confer resilience to high future energy demands (energy maximization).

484 Allison Edgar, Dorothy Mitchell, Joseph Ryan, Mark Martindale

The gene regulatory basis for an evolutionary loss of regeneration in ctenophores

The capacity for regeneration is widespread among animals but has been lost many times in their evolutionary history, despite being intuitively adaptive. Ctenophores, the sister group to all other animals, are well known for both their highly stereotyped embryonic development and their extensive capacity for regeneration, which begins at a well-defined time point during late embryogenesis and continues life-long thereafter. However, at least one lineage of ctenophores has lost the ability to regenerate. These taxa are thus an ideal system in which to interrogate the molecular changes underpinning this loss. We are examining the genome-wide regulation of gene expression during regeneration in a widespread model ctenophore capable of whole-body regeneration (Mnemiopsis leidyi) and a sympatric ctenophore that has entirely lost the ability to regenerate (Beroe ovata) to identify potential regulatory changes responsible for this difference in phenotype.

922 Chloe Edmonds, Kaitlyn Robbins, Stephen Howe, Kree Kerkvliet, Rebecca German, Christopher Mayerl

Rhythmic oral stimulation alters rates of feeding behaviors in infant pigs

Infant feeding relies on the integration of multiple sensory modalities to modulate motor output. Manipulating oral sensory experiences may therefore profoundly alter the activity of muscles involved in generating suction and transporting milk. For example, rhythmic vibrotactile and electrical stimulation in the oral cavity can modify rates of non-nutritive sucking and swallowing. However, there is limited insight into the mechanisms underlying these changes in performance. We used a pig model to compare normal bottle-feeding and bottle-feeding with exposure to two types of rhythmic oral stimulation: mechanical stimulation produced by a nipple equipped with a vibrating motor, and electrical stimulation produced by a nipple with exposed electrical contacts. For all three feeding modalities, we collected synchronized electromyographic (EMG) data, intraoral pressure values, and the timing of sucking and swallowing based upon high-speed videofluoroscopy. We found that rhythmic stimulation (either mechanical or electrical) significantly increased the rate of sucking, but that swallow frequency was only marginally impacted, resulting in pigs taking more sucks per swallow when stimulated than when feeding normally. Rhythmic stimulation did not affect the amount of pressure generated per suck, nor the firing amplitude of muscles involved in suction generation. These results suggest that rhythmic oral stimulation has the capacity to alter rates of infant feeding behaviors, but otherwise does not significantly impact sucking and swallowing.

516 Peter Edmunds, Chris Perry

Decadal-scale variation in coral calcification on coral-depleted Caribbean reefs

Many present-day coral reefs in the Caribbean are not spatially dominated by stony corals, which is a striking change relative to 50+ years ago. The ecology of these changes is well known, but the functional implications of a coral depleted state remain incompletely understood. We use annual surveys from 1992 to 2019 to describe coral communities at six shallow sites off St. John, US Virgin Islands, and scale up the effects to explore the interactions between ecological dynamics and coral calcification (G, kg CaCO3 m-2 yr-1). Ecologically, these communities changed incrementally through small annual changes that summed to large effects including depressed coral cover and dominance by weedy corals. Coral G remained low (0.3-1.3 kg CaCO3 m-2 yr-1) but differed among sites and years, largely through variation in the contribution to G of each species. Orbicella spp. was the dominant contributor to G at 4 of the 6 sites where G was the highest, and population collapse of this genus at one site caused G to collapse. These results show that coral-depleted reefs can maintain persistently low G, potentially at rates sufficient to sustain existing reef frameworks, although this capacity is dependent on diminutive populations of small Orbicella spp. Recent losses of the few corals capable of large relative contributions to G have profound consequences for reefs to sustain even low levels of coral G.

1097 Charles Edwards, Jacob Newell, Henry Astley

Lateral head rotation decreases penetration force of a robophysical model in damp granular media

Damp granular media is a challenging environment for burrowing organisms due to higher forces than dry media, but particle cohesion allows for the creation of permanent tunnels. Some limbless squamates such as amphisbaenians and skinks use lateral head rotations during locomotion to excavate and/or reduce the forces required for penetration through cohesive granular media. Sharpe et al (2015) found a decrease in required penetration force following horizontal rotation of a cylindrical intruder in dry granular media, but the advantage quickly dissipated as the intruder moved. To assess the consequences of head motion in damp granular media, we constructed a robophysical model consisting of a 3D-printed cylindrical shaft with a conical head attached via a hinge joint. The head rotation and shaft extension are actuated by hydraulic pistons driven by stepper motors, while load cells placed between the motors and driving pistons measure the forces involved. Forward penetration force in damp sand was recorded for three kinematic strategies: (1) no head movement, (2) side-to-side rotational head movement, and (3) side-to-side rotational movement at a doubled frequency. Penetration forces decreased with an increase in frequency, suggesting that the frequency of head rotation may be an important aspect of such a burrowing strategy. Overall, the mechanics involved in locomotion through damp granular media is understudied, and this research helps to address that knowledge gap.

1180 Phoebe Edwards, Gilda Stefanelli, Iva Zovkic, Melissa Holmes

Manipulating behavioral phenotype in eusocial naked mole-rats using adeno-associated viral vectors

What proximate mechanisms allow behavioral variation to arise in closely related individuals? Naked mole-rats (Heterocephalus glaber) have proven to be an exciting study system for answering this question. These eusocial rodents live in large subterranean colonies with a single breeding female ("the queen"), a breeding male, and dozens to hundreds of non-reproductive subordinates, which are typically the queen's offspring. It has long been documented that these subordinates express behavioral differences, and can potentially be separated into social subcastes or phenotypes. Some subordinates show high levels of aggression to unfamiliar conspecifics, and are the first to respond to a threat to the colony. These aggressive individuals, termed the "soldiers," are often the full siblings of the non-aggressive "worker" subordinates. Furthermore, these behavioral phenotypes cannot be characterized by differences in circulating steroid hormone levels. In order to understand what neural mechanisms may be involved in driving these behavioral differences, we are piloting the use of adeno-associated viral vectors in this species in order to manipulate gene expression in the brain. The species-specific challenges of stereotaxic surgery and the efficacy of serotypes designed for use in mice in this species will be discussed. Ultimately, the goal of this work is to manipulate soldiers to display a worker-like phenotype with down-regulated conspecific aggression.

1433 Noah Egan, Haolin Zeng, Ram Avinery, Shengkai Li, Takao Sasaki, Daniel Goldman

Global coordination using local information in fire ant pontoon bridge simulations

Ants can self-assemble into different structures, achieving colony-wide coordination despite the limited abilities of individuals. Laboratory experiments using subcolonies of 8000 fire ants [Solenopsis invicta] demonstrate that when the ants detect food located in the center of a 14 cm diameter bowl filled with water, they self-assemble into a floating pontoon bridge of approximately 500 ants, allowing the colony to reach the food. Although ants initially build multiple bridges, most of these proto-bridges retract and the colony consistently forms a single bridge by the end of the experiments. Given that individual ants do not have a way of coordinating which proto-bridge to augment, the ability for the colony to construct a single bridge was unexpected. Our agent-based model of the system suggests that ants constantly join and leave proto-bridges with probability that depends on how close they are to the food, and a single bridge emerges from the interactions between ants following this simple algorithm. Since our model results suggest ants do not share information globally, their ability to effectively collaborate should be sensitive to environmental conditions; the model's prediction that ants would form multiple bridges given a water bowl with nonuniform distance between the rim and food was verified in experiments. Our results provide an example of how biological collectives can effectively coordinate over long distances using only information available locally.

255 Austen Ehrie, Alec Iruri-Tucker, Yasmin Lord, Kevin Hunt, P. Polly, Adam Fudickar, Michael Wasserman

Measuring Mantled Howler Monkey (Alouatta palliata) Testes via Parallel Laser Photogrammetry: Expanding the use of Non-Invasive Methodologies

Parallel laser photogrammetry is an up-and-coming methodology that can be used to collect morphological measurements of organisms non-invasively. This method involves attaching two parallel laser beams at a known inter-beam distance to a camera. When a photo of an organism is taken, the lasers project onto the photo and act as a scale so that image analysis programs like ImageJ can be utilized. Traditionally, this methodology has been used to measure certain body markers (limb length, crown-rump length, etc.) as proxies for overall body size. However, recent studies have attempted to measure other body parts within a variety of contexts. Here, we add to this growing body of applications by measuring the testes of wild mantled howler monkeys (Alouatta palliata) with the eventual goal of testing hypotheses about the evolution of sperm competition. Because testes are relatively small and more globular than other body parts traditionally measured with parallel laser photogrammetry, tests of this methodology are required to determine whether it can detect differences between individuals. We measured the testes of eighteen individuals and found an average size of 36.16cm3 and a range of 16.35cm3-54.36cm3. These sizes are consistent with previous studies that collected measurements by hand, suggesting that parallel laser photogrammetry may become increasingly useful for future research.

1480 Chukwuyem Ekhator, Arnavi Varshney, Melody Young, Daniel Tanis, Michael Granatosky, Raul Diaz-Jr, Julia Molnar

Locomotor characteristics of the ground-walking chameleon Brookesia superciliaris

Understanding the locomotor characteristics of early diverging ground-walking chameleons (Genera: Brookesia, Rhampholeon, andRieppeleon) can help to explain how their unique morphology is adapted to fit their environment and mode of life. However, nearly all quantitative studies of chameleon locomotion have focused on the larger, "true arboreal" chameleons. We investigated kinematics and spatiotemporal gait characteristics of the brown leaf chameleon (Brookesia superciliaris) on different substrates and compared them with true chameleons, non-chameleon lizards, and other small arboreal animals. Brookesia exhibits a combination of locomotor traits: some traditionally arboreal, others more terrestrial, and a few that are very unusual. Like other chameleons, Brookesia moved more slowly on narrow dowels than on broad planks, and its speed was primarily regulated by stride frequency rather than stride length. While Brookesiaexhibits the arboreal trait of high degrees of humeral protraction at the beginning of stance phase, it uses larger shoulder and hip excursions on terrestrial substrates. At very slow speeds Brookesia often adopted unusual footfall pattern, lateral sequence lateral couplets. Because Brookesia is a member of one of the earliest-diverging groups of chameleons, its locomotion may provide a good model for an intermediate stage in the evolution of arboreal chameleons. Thus, the transition to a fully arboreal way of life in "true arboreal" chameleons may have involved changes in spatiotemporal and kinematic characteristics as well as morphology.

674 Sabrina Ellah, Kaja Arusha, Krystle Boadi, Daniela Kim, Carolyn Bauer

Relationships between offspring endocrine stress profiles and play behavior in Octodon degus

The purpose of our project was to explore the relationships between offspring play behavior and endocrine stress profiles in the degu (Octodon degus), a rodent native to northern and central Chile. In our study, we used different cross-fostering manipulations at postnatal day 8 to increase the variation of offspring endocrine stress profiles. We chose postnatal days 24 through 28 to analyze offspring play behaviors, as play behavior rates typically peak at this developmental stage. Play fighting, running/hopping, and resting behaviors were analyzed as these provide good metrics of social play, locomotor play, and general activity, respectively. We hypothesized that rates of offspring play behavior would be highest in pups with less reactive stress profiles, leading us to predict that rates of play fighting and running/hopping would be negatively related with stress-induced and post-DEX cortisol levels. These data will add to our knowledge of how endocrine stress profiles relate with play behavior specifically, and general personality more broadly.

1668 Cooper Elliott, Jennifer Dearolf, Shawn Noren

Fiber-type Profile Composition of Adult Beluga Whale (Delphinapterus leucas) Locomotor Muscle

Beluga whales (Delphinapterus leucas) inhabiting Cook Inlet, Alaska, are shallow divers (When comparing the muscle fiber composition, we found the muscle of the Chukchi Sea whales contained more slow type I fibers (81.11% $\pm$ 3.63%) than the Cook Inlet stock (53.12% $\pm$ 5.49%). These findings supported our hypothesis. Thus, the locomotor muscles of the Chukchi Sea whales are built to give them the ability to dive deeper to gather food in comparison to their Cook Inlet counterparts.

1767 Christina Ellison, Svetlana Maslakova

Nemerteans of Pacific Panama

Most marine eukaryotic species are unknown. In the context of modern environmental degradation and climate change, this gap in knowledge significantly impedes our ability to conserve precious resources, predict how larger systems will respond to projected changes, and to identify change in the first place. Molecular data have revolutionized our understanding of what species "look" like and our ability to detect them, but the utility of approaches like DNA barcoding and metabarcoding to rapidly characterize unknown diversity are limited by incomplete reference databases. The key way to extend the reach of these powerful tools is to observe, identify, barcode, and voucher individual specimens for input into databases and museums, and associate records with natural history information.Here, we present data on such an effort for phylum Nemertea, a fascinating and understudied group of (mostly) marine predatory worms, in Pacific Panama. Morphology and DNA barcoding (COI, 16S) suggests there are at least 90 species, compared to the $\sim$20 previously reported, and the 210 known in the (much better sampled) Caribbean. Among these, there are a dozen potential geminate species pairs, several of which belong to cryptic species complexes. 20% of species are represented by larvae and have not been encountered in their adult form. While sampling in the region is ongoing, we discuss potential patterns in diversity, divergence, post-isthmus origination, and cryptic speciation.

558 Max Ellsworth, Jennifer Bronson, Whitney Brownlee, Brittany Burton, Baudry Ilunga, Samuel Perez, Harrison Piper, Nathan Walker, Eric Domyan

Investigating SOX10 function in melanin synthesis in the domestic rock pigeon

Domestic rock pigeons (Columba livia) homozygous for either of two "recessive red" mutations, which are partially-overlapping deletions causing downregulation of Sox10, display brilliant red colors instead of blue/black feathers. Sox10 encodes a transcription factor important for melanocyte differentiation and function, but the precise role that it plays in promoting eumelanin over pheomelanin pigment production in pigeons is unknown. In this study, we performed transcriptomic comparisons of regenerating feathers from wild-type and recessive red pigeons to identify candidate SOX10 targets. We find that the gene expression profiles of pigeons homozygous for either recessive red mutation are similar, consistent with their similar melanogenic phenotypes. We also identify over 100 differentially-expressed (DE) genes between wild-type and recessive red feathers, providing candidate genes for further study. Using an antibody that recognizes the pigeon SOX10 protein, we determined that SOX10 is reduced but not abrogated in recessive red melanocytes, suggesting that other regulatory elements are able to maintain some expression in pigeons with the recessive red mutation. Currently we are using CUT and RUN with the anti-SOX10 antibody to compare the genome occupancy profiles of SOX10 in melanocytes from three different species; pigeon, chicken, and mouse. These data will provide novel insight into the role of SOX10 in melanin production in general, and the extent to which its function may have changed during vertebrate evolution.

1675 Sara ElShafie

Body size tracks precipitation in crocodyliforms and local temperature in lizards over deep time

Extant reptiles are susceptible to temperature and precipitation changes, but the effects of shifts in these climate variables on reptiles over geologic timescales are poorly understood. I investigated these dynamics for two higher order reptile groups occupying different habitats. I hypothesized that maximum snout-vent length (SVL) in both terrestrial lizards and semiaquatic crocodyliforms tracks temperature and precipitation over deep time, and that these patterns emerge across both regional and local geographic scales. I measured 283 lizard and 280 crocodyliform fossil specimens from intermontane basins across the North American Western Interior through the Paleogene (66-23 Mya), which spans warming, cooling, and aridification events. I used extant regressions to reconstruct body size from cranial and limb bones. I also collected over 100 estimates each for paleotemperature and paleoprecipitation from literature and tested for correlation between these variables and maximum SVL in each reptile group.I found that during the Paleogene, maximum lizard SVL (up to 1 meter) corresponded to local terrestrial paleotemperatures within basin assemblages but did not correlate strongly with paleotemperatures averaged across the Western Interior. Conversely, maximum crocodyliform SVL (up to 2 meters) was consistently high across the basins and indicated a strong linear relationship to paleoprecipitation. These results indicate that climate variables affect body size in some ectothermic reptiles over long evolutionary timescales, which deepens our understanding of these dynamics on shorter ecological timescales.

1123 David Elzinga, Charlotte Beckford, Christopher Strickland

A Mathematical Model of the Impacts of Climate Change on the Winter Tick Epizootic in Moose

The winter tick (Dermacentor albipictus) is a cervid-targeting parasite that poses serious conservation concerns for moose (Alces alces) in North America. Described as a greater "enemy" of moose than wolves, bears, and cougars, winter tick parasitism causes moose to excessively groom during nutritionally limited periods, leading to lethal combinations of malnutrition and wound-infections. We construct two mathematical models using ordinary differential equations (ODEs) which are informed by the empirical literature to recreate in silico the seasonal relationships between winter ticks and moose. We then use our mathematical model to forecast the stability of this parasitic relationship as season lengths fluctuate due to climate change. Finally, we test the high-risk conservation hypothesis that limited, seasonal culling can improve moose population stability in the face of these challenges. Our model suggests that delayed first-frosts due to climate change poses a serious threat to maintaining moose populations, but that moderate winter hunting strategies can reduce the threat of extirpation by lowering the tick burden.

34 Zachary Emberts, Wei Song Hwang, John Wiens

Weapon performance drives weapon evolution

Many sexually selected traits function as weapons, and these weapons can be incredibly diverse. However, the factors underlying weapon diversity among species remain poorly understood, and a fundamental hypothesis to explain this diversity remains untested. Although weapons can serve multiple functions, an undeniably important function is their role in fights. Thus, a crucial hypothesis is that weapon diversification is driven by the evolution of weapon modifications that provide an advantage in combat (e.g. causing more damage). Here, we test this fighting-advantage hypothesis using data from 17 species of coreid bugs. We utilize the fact that male–male combat in coreids often results in detectable damage, allowing us to link different weapon morphologies to different levels of damage among species. We find that certain weapon morphologies inflict much more damage than others, strongly supporting the fighting-advantage hypothesis. Moreover, very different weapon morphologies can inflict similarly severe amounts of damage, leading to a weapon performance landscape with multiple performance peaks. This multi-peak pattern could potentially drive different lineages towards divergent weapon forms, further increasing weapon diversity among species. Overall, our results may help explain how sexually selected weapons have evolved into the diversity of forms seen today.

1121 Madison Emery, Bradford Dimos, Laura Mydlarz

Trade-offs between symbiosis and immunity in Cassiopea sp. following Serratia marcescens exposure

In the cnidarian-dinoflagellate symbiosis algae in the family Symbiodiniaceae suppress host immunity in order to establish and maintain intracellular symbiont populations. Specifically, there are multiple lines of evidence that suppression of the master immune regulator NFkB is associated with the acquisition and maintenance of intracellular symbiont populations. This likely results in a tradeoff between the nutrition gained from the symbionts and the hosts' ability to successfully respond to pathogens. Here we utilize the facultatively symbiotic polyps of the scyphozoan Cassiopea, an emerging model system for studying the cnidarian-dinoflagellate symbiosis, to investigate the impact of symbiotic state on disease pathology and gene expression during bacterial infection. Symbiotic Cassiopea polyps are more susceptible to Serratia marcescens infection relative to their aposymbiotic counterparts. To further investigate the impact of maintaining intracellular Symbiodiniaceae populations on disease pathology in Cassiopea, we measure reactive oxygen species (ROS) accumulation, autophagy, programed cell death, and gene expression of symbiotic and aposymbiotic Cassiopea polyps following exposure to Serratia marcescens. Together these data will provide insight on the potential trade-offs between symbiosis and immunocompetence in symbiotic cnidarians.

171 David Ensminger, Nicholas Wheeler, Reem Al-Makki, Kristen Eads, Noah Ashley

Contrasting effects of sleep disruption and Ang-II treatment upon pro-inflammatory responses in mice

Disordered sleep promotes inflammation in brain and peripheral tissues, but the mechanisms that regulate these responses are poorly understood. One hypothesis is that activation of the sympathetic nervous system (SNS) from sleep loss elevates blood pressure to promote vascular sheer stress leading to inflammation. As catecholamines produced from SNS activation can directly regulate inflammation, we pharmacologically altered blood pressure using an alternative approach- manipulation of the renin-angiotensin system (RAS). Male C57BL6/J mice were treated with angiotensin or captopril to elevate and reduce blood pressure, respectively and then exposed to 24-h of sleep fragmentation (SF) or allowed to sleep (control). Pro- and anti-inflammatory cytokine gene expression and as endothelial adhesion gene expression as well as serum glucocorticoids (corticosterone) were measured. RAS manipulation elevated cytokines and endothelial adhesion expression in heart and aorta while SF increased cytokine expression in peripheral tissues, but not brain. However, there were interactive effects of angiotensin-II and SF upon cytokine gene expression in hippocampus and hypothalamus, but not prefrontal cortex. SF, but not RAS manipulation, elevated serum corticosterone concentration. These findings highlight the contrasting effects of RAS manipulation and SF, implying that inflammation from SF is acting on different pathways that are largely independent of RAS manipulation.

897 Marie Ervin, Jackie Culotta, Allen Mensinger, Brooke Vetter

Enhancing Silver Carp Negative Phonotaxis to an Acoustic Stimulus by Reinforced CO2 Conditioning

Invasive silver carp (Hypophthalmichthys molitrix) have created ecological and economic damage in the Mississippi River Basin and are well known for their jumping behavior in response to motorized boat traffic. A promising method of preventing carp migration is the use of non-physical acoustic barriers. However, there is concern that silver carp will habituate to a unimodal acoustic stimulus. Here, we aim to enhance the carp's aversion to an acoustic stimulus by utilizing a reinforced conditioning paradigm. In this study, we trained schools ($N = 5$ individuals) of silver carp to associate a broadband sound stimulus (0.06 – 10kHz) recorded from an outboard motor to the presence of CO_2 ($\sim$25,000 ppm). After a 2-day period of conditioning, we tested the schools with broadband sound only over one week with a reinforced conditioning after the first day of sound testing. To evaluate conditioned schools' responses to sound, we used overhead cameras to film behavior in a two-choice shuttle tank and measured 1) time to exit the sound chamber; 2) time spent in the quiet chamber; and 3) swimming speeds. Results suggest that for schools ($N = 5$) which underwent reinforcement, fish demonstrated increased response to the broadband sound compared with schools ($N = 5$) not reinforced. Findings from this project could be applied to increase acoustic barrier effectiveness at the downstream lock gates along the Mississippi River.

161 Ignacio Escalante, Jerald Kellner, Camille Desjonquères, Rafael Rodriguez

The function of a female-mimic signal type in the vibrational repertoire of male treehoppers

Some animals mimic behaviors or signals of conspecifics while courting. Sexual mimicry is beneficial when it increases reproductive success. We explored the function of a novel form of sexual mimicry in the courtship display of male Enchenopa treehoppers. Males produce plant-borne vibrational advertisement signals, to which females respond with their own signals. Interestingly, males also produce a signal that mimics these female responses. We experimentally tested its function. First, we tested if this signal would increase female response. However, females were as likely to respond to playbacks with or without the female mimic signal. Second, we tested if the mimic signal would inhibit competing males. However, males were as likely to produce displays after playbacks with or without the mimic signal. Third, we tested if this signal would provide a self-boost to males, and expected that males performing it would show higher signaling effort. Males that produced the mimic signal had higher signal rates and longer signals than males that did not produce it. We suggest that the mimic signal provides the males with positive motivational feedback. Thus, the evolution of sexual mimicry –and signal repertoires– may be influenced by the effects on the sender itself, besides the effects on the audience.

1771 Jacqueline Esimike, Mitchell Ford, Arvind Santhanakrishnan

Multi-scale flow characterization around and through physical models of a reticulate sea fan

Sea fans are an order of corals consisting of large colonies of tiny polyps. These colonies can take on a range of morphologies that contain numerous branches and porous spaces between polyps. The polyps rely on environmental currents flowing over the colony for suspension feeding, removing waste and gas exchange. Existing literature shows that small-scale recirculating flow patterns behind polyps can help in enhancing particle capture rates. However, it is unknown how the interaction between the large-scale flow over the colony and the small-scale flow through the pores affects the filtration efficiency under varying background flow conditions. In this study, we conducted planar particle image velocimetry (PIV) measurements on a 3D printed physical model of a reticulate sea fan (Gorgonia ventalina) in a water tunnel under continuous flow speeds ranging from 7-28 cm/s. Preliminary results indicate that volumetric flow rate downstream of the model increases for smaller fan bending angles. The effects of varying fan bending angle on large-scale flow patterns and leakiness of flow through the pores will be presented.

1627 Miguel Estrada-Caballero, Brian Tsukimura

Potential Climate Effects on the Chinese Mitten Crab, Eriorcheir sinensis, Populations in the SF Bay

In 1992, the invasive Chinese Mitten Crab (CMC), Eriocheir sinensis, was discovered in the San Francisco Bay Delta system due to human introduction. Since the establishment of CMC, there have been many negative environmental and economic impacts surrounding the San Francisco Bay. Explosions in adult populations can potentially have negative effects on native species through competition and predation. Monthly plankton tows taken by California Department of Fish and Wildlife (CDFW) at station D41 were analyzed for E. sinensis zoeae. Brachyuran zoeae and megalopa were keyed to species with the use of a dichotomous key (Rice and Tsukimura, 2007; Gonzales et al., 2009). In April 2003, was the highest number of CMC zoeae where they recorded a total of 407 larva samples (CPUE = 4064.5). By 2005, no adult crabs were found in Otter trawls conducted by the CDFW and by 2008, no CMC zoeae were found in plankton tow surveys. However, in 2012 a total of 26 CMC megalopa were discovered and in 2013, another 9 CMC megalopa were found. Temperatures below 11.8°C and salinities below 15 psu are associated with declines in CMC abundances. Strong La Niña intensities are associated with increased abundances of CMC. If population explosions can be predicted, preparations can be made for the negative effects caused by the downstream migration of CMC juveniles.

671 Allyson Evans, Emily Naylor, Sandy Kawano, Nathan Lujan, Patricia Hernandez

Functional Morphology and Kinematics of Jaw Protrusion in the Hingemouth, Phractolaemus ansorgii

Variation in the mechanisms of premaxillary protrusion and the performance advantages they confer have been implicated in the success of diverse teleost fish lineages such as minnows and spiny-rayed fishes. Highly kinetic systems that actuate jaw protrusion have long been fascinating to functional morphologists as they represent multiple solutions to the same ecological challenge — that of feeding in a viscous, fluid medium. However, scarce are the studies that investigate jaw protrusion beyond Cypriniformes and Acanthomorpha and beyond the relatively conserved musculoskeletal architecture enabling it. Here we investigate an isolated and independent origin of jaw protrusion in the hingemouth, Phractolaemus ansorgii, which employs a novel arrangement of bones, musculature, and connective tissue to feed on detritus via a deployable proboscis. We quantify 3D feeding kinematics and find P. ansorgii are capable of modulating the angle and distance of jaw protrusion, with maximum anterior protrusion exceeding 30% of head length. This represents a previously undescribed example of extreme jaw protrusion on par with many cichlid species. Furthermore, we describe what is in essence a second functional mouth at the end of the proboscis composed of flexible connective tissues and intricate skin folds that function to probe and grasp along the substrate. Though this highly specialized mechanism may have limited versatility over evolutionary timescales, it represents a unique functional solution for life evolved in fluid.

1366 Katherine Evans, Steven Juliano

Better Late than Never? Evaluating when the Sterile Insect Technique will work against Aedes

The Sterile Insect Technique (SIT) is a species-specific pest control technique that has recently been used to target disease-carrying mosquitoes. I am interested in measuring ecological factors that can be used as indicators of the likelihood for success of this technique across different environments. I tested the hypothesis that the Sterile Insect Technique is effective when the interaction between resource level and larval density does not result in strong negative-density dependent effects. I carried out two iterations of this experiment over the summer of 2022. The early summer iteration corresponds with low population numbers of Aedes albopictus; the late summer iteration corresponds with high population numbers of Ae. albopictus. Eggs were collected at naturally occurring densities in the field. Larvae were hatched in the lab and counted to the densities surveyed, and subjected to either an "SIT" mortality treatment or left at the surveyed densities as a control.Preliminary data indicate that densities were greater in the late summer. I predict to see strong negative-density dependent effects in containers in the late summer iteration of the experiment, potentially leading to less effective execution of SIT at that time. This research will lead to an ecological framework for the success of SIT against Aedes mosquitoes.

1135 Rebecca Evey, Matthew Savoca, John Ososky, Michael McGowen, Jeremy Goldbogen, Kathleen Hunt

Reconstructing Stress and Reproductive History of Critically Endangered Rice's Whales Using Baleen

The Rice's whale (Balaenoptera ricei) is a newly characterized species of baleen whale found in the Gulf of Mexico. With fewer than 50 adults remaining, the Rice's whale is the world's most endangered baleen whale species. Analysis of reproductive and adrenal hormones could assist in understanding stress physiology and reproductive cycles in this poorly understood species. Baleen plates contain steroid hormones stored throughout the period of baleen growth and have been used for continuous, multi-year retrospective assessment of reproductive and stress history of individual whales. We measured progesterone, testosterone, cortisol, and corticosterone in baleen plates of seven individual Rice's whales (four males and three females), including two individuals believed to have died from starvation. Baleen powder was obtained by drilling every 1 cm (~15-30d intervals) from the base of the plates to the distal end. Hormones were extracted from the powder with methanol and concentrations quantified with commercial enzyme immunoassay (EIA) kits. All assays demonstrated parallelism for Rice's whale baleen extract. In the two individuals that died of starvation, all four steroid hormones show increases in the most recently grown baleen, a pattern observed in other baleen whales in cases of prolonged illness or injury before death. In addition, pregnancy was successfully detected in one individual. Baleen hormone analysis may help clarify endocrine history and causes of mortality in this critically endangered species.

317 Josh Faber-Hammond, Suzy Renn

Transcriptomics of Astatotilapia burtoni mouthbrooding reveals extensive stock divergence

Parental behavior has evolved multiple times in animals. Although it is a costly reproductive strategy for the parents, it increases fitness through a higher survival rate in offspring. Cichlid fishes are an evolutionary model system since they have a high propensity for speciation and have undergone recent radiation. In cichlids, parental behavior has independently evolved multiple times and in Astatotilapia burtoni, for example, females protect their developing fry in a buccal cavity, which protects underdeveloped fry from predation and environmental pathogens. During mouthbrooding, the females voluntarily fast so they do not accidentally swallow their offspring. In this study, we sequenced A. burtoni whole-brain transcriptomes from both lab stock and mixed wild stock females at different timepoints throughout the reproductive cycle in order to discover candidate genes linked to these evolved mouthbrooding and fasting behaviors. We found genes that are differentially expressed between reproductive timepoints involved in oxygen transport, lipid metabolism, and other metabolic processes. Interestingly, the genetic background of individuals was far more predictive of global expression profiles and points to extensive transcriptome evolution driven by potential environmental and/or domestication selection having an outsized influence on gene expression in the brain.

1330 Samantha Falcone, Jason Ramsay

Functional morphology of the feeding apparatus in Esox niger: Adaptations for manipulation of prey

The prey processing mechanism of fish like Esox niger, chain pickerel, appears to be unique to the Esox genus. Following ambush and capture of large prey, pickerel processes it by "walking" their jaws along the prey's body until its head is reached, at which point the prey is swallowed head-first. This is paradoxical, for these fish appear to be holding onto live prey to prevent escape yet letting go at the same time to reposition it for swallowing. Here we explore the musculoskeletal features of pickerel that may facilitate the large-prey processing mechanism. We also compare these features with those of largemouth bass, Micropterus salmoides, a suction feeder, to better expose the anatomical differences that may be associated with the mechanism. Increased mobility of maxilla and palatine bones are observed in pick-

erel, which allows for independent elevation and depression of left and right palatine tooth pads. The independence of movement may let one side hold prey while the other is repositioned. Architecturally, the jaw closing muscles in pickerel and largemouth differ in muscle fiber, and tendon length, but not cross-sectional area. Jaw closing leverage is higher in pickerel, but this is due to their increased lateral gape. The exposed gape allows for a larger functional surface available for biting that extends much closer to the jaw joint than that of largemouth.

1290 Jay Falk, Alejandro Rico-Guevara

The daily life of a hummingbird: Developing a movement ecology of the tiniest birds

Hummingbirds live life at the extremes of vertebrate mobility capabilities. Simultaneously, their small size and rapid movement make them challenging to study. This has occasionally led to widely held, but rarely tested assumptions. For example, hummingbirds are thought to exhibit either territorial or trap-lining feeding strategies which vary by sex and species, yet there have been few attempts to study these behaviors at the individual level. We developed a technique to monitor movement strategies of individual hummingbirds using Radio Frequency Identification (RFID) and gathered data on over 150 white-necked jacobin hummingbirds (Florisuga mellivora) and 70,000+ feeder visits in Gamboa, Panamá. We found that individual hummingbirds demonstrate a high degree of flexibility, often shifting their feeding strategies from one day to the next. We also found that females and males are not categorically different in their feeding strategies – some males exhibit territoriality more often than females, but this was not consistent within nor across individuals. Ultimately, these data represent a powerful technique for studying small birds in the field and offer a more nuanced understanding of the daily lives of hummingbirds.

1364 Victoria Farrar, Alison Ramirez, Jaime Morales-Gallardo, Rebecca Calisi

Does gaining parental experience alter neural hormone receptors? Insights from biparental rock doves

Individual animals with prior parental experience often show increased responsiveness to offspring and more rapid onset of parental care behaviors. Further, experienced parents often show reduced levels of hormones associated with stressors, such as glucocorticoids, during parental care when compared to inexperienced individuals. One mechanism by which parental experience may lead to more efficient care may be increased neural sensitivity to hormones associated with parental behaviors. Conversely, experienced parents may be less sensitive to hormones involved in stress responses, allowing them to maintain care in the face of challenges. To test these hypotheses, we evaluated gene expression of receptors for prolactin, vasoactive intestinal peptide (VIP), and glucocorticoids in the hypothalamus, pituitary, and hippocampus, respectively, of both male and female biparental rock doves (Columba livia). We measured these receptors in birds that had either previously raised chicks or had not. We also attempt to control for the effect of age, as animals cannot gain parental experience without also getting older. We found that parental experience did not appear to increase neural receptors for parental hormones (prolactin and VIP). However, parental experience did alter expression of hippocampal glucocorticoid receptors involved in negative feedback regulation. Our results shed light on a potential neural mechanism by which parental experience may increase fitness outcomes over an animal's lifespan.

1663 Hannah Farrell, Callum Ross, Zeresenay Alemseged

Cortical bone distribution in the hominoid clavicle through ontogeny

Extant apes (Gorilla, Pan, Pongo, Homo, and Hylobates) are well known for their locomotor diversity and versatility, made possible in part by their highly mobile shoulder joints. Some taxa also show significant locomotor regime shifts through ontogeny – for example, Gorilla and Pan transition from performing predominantly arboreal behaviors as young juveniles to being almost entirely terrestrial as adults, though they never fully give up climbing. Previous investigations of the cortical bone distribution in the adult hominoid clavicle have hinted at the utility of cross-sectional geometry to distinguish between taxa and provide insights into how the bone is loaded during locomotion. Here, we expand the original sample ontogenetically to explore how the previously identified trends in adult cortical distribution are established through adolescence. Using micro-CT scans of wild-origin adult and juvenile hominoid clavicles ($N = 121$) and the R package morphomap, we calculated the minimum (IMIN) and maximum (IMAX) area moments of inertia (second moments of area) as well as the moments of inertia in the dorso-ventral (IDV) and cranio-caudal (ICC) planes at 20 evenly spaced cross-sections across the diaphysis in order to document variation between taxa through ontogeny. Preliminary analysis of these data suggests the overall distribution of cortical bone in the hominoid clavicle is dynamic through ontogeny, modeling in response to habitual loading incurred during each life stage.

1584 Kayla Fast, Matthew Scott, Alex Rakestraw, Magdalene Dogbe, Heather Jordan, Sophie Picq, Joseph Receveur, Alexandra Bauer, Christine Chevillon, Jean-François Guegan, Jennifer Pechal, Eric Benbow, Michael Sandel

Assessing the effects of nonindigenous aquatic species on freshwater microbial communities

The Guppy (Poecilia reticulata) and related species rank among the most widespread and common invasive freshwater fishes on Earth. As larvivorous fishes, they have been introduced globally as biocontrol agents, in the hope of reducing human exposure to Malaria and other mosquito-borne diseases. We sought to assess the potential of nonindigenous poeciliids to serve as reservoirs of aquatic and zoonotic bacterial pathogens. We collected Guppies from a variety of native and non-native habitats in the Caribbean Islands, French Guiana, Hawaiian archipelago, southeastern coast of the United States, and geothermal waters of the continental United States. We used traditional 16S metabarcoding to characterize the dermal and subdermal microbial communities of each population and used multivariate statistical tools to assess differences across taxa and habitats. Our results indicate that nonindigenous Guppies and related species may serve as important sources of opportunistic pathogens that negatively impact aquaculture and human health.

1152 Michael Fath, Eric Tytell

Bluegill (Lepomis macrochirus) minimize destabilizing torques by resting at an unstable equilibrium.

Static stability in fishes is dependent on the relationship between gravity, which acts at the center of mass (COM), and buoyancy, which acts at the center of buoyancy (COB). These forces will generate rotational torques unless the COM and COB are vertically aligned. With the COB above COM, the configuration is self-stabilizing. In the opposite configuration, with the COM above COB, the fish is in an unstable equilibrium – even the smallest perturbation will move the system out of alignment and result in further rotation. Previous studies measuring the location of the COM and COB in dead bluegill have found different results: either no statistical difference between the location of the two points, or a dynamic, pitch dependent relationship. To better understand the COM/COB relationship in bluegill we measured pitch angle and rotation in living and anesthetized fish. Our results indicate that in live bluegill, the COM is dorsal and posterior to the COB, indicating that the stable equilibrium is belly up and the unstable equilibrium is at a head-down pitch angle. We found that in periods of low activity at night, bluegill ($n = 5$) remain pitched 18 ± 12 degrees head down. Thus, resting bluegill assume a pitch angle that may vertically align their COM and COB, minimizing destabilizing torques.

646 Avalon Feiler, Matthew Kolmann, Cassandra Donatelli

Relating active and passive bending to armor overlap in the starsnout poacher(Bathyagonus alascanus)

Animal armors have evolved frequently across the tree of life, with most vertebrates adopting some manner of overlapping or adjoining bony plates. The poachers (Agonidae) are bottom-dwelling temperate marine fishes, characterized by overlapping armor plates which cover their entire bodies. As with other heavily armored fishes, agonids still retain some significant body flexibility. However, agonids do not use their lateral flexibility for swimming; instead they propel their straightened body forward with their pectoral fins. To investigate the function of this flexibility and explore a potential trade-off between protection and flexibility, we measured curvature during both passive and active bending and used micro-computed tomography (μCT) scanning to determine the extent of armor plate overlap. We have determined that flexibility in our study species, Bathyagonus alascanus, varies directionally and that high lateral flexibility seems to be used defensively to thrash out of a grasp. Additionally, morphology determined with μCT scans indicates that scale movement is dictated by interlocking rail mechanisms between scales, and that flexibility and curvature are restricted by material barriers that act as brakes or curbs, limiting the extent to which scales can overlap. This all suggests that while armor does limit range of motion, it does so selectively - bending more in some directions than others, a behavior that might be well applied to biomimetic design in protecting joints while preserving motion.

176 Ryan Felice, Ryan Marek

Phenotypic integration shapes the evolution of the neck and forelimb in birds

The morphological diversity of birds is thought to have been facilitated by the acquisition of a suite of key innovations, including powered flight, an edentulous beak, and large brain size. In contrast to these well-studied morphological traits, the long and highly mobile neck of birds has often been overlooked as a key anatomical innovation. How did variation in this structure evolve and how has its morphology been shaped by functional correlations with other traits? Here, we interrogate a hypothesized three-way trade-off between the neck, head, and forelimb of crown birds. Using geometric morphometrics and linear metrics, we quantified cervical vertebral shape, limb proportions, and head size in 170 species of birds. Using phylogenetic two-block partial least squares analysis we demonstrate that cervical morphology is tightly integrated with forelimb morphology (PLS correlation = 0.78-0.81, p = 0.001), with the strongest correlation observe in the pre-thoracic vertebra. The rate of multivariate morphological evolution differs across regions of the cervical column, with the caudal-most vertebra exhibiting the highest rate. These results support the hypothesis that that the neck and wing are tightly integrated, likely due to associations related to flight muscles that attach to the pectoral girdle and neck (mm. latissimus dorsi and mm. rhomboideus). Thus, we propose that neck evolution is an important but previously underappreciated facet of morpho-functional evolution in birds.

776 Kate Feller

Neuromechanics of latch & spring ballistic movement control in the mantis shrimp, Squilla empusa

Mantis shrimp crustaceans use a latch-mediated, spring-actuated mechanism to produce extremely fast, ballistic strikes. These strikes are not deployed at consistent speeds, but varied to meet the needs of the animal in different ecological contexts. To understand the neuro-muscular controls that underlie mantis shrimp strike and their tunability, multi-channel electromyogram (EMG) recordings were conducted on live, restrained specimens of the species Squilla empusa. To analyze variable strike speeds, restrained animals were provoked to produce repeated, defensive strikes while recording simultaneous EMG and high-speed video (8000 fps) in either air or water. Differential EMG electrodes were inserted into each of the four muscles housed in the merus, the limb segment responsible for producing strike movement. Anatomical positioning of the electrodes was confirmed via microCT imaging of the limb, post hoc. The four muscles in the merus, a lateral and medial extensor/flexor pair, demonstrated highly synchronized activity, or co-contractions, prior to almost all strike movements. Comparisons of muscular spike timing and length of activity prior to movement at different peak angular velocities and accelerations were also conducted. Overall, this study advances our understanding of the neuromuscular controls underlying latch-mediated, spring-actuated biomechanical systems.

55 Catie Fenstermaker, Zachary Morris

Unraveling the embryonic origins of squamate palate diversity

Extant lizards and snakes (squamates) possess a diverse range of anatomical specializations, including modifications to the palate which impact olfaction, diet, and cranial kinesis. Although the evolutionary and functional consequences have been extensively studied, the developmental origins of this disparity remains poorly understood. To address this, we used CT scanning to capture palate shape for an embryonic and post-hatching growth series (i.e., ontogeny) of one species of gecko, Paroedura picta. We performed a 2D geometric morphometric analysis to quantify and compare this variation to a representative sample of adult squamates (n = 36). Morphospaces for both the complete palate (17 fixed landmarks) and pterygoid only (3 fixed and 8 semilandmarks) datasets revealed that major clades form distinct clusters, with ‘neochoanate’ species as most distinct. Analysis of P. picta reveals three distinct morphotypes that correspond to embryonic, juvenile, and adult conditions for both the pterygoid and complete palate. Across ontogeny, the pterygoid elongates, flares anteriorly, and increases in medial curvature. Additional expansion of the maxillary shelf, palatine, and vomer were observed in the complete palate ontogeny. These transformations are relatively minor compared to the variation recovered among species, suggesting changes to early embryonic development (i.e., before onset of ossification) may be key to the evolution of squamate palate diversity. Future analyses including ontogenies of additional species and comparisons of 3D palate shape will further test this hypothesis.

1749 Stephen Ferguson, Morgan Fimreite, Harrison Williams, Elizabeth Danka

A test of physiological trade-offs in response to artificial light at night in passerine nestlings

Exposure to artificial light at night (ALAN) can disrupt the circadian rhythms of animals, resulting in altered behavior, physiology, and development. While many of these effects are negative, including a reduction in circulating melatonin, increased glucocorticoids, decreased body mass, and altered activity patterns, exposure to low-level ALAN often induces an exaggerated response in tests of immunocompetency. These improved responses may themselves come with a physiological cost in altricial young, which must balance maintenance efforts with growth and development. We hypothesized that two costly physiological processes, the innate immune response and telomere dynamics, trade off in developing passerines. We tested this by exposing house sparrow (Passer domesticus) and tree swallow (Tachycineta bicolor) chicks to low-level ALAN (~1 lux) in nest boxes for 5 nights mid-development (nights 5-9 and 7-12, respectively). We conducted Escherichia coli bactericidal assays on plasma and measured telomere lengths from DNA collected pre- and post-exposure. Bactericidal effects increased as birds aged and in ALAN exposed chicks. We will discuss the effects of ALAN on telomere dynamics and trade-offs between telomere maintenance and immunocompetency, as well as differences in outcomes between a declining native and successful invasive species.

1817 Ryan Ferrer, Eric Long, Baine Craft

Effects of predator odors on deer-fir interactions in a predator-free environment

Although decoupling of plant-herbivore interactions by herbivore predators has been studied extensively, few studies have examined potential changes in plant chemical responses to chronic herbivory when predator-naïve herbivores are confronted with historic predator chemical cues. In this study, we examined interactions between blacktail deer (Odocoileus hemionus columbianus) and Douglas fir (Pseudotsuga menziesii) in an island environment lacking deer predators for over a century. We video recorded free-ranging deer behavior with trail cameras at sites conditioned with either wolf urine (historic predator) or cow urine (control) as an indicator of predation risk. In addition to assessing browsing intensity, monoterpene chemistry was measured with GC-MS in both caged and uncaged fir saplings at each site.

531 Marioalberto Ferrero, Benjamin Cellini, Jean-Michel Mongeau

Altering visual feedback in augmented reality reveals that Drosophila's gaze system is not flexible

Like many animals, fruit flies (Drosophila) must differentiate between external (exafferent) and self-generated (reafferent) feedback to guide locomotion. However, if and how flies adapt to changes in reafferent feedback by updating a putative internal model is currently unclear. We developed a novel experimental paradigm that enabled real-time augmentation of natural reafferent feedback in tethered flies that were free to rotate about the vertical axis. Flies were placed in a virtual reality flight simulator and the visual display was updated proportionally to body motion, with distinct coupling gains. We discovered that gaze stabilization responses to augmented feedback displayed little change over a span of 30 minutes, suggesting that flies do not learn to update their putative internal model. We modeled the gaze stabilization system as a linear dynamical system and applied control theory to make specific predictions of a fly's response to augmented feedback. The close match between our predictions and experimental data strongly supports a reflexive, rather than adaptive, neural architecture. Lastly, we found that augmented reafferent gains large enough to invert natural reafference led to flight instability–a feature predicted by linear systems theory. Altogether, these findings demonstrate that flies do not learn to update their putative internal model when natural feedback is altered, implying that the internal circuitry for gaze stabilization might be hardwired and thus not adaptable on appreciable timescales.

389 James Fifer, Sarah Davies, Kelly Speare, Megan Maloney, Marie Strader

Impacts of an extreme coral bleaching event on population connectivity and genetic variation

Bleaching episodes can act as major selective events by causing widespread mortality if corals fail to recover. These events can impact island-wide distributions of genetic variation in a myriad of ways. For example, if certain haplotypes are better adapted to surviving heat stress or recolonizing newly available space created by the mortality event, then the abundance of these variants would be expected to increase. Likewise if the selection strength (in this case extent of temperature increase) is variable and the pre-bleaching spatial distribution of genetic variation is non-uniform across sites, then this too would cause restructuring, albeit in a more random fashion. If restructuring is non-random, tracking changes in allele frequencies before and after a bleaching event could provide insight into genomic loci that are responsible for adaptation to heat stress. Additionally, sampling once newly available space is colonized by recruits can elucidate the permanence/transience of these shifts. In 2019, a mass bleaching event occurred in Mo'orea, French Polynesia, where 50-80% of Acropora hyacinthus at key sites died as a result of bleaching. Whole genome sequencing was performed on adult coral A. hyacinthus colonies surrounding the island of Moorea during the following timepoints: 1) the May 2019 bleaching event in May, 2) after bleaching had subsided in October, and 3) new recruits in November 2021. High resolution sampling of the population prior.

1578 Sara Filler, Nivea Patel, Sophie Kogut, Daniel Munteanu, Sara Cahan, James Waters, Seth Frietze

Comparative analysis of RNA-seq library preparation protocols on thermally-stressed D. melanogaster

The transcriptome provides a way to measure how environmental changes affect an organism on the molecular level. It yields information regarding which genes are being expressed, in what quantities, and which isoforms. It also provides information regarding the use of regulatory molecules, including long non-coding RNA (lncRNA). Through current RNA-sequencing methods, RNA transcripts are isolated, reverse transcribed, and sequenced via high-throughput sequencing. Currently, there are two main methods for isolating RNA transcripts. PolyA selection collects all transcripts that are polyadenylated, primarily messenger RNA and some lncRNA. Ribosomal RNA (rRNA) depletion collects all RNA transcripts except those that are ribosomal. The rRNA depletion method is less established for Drosophila melanogaster, but is predicted to capture more transcripts encoding lncRNA. Given D. melanogaster is a model organism, we aimed to compare these existing methods of RNA-seq library preparation in thermally stressed D. melanogaster by examining changes in gene expression and splicing. Our results show rRNA depletion identifies more differentially expressed genes overall, but is not better than polyA selection at detecting differentially expressed lncRNAs. Furthermore, polyA selection allowed for much higher quality splicing analysis. Overall, our results found rRNA depletion to provide no substantial advantage over the polyA selection method of RNA transcript isolation.

1103 Rose Fiorenza, Jessica Goodheart, Hereroa Johnston, Antonia Bock, Park Masterson, Deirdre Lyons

Using in situ HCR and scRNAseq to Identify Juvenile Cell Types in Nudibranch Berghia stephanieae

Characterizing distinct cell types in metazoans necessary to understanding the mechanisms behind their function and evolution. The nudibranch Berghia stephanieae is emerging as a model to study the cellular mechanisms behind neurogenesis and nematocyst sequestration (the uptake of stinging cells from cnidarian prey), due to its feasibility for culturing. To begin investigating how cell identity becomes established in Berghia, it is necessary to first identify genes that characterize particular cell types. We collected single-cell RNA sequencing data to cluster these distinct cell types in Berghia juveniles immediately following metamorphosis. We have previously optimized HCR protocols in Berghia using the phagocyte membrane receptor C-type lectin as a target gene due to its role in the selection of nematocysts in cnidosac cell and upregulation in the distal ceras of Berghia.We plan to use in situ hybridization chain reaction (HCR) to visualize mRNA expression of the clusters' top differentially expressed gene to validate our scRNAseq data set. Validation of neural clusters and identification of neural cell types in juveniles will allow for a future spatio-temporal understanding of neural specification and differentiation. Validating our scRNAseq data and identifying cell types will allow us to investigate the mechanisms behind how these cells differentiate in Berghia stephanieae and how these identities may be conserved across taxa.

98 Melanie Fischer, Gareth Fraser, Karly Cohen

By the skin of their teeth: morphology and replacement of Squalus suckleyi

All sharks are covered in denticles; ectodermally derived tooth-like structures that are highly variable in shape and size due to function and hydrodynamic responsibility. Denticles develop similarly to teeth however, it is not clear if like teeth denticles ever replace and if they do, what mechanisms are responsible for renewal. In oral teeth, replacement is controlled by the dental lamina – tissue located in the jaws that secretes the necessary genes for building and maintaining teeth.Using micro-CT scanning, electron microscopy, and histology we investigate the morphology and replacement of denticles in the Pacific spiny dogfish, Squalus suckleyi. We initially hypothesized that denticles would replace differently than oral teeth due to the lack of dental lamina and that replacement is instead driven by damage. Instead, we found denticles replacing across the body of the shark and replacement was not inherently due to damage or loss. Replacement denticles were superficial to the dermal region of the skin and not associated with any identifiable dental lamina-like structure. Denticles typically emerge first as two dorsolateral rows in eggcase developing sharks, however in S. suckleyi, a viviparous shark, we saw no apparent dorsolateral row. This could indicate a difference between internal, uterine and external, eggcase developing sharks. This study shows denticle replacement differs from oral teeth replacement and that the emergence pattern is not a shared characteristic amongst all sharks.

365 Bean Fischer, Josh Faber-Hammond, Suzy Renn

So hungry they could eat a fry: Neural expression of mouthbrooding female African cichlid

The neuropeptide orexin, in addition to its namesake role in the regulation of feeding, has been shown in recent research for its role in regulating other social behaviors: arousal, stress, and multiple facets of motivation in maternal caregiving. Other regulatory neuropeptides, such as galanin, have been investigated for their role in mouthbrooding female Astatotilapia burtoni, providing a basis for this research to expand on using orexin for its combined role in feeding and motivation. If mouthbrooding is a costly behavior, putting the female into a period of starvation, how does orexin contribute to the motivational reward circuitry to continue the promotion of maternal care? In understanding the costs and underlying mechanisms for maternal behaviors other neuropeptides have been investigated; it is orexin's specific association with motivation and reward behaviors that prompt its interaction with costly maternal care. The neural expression and regulation of orexin were quantified using in-situ hybridization and immunohistochemistry antibody staining. Increased orexin expression is associated with increased appetitive signaling, suggesting that mouthbrooding A. burtoni will have increased orexin expression compared to females with access to food. As orexin impacts the dopaminergic system of the reward circuit concerning maternal care, interaction effects of dopaminergic and orexigenic systems may contribute to the complex mouthbrooding behavior of female cichlids.

136 Frank Fish, Caitlyn Swiston, Scott Moon, Allison Kolpas, Megan Leftwich

Taking a new heading: the sea lion head as a control surface

The California sea lion (Zalophus californianus) is highly maneuverable and agile in the aquatic environment. The sea lion has large control surfaces for aquabatic maneuvering that are modifications of the fore and hind flippers, respectively. However when executing rapid turning maneuvers, it is the head which leads the turn. Sea lions were examined when performing hairpin turns from video recording the animals from above as they swam under a floating viewing window. Coming into the turn, the sea lions would hyperextend the head and neck and roll 90 deg so that the dorsum was facing the inside of the turn. The forward velocity of the animal and bending of the neck gave the head an angle of attack of approximately 20 deg. A cadaver head from a female sea lion was 3D scanned and used to build a 3D model. The model was connected to a force transducer and placed in a flow tank and tested at 1 m/s. The model head generated lift with a maximum lift coefficient of 0.77 at 38 deg and the maximum lift/drag of 1.31 at 26 deg. The position of the head well anterior of the center a mass and generation of lift would provide sufficient torque to aid the other control surfaces in rapid turning maneuvers.

1773 Adrian Fisher, Jordan Glass, Nicole DesJardins, Cahit Ozturk, Yash Raka, Keerut Chahal, Gloria DeGrandi-Hoffman, Brian Smith, Jennifer Fewell, Jon Harrison

The impact of a widely used fungicide on honey bee (Apis mellifera) health

The honey bee (Apis mellifera) is essential for crop pollination worldwide. Despite their importance, honey bees and other pollinators face ongoing declines due in part to pesticide exposure in the foraging environment. Honey bees frequently encounter fungicides, in particular, because they are applied to blooming crops. To assess the effects of the widely used fungicide Pristine₮ (25.2% boscalid, 12.8% pyraclostrobin) we exposed colonies to concentrations of the fungicide reflecting levels detected in almond orchards. Chronically exposed hives experienced reduced worker populations and increased winter mortality. We also observed elevated rates of pollen foraging and consumption, potentially indicating impaired protein processing. Pristine₮ consumption induced several sublethal effects on individual workers including precocious foraging, reduced longevity, reduced cognitive abilities, and lower thorax mass. Adverse effects of fungicide exposure also resulted from reduced exposure durations simulating the bloom period of a major bee pollinated crop but with differences in severity by season. A four-week exposure to the fungicide Pristine₮ reduced worker longevity, induced precocious foraging and temporarily reduced colony population levels during summer. Fall exposure was not associated with negative outcomes and coincided with differing colony conditions including reduced brood production and pollen consumption. Together, these findings support the hypothesis that fungicides such as Pristine₮ negatively impact honey bee health at least partly by impairing protein digestion. This research was supported by USDA 2021-67034-35009.

1811 Allison Fisher, Ke Cao, Ethan Hill, Allen Allison, Marguerite Butler

Taxonomic resolution of the paraphyletic Oreophryne

In the ongoing effort to decipher the phylogenetic relationships within the incredibly diverse microhylid frog subfamily Asterophryinae, one clade, Oreophryne, is of particular concern for revision. Oreophryne is a large genus with a surprisingly expansive distribution across most of Papua New Guinea to Southeast Asia, representing nearly all of the arboreal species in Asterophryinae. A recent molecular phylogeny has demonstrated that Oreophryne as currently recognized is paraphyletic and instead consists of two reciprocally monophyletic genera, one of which is highly supported as being the most basal of the entire subfamily whereas the other unrelated genus is much younger. Our acquisition of four specimens from North Maluku Island, Indonesia, including a specimen of the type species, O. senckenbergiana, has now allowed for a decisive resolution as to which clade can bear the name Oreophryne. We sequenced five loci (three nuclear: BDNF, SIA, NXC, and two mitochondrial: CytB, ND4), aligned them to the 236 tip Asterophryinae molecular dataset of Hill et al (2022) and regenerated the phylogeny using Bayesian inference with time calibration in BEAST. The type species fell into the more basal clade (Oreophryne A in Hill et al. 2022) indicating that the true Oreophryne is the sister branch to the rest of Asterophryinae. All four North Maluku island specimens were closely related and formed a monophyletic clade, which diverged sister taxa on New Guinea Island.

1764 Adam Fitch, Sterling Nesbitt

A new hypothesis for the flight musculature of pterosaurs, the first flying vertebrates

Pterosaurs represent the earliest appearing of only three clades of flying vertebrates, the pioneers of aerial vertebrate ecospace, and the lineage to produce the largest known flying organism. The construction of the pterosaur flight apparatus has remained preliminary when compared to other vertebrate flyers due to a lack of living members. Here, we compare the forelimb muscle attachment sites in fossil pterosaurs to those of the musculoskeletal systems of their closest living relatives, birds & crocodylians, in order to elucidate the muscular component of pterosaur flight systems. While most muscle attachment sites in pterosaurs are equivalent to (if proportionally distinct from) those of other archosaurs, we notably find extensive muscular transformation associated with the 'cristospine', a keeled structure unique to pterosaurs that projects from the anteroventral sternum. Traditionally considered part of the origin site for the pectoralis, we determine instead that the cristospine represents a large, novel origination point for the supracoracoideus, a muscle typically originating on the scapula/coracoid in archosaurs. This ventral migration of the supracoracoideus shifts its action from forelimb pronation to adduction, and we hypothesize that, in conjunction with the pectoralis, the supracoracoideus powered the downstroke when flapping. Such transformation and use of the forelimb musculature is unlike that seen in any other vertebrate and demonstrates the uniqueness of the pterosaur flight apparatus amongst the three 'convergent' vertebrate flight systems.

604 Megan Flanagan, Caitlin Gabor

Traffic noise informs early development in two species of tadpoles

Along with increased urbanization, traffic noise has responded in tandem. Increased noise leads to glucocorticoid dysregulation and behavioral changes across a range of taxa, including amphibians. We measured growth, activity and the glucocorticoid profile of two tadpole species; Acris crepitans (Ac) and Lithobates berlandieri (Lb) in response to natural levels of traffic noise. Subjects were exposed to control or traffic noise first for 8 days (early), then the opposite second (later). Ac and Lb utilized different strategies to contend with noise when exposed earlier in life. Tadpoles exposed to noise first lost mass, with Ac regaining mass but not Lb. For both species if they started in the control, they moved the same amount when exposed to noise. Both species moved less when exposed to noise first, but Lb increased movement when moved to control while Ac didn't change their movement but moved overall less than frogs exposed to control first. Early life exposure to traffic noise decreases growth but not later in life exposure. The greater decline in mass for Lb may be associated with decreased size at metamorphosis which decreases chance of survival and decreased activity could have contributed to the loss of mass over the long term. Whereas Ac seems to contend better with noise. The different coping strategies may be due to differences in life history and glucocorticoid response between species.

1089 Leo Fleishman

The visual ecology of Anolis dewlap colors

Anoline lizard species occupy densely vegetated habitats ranging from unshaded grasslands to fully shaded forest understory. Males of most species display a colorful throat fan (the dewlap) to repel other males and attract females. We have extensively studied the relationships between dewlap color, habitat light and anoline visual systems. The anoline retina possesses four spectral classes of cones, which are similar across most species. Our behavioral studies have shown that dewlap detectability depends on dewlap-versus-background luminance and chromatic contrast. Background luminance is highly variable, so that a wide range of dewlap luminances are equally effective. Chromatic contrast against the largely green background of most habitats is generally greatest for red or orange dewlaps. However, in shaded habitat, the relatively low photon flux emitted by such colors limits their effectiveness. This is because photon-shot noise limits color visibility under low light conditions for small-eyed animals like anoles. Broader-band colors, such as white or yellow, are often more visible in moderate-to-heavy shade because they reflect more photons and, in many cases, diffusely transmit more light, which makes them several times more radiant across the spectrum, and gives them a glowing appearance. Consistent with these observations, most anoles in low shade habitats possess red or orange delwaps, while those in shaded habitats more often possess white or yellow dewlaps.

649 Caroline Fleming, Randi Rotjan, Justin McAlister, Grace Beery, Itasca Motter, Wendy Heiger-Bernays

Nutrient or pollutant? Disentangling the effects of nitrogen on urbanized corals in a changing ocean

Marine coastal ecosystems that exist downstream from urban centers are subjected to excess dissolved inorganic nitrogen (DIN) in the form of wastewater effluent, industrial waste, and fertilizer runoff that can overwhelm organismal function, turning nitrogen from a nutrient to a pollutant. One group of urban marine organisms that are particularly vulnerable to nitrogen pollution are corals, due to the presence of endosymbiotic algae (zooxanthellae). While nitrogen is critical for the symbiont to photosynthesize and ultimately assimilate photosynthates into workable energy, research suggests excess nitrogen can harm tropical corals: the overactivity of the symbionts generates harmful reactive oxygen species that can lead to coral mortality. In this study, we leveraged the facultative symbiosis of the urban coral Astrangia poculata to quantify the physiological tolerance threshold of adult and larval A. poculata exposed to two four levels of nitrogen species (ammonium and nitrate) under ambient and increased temperature conditions. Using metabolic, morphological, and physiological outputs, we directly quantified the levels of pollution and temperature that cause distress. Overall, we hypothesized that 1) the impacts of increased DIN will be amplified in elevated temperature conditions 2) larval corals will experience more severe physiological outcomes compared to adults due to their larger surface area to volume ratio, and 3) nitrate, rather than ammonium, will have stronger deleterious effects, given the increased energetic investment needed by the coral to process nitrate.

945 Rachel Fleming, Thomas Roberts

Evidence for a spring-powered mechanism in woodpecker drumming

Almost all woodpecker species perform drumming: a high-speed, sociosexual display that consists of rapidly hammering their bill against a tree. Drilling behavior, by contrast, is less rapid and used for foraging and nest excavation. The acoustic signature of these behaviors vary between species in both length and speed. Though both behaviors are common for woodpeckers, the mechanical basis of woodpecker drumming and drilling are still not well understood. We hypothesize that the very high frequency of drumming (20-30 Hz for many species) requires significant elastic energy storage and recovery to maintain the motion. Since spring-mass systems operate most effectively at the system natural frequency, we predicted that drilling frequencies in a given species would be constrained to a narrow range. Drilling is slower and more likely to be powered by muscle action, thus we predicted drilling frequencies would be less constrained. We analyzed audio recordings of drumming and drilling to measure the rate (beat s-1) for several species and found, as predicted, a relatively narrow range of drumming frequencies within a given individual. Drilling frequencies were slower, and, in all species, there was a substantial gap between drilling and drumming frequencies where no beak behavior occurred. A simple mathematical model of the drilling and drumming motion suggests that this gap represents a frequency regime where neither elastic power or muscle power are sufficient to drive the motion.

1046 J. Morgan Fleming, Katie Marshall, Timothy Meidl, Jorge Celi, Kimberly Sheldon

Metabolic plasticity of tropical and temperate dung beetles to increasing temperature variation

Increasing temperature fluctuations associated with climate change are expected to have profound effects on species performance and fitness, but these effects might vary among organisms that evolved in different thermal environments. For instance, tropical species that have evolved in relatively stable thermal conditions may have limited capacity to cope with increasing temperature fluctuations compared to temperate species that evolved in more variable thermal conditions. We used dung beetles from tropical (Ecuador) and temperate (Tennessee) sites to examine thermal sensitivity of metabolism in response to increasing temperature fluctuations. We exposed female beetles to one of three treatments with the same temperature mean but different amplitudes of temperature variation (22±2, 22±6, 22±10°C). We then measured CO2 production of adult beetles across a series of temperatures to calculate the thermal sensitivity of metabolism (i.e., the change in metabolic rate with a change in temperature). We expected that higher temperature fluctuations would be more stressful, and therefore metabolic rates would be higher in both temperate and tropical beetles exposed to greater thermal fluctuations. However, we also predicted the temperate beetles would have lower thermal sensitivity of metabolism because they evolved in more variable thermal environments. Our results highlight the role that evolved differences in thermal physiology of temperate and tropical beetles may play in organismal responses to increasing temperature variation and vulnerability to future climate change.

884 Andrea Flores, Gerad Sandate, Matt Steffenson

The effect of energy expenditure on immunological response between drones and worker honeybees

Colony collapse disorder (CCD) is an occurrence where worker honeybees abandon what appears to be a healthy colony. Numerous factors can induce CCD, but the specific cause is still unknown. It is hypothesized that immunological threats may increase the occurrence of CCD, therefore understanding factors that can influence the ability to invest energy into immunological activity may provide insights into combating CCD. Colony makeup has the potential to affect energy investment. For example, drones contribute nothing to the functioning of the colony, but drain accumulated resources like honey and pollen. Worker bees spend their entire lives performing vital activities to support the colony and thus have different energy expenditures than drones. The goal of this project is to determine if energy expenditure between drones and workers affects both their basal and activated immunological responses. For basal immunity, hemolymph was extracted from workers and drones and several immunological assays were performed to determine specific protein activity levels. For activated immunity, an immune response was induced by feeding bees 1 ul of a nectar/lipopolysaccharide solution. Hemolymph was extracted at 0, 1, 2, or 3 hours to determine immunological activity over time since simulated pathogenic exposure. Data analysis is ongoing, but we predict that the worker bees' immunological responses will be negatively affected by the increased energy expenditure compared to the drones.

1316 Sarah Foltz, Nolen Miller

Fighter-pilot parents: relationships between offspring age, quality, and parental nest defense

Many birds invest large amounts of time and energy in reproduction, spending weeks to months feeding and caring for offspring. In addition to the heavy resource demands of breeding, these parents assume significant risk as they defend their offspring from predators and other threats. To optimize reproductive success, parents must balance risk to their own health and survival against the fitness value of their current offspring. We studied this trade-off in parents' investment strategies in breeding populations of eastern bluebirds (Sialia sialis) and tree swallows (Tachycineta bicolor) in southwest Virginia, USA. Both species actively defend nests from perceived predation threats as well as conspecific and heterospecific breeding pairs competing for their nest box. We measured dives, alarm calls, and beak clicks (conspicuous behaviors associated with nest defense in both species) during regular nest-monitoring checks, recorded nest stage and brood size, and collected weight and size data from nestlings that reached 11 days of age. We predict that later nest stages (nestlings, as opposed to eggs), larger broods, and healthier nestlings will be associated with more aggressive parental nest defense because these older nests and larger broods represent a greater resource investment and healthier nestlings have higher fitness value. We also expect to see a difference in parental aggression between species based on differences in their respective breeding season length and re-nesting attempts.

880 Kassandra Ford, Patricia Hernandez, Pooja Singh, Mikki Law, David Haberthür, Ruslan Hlushchuk, Kory Evans, Ole Seehausen

Analysis of Craniofacial Evolution in Lake Victoria Cichlids based on CT-scans

African cichlids have many examples of repeated evolution of trophic adaptations. However, most of the better-documented cases illustrate these instances between lakes and radiations. Here we study trophic adaptations within the Lake Victoria radiation that emerged over the last 15,000 years. Previous work primarily focused on oral and pharyngeal jaw morphology, but there has yet to be a comprehensive study on Lake Victoria species using the whole skull. This study examined 131 species (n = 301) using CT-scanning and geometric morphometrics. We estimated a phylogenetic tree using whole-genome sequencing, assessed levels of convergence with R to assess repeated evolution, and compared these data to dietary guilds. Our results show certain specialized phenotypes evolved multiple times within this clade, with significant levels of similarity. We also found that craniofacial morphology is most closely tied to diet, particularly in species with specialized diets (i.e., algae scraping, mollusk crushing, and piscivory). Shape changes across this lineage fall into two major patterns: heterocephaly (relative braincase and snout size) and the proportion of head depth and head width. Both trends appear closely linked with diet, with discernable patterns correlating diet to head shape. Additional examination is imperative to understanding how such a large diversity of craniofacial morphologies evolved in such a short period of time.

1690 Mitchell Ford, Maura Niemisto, Zachary Wagner, Griffin Wagner, Jeannette Yen, David Fields, Arvind Santhanakrishnan

Effects of viscosity and temperature on Paraeuchaeta locomotor performance

Copepods form essential links in marine food webs and perform daily vertical migrations, experiencing a range of environmental temperatures. Copepods of the genus Paraeuchaeta are predatory and prey on smaller zooplankton. Paraeuchaeta congeners are found at different latitudes, from the polar regions where water surface temperature is about 0oC, to the tropics where water surface temperature is about 20oC. Along with typical metabolic effects associated with varying temperature, these organisms must contend with changes in the water viscosity, which can double between the tropical and polar regions. Increasing viscosity increases fluid resistance to swimming motion and cost of transport. In this study we examine the effects of varying water temperature (using a cold water bath) and water viscosity (using PVP polymer solutions in seawater) on swimming performance of P. elongata collected from Alaskan waters. Swimming performance is quantified using 2D particle image velocimetry and 3D particle tracking velocimetry. Individuals performed a variety of swimming behaviors, including cruising using cephalic appendages, jumping using swimming legs, and turning using antennules and uropods. The effects of temperature and viscosity on swimming speeds and turning rates will be presented. Physical analysis of the flow fields (vorticity and strain rates) will be presented to help explain the differences in swimming performance caused by changing fluid viscosity. This research was supported by the National Science Foundation (OCE 2023675).

1031 Jacquelynn Formosa, John Hranitz, Victor Gonzalez, Charles Abramson, Theodora Petanidou, Thomas Tscheulin

Investigations into constraints on dim-light foraging within a Mediterranean Carpenter Bee community

While most bee species are diurnal foragers, some species forage in low-intensity (dim) light. We studied three species of carpenter bee (Xylocopa violacae, Xylocopa iris, and Xylocopa olivieri) to test the hypothesis that diurnal UV light stress affects foraging by the carpenter bee community on Lesvos Island, Greece. We predicted that two dark-bodied, diurnal-foraging species have greater UV light tolerance than the light-bodied, crepuscular-foraging species. We recorded ambient light, humidity, and temperature during Xylocopa visitation on Vitex agnus-castus to measure natural summer exposures. We studied the effects of full sunlight (UV/VIS) on bees, when TEnv was below CT-Max, and measured agitation using a shuttle box behavioral method. Visitation studies revealed that X. olivieri foraged in morning and evening dim-light (ambient light These results support the hypothesis that physical conditions (ambient VIS/UV light) elicit crepuscular foraging by X. olivieri but do not reveal whether UV stress or overstimulation of dim-light visual systems cause stress. We contribute to understanding constraints within bee communities to adaptation to climate change.

1436 Kiersten Formoso

Axial morphology may drive swimming style in secondarily aquatic tetrapods

Secondarily aquatic transitions which are captured by tetrapods which returned to aquatic environments from land are excellent models for understanding the biomechanical, functional, and morphological changes, drivers, and constraints that underly major evolutionary transitions. Secondarily aquatic tetrapods evolved one or a combination of appendicular versus axial swimming propulsion styles. Primarily appendicular swimmers are characterized by using the limbs to propel themselves through the water, and axial swimmers primarily use undulations of the body and tail for propulsion. In seeking to ask why some clades evolved one or another swimming style, I set out to compare aspects of the axial skeleton, namely the trunk and tail to determine any links between proportions, flexibilty, and size and appendicular versus axial swimming style. The compared clades include sauropterygians, thalattosaurs, mosasauroids, crocodylomorphs, cetaceans, pinnipeds, otters, marine sloths, and sirenians, as well as various extant semi-aquatic taxa like platypus, beavers, and water shrews. Turtles, which are completely constrained in trunk flexibility and have short tails served as a comparative baseline. A plot reveals statistically significant association between longer, less flexible trunks with shorter tails and appendicular swimming, and association between more flexible trunks with longer tails and axial swimming. These axial characters may reveal a part of the story behind why some clades initially or eventually specialized in certain swimming styles when transitioning to aquatic environments.

1657 John Fortner, Kaleb Sellers, Kevin Middleton, Casey Holliday

Functional Morphology of the Intramandibular Joint and Mandibles of Alligator

All diapsids possess an intramandibular joint (IMJ) between the rostral and caudal mandibular elements. IMJ construction varies among diapsids, but its influence on their mandibular performance is uncertain. While finite element (FE) modeling suggests the IMJ is a biomechanically important region, relationships between muscle loads, IMJ orientation, and bite force are unknown. We therefore built FE models of Alligator mandibles with simplified planar IMJs of varying orientation, and oriented contractile forces from mIM and mPTv muscles' origin and insertion sites to centroids of their wrapping areas, to analyze the relationships between muscle loads, IMJ orientation, and bite force.We find IMJs oriented orthogonally to the jaw adductors' net resultant best reduce IMJ strain, and that mIM and mPTv reduce IMJ rostrocaudal and shear strains, respectively. Inactive mIM has minimal effect on bite force but a significant effect on IMJ loading, suggesting that mIM contributes more to joint stability, and not so much to bite force as previously thought. Such postural muscles may help stiffen the material of the mandible, facilitating force transmission across joint surfaces and thereby indirectly increasing bite force. Skull flattening and elongation during suchian evolution may have shifted these muscles' function towards postural modulation.

1202 Brent Foster, Fredrik Hugosson, Joseph Ryan, Mark Martindale

Characterizing Notch Signaling in the Ctenophore Mnemiopsis leidyi

In many species, the Notch signaling pathway helps establish neural cell fate via lateral inhibition and intracellular cascades. The canonical pathway consists of 22 molecular components, although many species contain fewer components, suggesting that Notch function may have diversified from its ancestral origins. Ctenophores, as the sister group to all other animals, hold a key phylogenetic position to examine the ancestral function of the Notch pathway. Unfortunately, the Notch system has not been characterized in ctenophores due to incomplete genomic data and a paucity of optimized experimental techniques. Our lab is filling this gap by examining whether the ctenophore Mnemiopsis leidyi has a functional Notch pathway that plays a role in early development. Using the Mnemiopsis genome, we have identified 16 components of the canonical Notch pathway, 4 of which lack so-called diagnostic domains. We are developing a molecular tree of Notch signaling molecules to determine their relatedness to other Notch components in key phylogenetic species. We are also examining active expression of Notch molecules with in-situ hybridizations and conducting drug inhibition and gene knockdown studies to test the functional role of Notch in early Mnemiopsis development. With this data, we hope to shed light on the ancestral function of the Notch pathway and its role in the evolutionary origins of nervous systems.

641 Caroline Fox

Exposure to butyl-paraben results in developmental abnormalities in zebrafish

Parabens are chemicals commonly found in mascaras, lip glosses, lotion, scrubs, and other cosmetics as a preservative. They enter the body through skin, and esterases are unable to break them down. Parabens have been found in fetal blood, indicating their ability to cross the uteroplacental barrier. They act as an endocrine disruptor, interfering with the nuclear receptors for androgens, estrogens, progesterone, and influencing enzymes that metabolize natural hormones. Using zebrafish (Danio rerio) embryos as my model organism, I sought to find if parabens influence fetal development. At 24 hpf, dechorionated embryos were exposed to different concentrations of butyl-paraben [3.125 μM, 6.25 μM, 12.5 μM. 25 μM]. Zebrafish were also placed into two controls, the E3 solution and E3 with 0.1% DMSO. The fish were observed 48, 72, and 96 hpf for developmental defects and measurements of the yolk sac, pericardial sac, total length, eye diameter, and heart rate were taken. A significant enlargement of the pericardial sac and yolk sac was observed upon treatment, particularly in the higher concentrations. Many of the fish in concentrations 6.25 μM and above also exhibited a curved, deformed body. This information indicates parabens likely interfere with developmental processes.

1741 Alicia Fox

Bringing wildlife into the lab: Lower division Zoology students use camera traps to observe animals

At Allan Hancock College, a community college in California, we have a 3-semester sequence for biology majors that includes a General Zoology class. To increase time spent in the field and to observe wildlife, students participate in a camera trap project at a local University of California reserve, Sedgwick Reserve in Santa Ynez, CA. Students attend two fieldtrips that give them the opportunity to place and then pick up cameras at multiple water troughs at the reserve. This project offers students the opportunity to make observations in the field, learn animal ID, collect data on animal presence at water troughs, and determine patterns in animal visits at those water troughs. This project has enabled students to view wildlife they may not typically see on their own. Finally, students get involved in putting together slide shows of their favorite pictures and videos for use at Friday Night Science, our Spring community outreach event.

1037 Austin Francis

Analytical and Experimental Hydrodynamics of the Great Hammerhead Shark Cephalofoil

The cephalofoil is a distinctive lateral expansion of the head of hammerhead sharks (Family Sphyrnidae) that has been hypothesized to generate lift. The great hammerhead shark, Sphyrna mokarran, has a moderately broad, straight cephalofoil that is 23-27% of total body length. A computed tomography (CT) scan of an S. mokarran was used to generate a 3D computer model for performance testing using computational fluid dynamics (CFD). This model was tested at two free-stream fluid velocities and multiple angles of attack (pitch) to determine the velocities, forces, pressures, lift coefficients, and drag coefficients generated by the cephalofoil. Preliminary analysis revealed a positive coefficient of lift from an angle of attack of $+5.25^\circ$ through $+30^\circ$. Coefficient of drag was at its lowest at an angle of attack of -8.25° through $+8.0^\circ$. Subsequently, digital particle image velocimetry (DPIV) was performed with a 3D printed model of the cephalofoil submerged in a water tunnel and oriented at selected angles of attack to water flow. Water seeded with tracer particles and illuminated using a 532 nm laser was recorded at 250 frames/s. Cross-correlation analyses revealed greater velocities above the cephalofoil than below. Vortex shedding was also observed in the wake of the cephalofoil. Evidence the cephalofoil provides modest lift at the anterior of S. mokarran was corroborated by both CFD and DPIV.

1354 Ashley Franklin, Camila Carlos-Shanley, Mike Matthews, David Prangnell, Mar Huertas

The Impact of Nitrite and Edwardsiella ictaluri on Channel Catfish Nose Morphology

Nitrite is a byproduct of nitrogen excretion in fish that can accumulate in fish holding systems and act as a toxin, including damage to external sensory organs that are directly exposed to water. In addition, aquatic nitrite increases the sensitivity for Edwardsiella ictaluri infections (a bacterium that causes significant losses in the aquaculture industry) in channel catfish. Since a common route of infection of E. ictaluri is through the nasal cavity of fishes, we hypothesize that sublethal nitrite exposure increases susceptibility to E. ictaluri infection in catfish by damaging the nose and allowing the systemic entry of the bacterium. We investigated the impact of combined nitrite and E. ictaluri treatment on catfish nose morphology. First, we determined the concentration of E. ictaluri that kills 50% of catfish (LC50). Then, we exposed catfish to 0.2 mM or 0 mM nitrite for 30 days with an addition of pathogen for the last 3 days of treatment. Nose samples were extracted and fixed. Histological analysis showed that nitrite induced loss of olfactory receptor cilia and death of supporting cells. In the LC50 experiments, catfish displayed ulceration of the nares, inflammatory responses and epithelial damage in the nose. Nitrite exposed fish noses showed more morphological signs of bacterial damage. Our results indicate that nose damage due to water pollutants open a portal of pathogen infection to the fish brain.

191 Andrea Frías-Vellón, Whitney Leach, Jeff Lange, Matt Gibson

Dark Necessities: Uncovering the effects of light on larval settlement in Nematostella vectensis

Many sessile marine invertebrates have motile larval stages that seek suitable environments for settlement and metamorphosis into their adult form. For some cnidarians, light functions as a settlement cue that initiates metamorphosis. Adult polyps of the model sea anemone Nematostella vectensis are known to sense light, which is evidenced by nocturnal locomotory patterns that dampen in the absence of external light cues. However, the potential role of light during Nematostella larval stages remains poorly understood. Here we describe ongoing and planned experiments to ascertain the role of light during Nematostella larval settlement by investigating larval phototaxis and circadian activity patterns. Phototactic behavior will be quantified in a directional light experiment to observe whether planula exhibit phototaxis when exposed to a light or dark environment. Preliminary data from this experiment suggests that early planula have little light preference, positive or negative, but late planula exhibit an increasing negative phototactic response. Differential preference for light intensity will be measured in a light-gradient experiment, where we hypothesize that planula will avoid both high and low light levels. A final experimental paradigm will record the period of highest larval locomotory activity, potentially revealing a circadian behavioral pattern. Combined, we postulate that planula will become increasingly responsive to light cues temporally throughout development and exhibit measurable rhythmicity under light/dark conditions, with peak activity occurring during the scotophase.

220 Sarah Friedman, Martha Munoz

A latitudinal gradient of deep-sea invasions for marine fishes

Although the tropics harbor the greatest species richness globally, recent work has demonstrated that, for many taxa, speciation rates are faster at higher latitudes. Here, we explore oceanic depth as a potential mechanism for this pattern in the most biodiverse vertebrates – fishes. We demonstrate that clades with the highest speciation rates also rapidly diversify along the depth gradient, drawing a fundamental link between evolutionary and ecological processes on a global scale. Crucially, these same clades also inhabit higher latitudes, creating a prevailing latitudinal gradient of deep-sea invasions concentrated in poleward regions. We interpret these findings in light of classic ecological theory, unifying the latitudinal variation of oceanic features and the physiological tolerances of the species living there. This work advances the understanding of how niche lability can shape global patterns of species distributions and underscores the vulnerability of tropical lineages to changing environmental conditions.

1563 Alaina Friedrich, Donald Miles

Illuminating the effects of artificial light at night on vocal phenology in the cavity-nesting guild

The predictability of natural light and dark cycles has had a paramount effect on the organization of Earth's biota. A growing body of literature suggests that anthropogenic light at night (ALAN) and noise have elicited a diverse response to the alteration of natural light regimes with a complex network of ecological consequences. The full extent of ALAN's impact is unknown; field studies on wild populations are lacking and many avian studies are limited to diurnal activity during the breeding season. In songbirds, there is evidence that ALAN impacts several biological processes and life history events in wild populations. ALAN's impact on the cavity-nesting guild has received limited attention. Woodpeckers are considered to be predictors of bird diversity in forests as ecological engineers that provide critical nesting habitat to other species. This study aims to evaluate the seasonal impact of ALAN at a community level and to investigate abnormal nocturnal behavior. ALAN-induced differences in woodpecker occupancy, abundance, and behavior may have cascading effects on habitat availability for secondary cavity nesters. We used bioacoustic methods to evaluate differences in vocal phenology and daily activity of nine cavity-nesting species in southeastern Ohio at both dark and light-polluted sites over the course of three meteorological seasons. Preliminary results have demonstrated potential shifts in species' activity patterns at ALAN-impacted sites, providing grounds for further investigation within this guild.

312 Sonja Friman, Siyang Hao, Cory Elowe, Laura Mendez, Raúl Ayala, Caylan Hagood, Dayna Jackson, Gabriella Orfanides, Evrim Ozcan, Jared Ramirez, Ian Brown, Alexander Gerson, Tyson Hedrick, Kenneth Breuer

Can flight in flocks be less costly than solo flight?

Group flight in a V-formation is a known means to reduce flight costs in larger birds, but it remains unknown if this is the case for flight in bird flocks for small song birds. Here we quantify the energetic cost or benefit of bird flight in vortex wakes, using wind tunnel flight tests with a medium-sized bird, European Starling (Sturnus vulgaris), which is known for flocking flight in huge numbers. Here the birds are flown solo, with one or more companion birds, and in the wake of an actuated airfoil. The birds' responses are measured using (i) a camera system to record position and body dynamics with respect to the tunnel and neighbor birds, (ii) a lightweight inertial measurement unit (IMU) to record body motion, and (iii) the 13C-labelled sodium bicarbonate method (NaBi) to record the metabolic cost of flight. By combining kinematics, metabolic and aerodynamic results, we formalize and test hypothesized predictive relationships between wake structure, flight behavior and metabolic energy expenditure. We find that statistically, the starlings' mean relative locations in flight with a companion bird align as in V-formation flight with a lateral offset of around 1/2 wingspan. The effects of this positioning are further investigated using the IMU and NaBi results.

1377 Brett Frye, Dakota McCoy, Jennifer Kotler, Amanda Embury, Judith Burkart, Monika Burns, Simon Eyre, Peter Galbusera, Jacqui Hooper, Irun Idoe, Agustín Goya, Jennifer Mickelberg, Marcos Quesada, Miranda Stevenson, Sara Sullivan, Mark Warneke, Sheila Wojciechowski, Dominic Wormell, David Haig, Suzette Tardif

Exploring the impacts of variation in litter composition in callitrichine monkeys

Callitrichine primates – marmosets, tamarins, and lion tamarins – are South American monkeys that produce small litters, ranging from 1 to 5, with twins being the modal litter size in both captive and wild settings. Litters can vary in both size- and sex-composition, thereby providing opportunities to explore how such characteristics may underlie inter-individual variation in development, behavior, survival, and reproduction. Here we present a synthesis of a series of studies illustrating the lasting impacts of variation in litter size- and sex-composition in a sample representing species across the callitrichine lineage. We focus primarily on data derived from demographic and health records of monkeys living in captivity, and complement this work with data from a population of free-ranging golden lion tamarins. Themes of this synthesis include 1) the trade-offs between quantity and quality of offspring (and the role of sibling competition in shaping these tradeoffs), 2) the proximate mechanisms that may underlie familial interactions during infancy, and 3) the short- and long-term implications of familial interactions for behavioral, reproductive, and survival outcomes. This project will help to shed light on the potential mechanisms underlying inter-individual variation in developmental trajectories in litter-bearing species. Understanding these mechanisms will help to inform future predictions of how the early familial environment shapes developmental outcomes across a diversity of animal taxa.

388 Xun Fu, Juri Miyamae, Talia Moore

Untangling the function of complex tendon branching patterns

Proximal muscles connect to elongate, lightweight tendons to actuate distal appendages while reducing moment of inertia. For example, dextrous human finger motions are primarily controlled by tendons connected to extrinsic muscles, rather than intrinsic finger muscles. Similarly, prevailing hypotheses state that mammalian tail motions are controlled primarily by extrinsic muscles connected to long tendons. We know very little about how muscles and tendons generate motion in these highly articulated appendages. The structure of tendons determines how muscle shortening translates into joint movement. Hypothetically, complex shape changes along the length of the tail would require that each muscle is attached to a single tendon with a single insertion. Alternatively, if there is strong correlation between multiple joints in the tail, we might expect a single tendon to branch and attach in multiple insertion sites. We used microCT scans and anatomical dissections to examine the tendon branching structure in jerboas, small desert rodents that use their tails for a variety of behavioral and locomotion tasks. We found 9 dorsal tendons on each side of the tail, a subset of which have complex branching patterns. We used the anatomical data to build a simulated model of the jerboa tail and virtually stretched tendons to find the effect on overall tail motion. Such models can help us mechanistically link tendon structure and function.

701 Lauren Fuess, Amanda Hund, Daniel Bolnick

Investigating mechanisms of variation in parasite resistance using experimental immune challenge

Host-parasite interactions are poorly understood, despite their effects on a range of ecological and evolutionary processes. Specifically, variation in host resistance to parasites is well described from the standpoint of infection outcomes, but poorly understood on a mechanistic basis. The three-spined stickleback, Gasterosteus aculeatus, is a particularly powerful system for addressing questions related to variation in parasite resistance: populations of G. aculeatus vary considerably in their resistance to the cestode parasite, Schistocephalus solidus. To investigate the cellular mechanisms contributing to variability in parasite resistance across populations of stickleback, we subjected fish from three populations (ancestral, susceptible, and resistant) to immune challenge using either: a generalized pro-inflammatory compound, parasite extract, or a combination of the two. We then tracked responses of fish to these treatments over ninety days, measuring both resistance phenotypes (peritoneal fibrosis) and gene expression responses in an important immunological tissue (head kidneys). Fish differed significantly in induction of the resistance phenotype dependent on treatment, source population, and sampling time. Gene expression patterns underlying these responses were similarly variable, revealing differences in extent and timing of response across populations and treatments. Finally, genetic signatures of the resistance phenotype were highly variable across populations and treatments. Our results highlight the complex nature of cellular mechanisms underlying variation in parasite resistance and tolerance.

112 Luca Fuller, Kourosh Karimy, Paige Ruschke, Meredith Taghon, Alfred Crosby, Seth Donahue

Structure-property relationships of the energy absorbing horncore velar bone of bighorn sheep rams

The horncore of bighorn sheep rams is filled with velar bone, which has a unique porous bone architecture with a similar bone volume fraction to trabecular bone, but strut thickness and separation that are an order of magnitude larger. Computational modeling of bighorn sheep ramming has demonstrated that velar bone absorbs energy and reduces brain cavity accelerations. These findings have implications for brain injury mitigation, but the material properties of velar bone tissue were unknown. We hypothesized velar bone is tougher than other bone tissues because of its role in energy absorption. Velar bone beams were tested with dynamic mechanical analysis and loaded to failure in 3-point bending to quantify material properties. The elastic modulus (8.6 ± 3.5 GPa) was higher than trabecular (2.11 – 5.72 GPa), but lower than similarly mineralized cortical bone (16.0 – 29.5 GPa) loaded in bending. The damping factor, ultimate stress, and modulus of toughness were lower than cortical bone values. Porosity and mineral content were comparable to typical cortical bone. Surprisingly, velar struts contained osteons which are rare in trabeculae, but osteon population density was lower than in human cortical bone. Velar bone osteons may provide crack arrest and deflection to absorb energy and prevent strut failure during impact. Thus, the unique combination of a trabecular-like foam with osteon filled struts may promote velar bone energy absorption during ramming.

113 Luca Fuller, Evan Marcet, Laura Agarkov, Prisha Singh, Seth Donahue

Morphology and material properties of the bighorn sheep horn-horncore interface

Bighorn sheep horncore bone plays a critical role in absorbing energy and reducing brain cavity accelerations which has implications for brain injury mitigation. The horn-horncore interface is responsible for load transfer between the impacted horn and energy absorbing bony hornore, but the properties of this interface were unknown. The equine laminar junction transfers load from the hoof to the skeleton and has a lamellar microstructure believed to increase contact area and reduce stress magnitudes. We hypothesized that the morphology of the horn-horncore interface increases contact area and that contact area is positively correlated with interface shear strength. Interface mechanical properties were determined through lap-shear testing and morphology and composition were assessed via histomorphometry. Horn-horncore interface demonstrated non-linear strain stiffening and had similar shear moduli to the equine laminar junction at low strains (154 ± 95 kPa vs. 396 ± 312 kPa) and high strains (4.47 ± 3.73 MPa vs 5.38 ± 1.49 MPa). Collagen fibers resembling Sharpey's fibers penetrated the bone surface. Keratinized tissue formed microscopic surface pores and branched interdigitations with the collagenous interface on the horn surface which resulted in a nearly 4-fold increase in the contact surface area. The increase in contact area was positively correlated with lap-shear strength and may reduce stress magnitudes and promote efficient load transfer between horn and bone similar to the equine laminar junction.

918 Morgan Furze, Dylan Wainwright, Brett Huggett, Thorsten Knipfer, Andrew McElrone, Craig Brodersen

Ecologically driven selection of nonstructural carbohydrates in oak trees

A major axis of plant diversity involves leaves and their persistence in the face of changing environmental conditions throughout the year. Differences in leaf habit have consequences for carbon allocation since the leaf is the site of photosynthesis, and nonstructural carbohydrates produced in the leaves can be transported throughout the plant and stored for later use. These stored reserves may serve as a resiliency mechanism to stress, however, how leaf habit influences nonstructural carbohydrate storage deserves further attention. Using a comparative physiological framework and evolutionary model fitting, we explored if variation in nonstructural carbohydrate storage is explained by leaf habit. We measured sugar and starch concentrations in the leaves and stems of 51 Quercus (oak) species, representing multiple evolutions of different leaf habits (deciduous, brevideciduous, and evergreen) and growing in a common garden setting. The best fitting evolutionary models showed that deciduous oakspecies were evolving towards larger nonstructural carbohydrate concentrations than their relatives. Notably, this was observed for starch in the stemwood. Overall, this work suggests that a deciduous strategy may benefit trees in a changing world.

271 Molly Gabler-Smith, Tess Avery, George Lauder

Denticle Multiverse 3: quantifying variation in denticle morphology through leopard shark ontogeny

The immense morphological diversity of dermal denticles (the tooth-like protrusions covering the skin of elasmobranch fishes) results in many proposed functions of these structures including abrasion reduction, protection against parasites, drag reduction, and increased lift during swimming. The recent application of new techniques such as surface profilometry and micro-CT scanning, combined with histology, have advanced our understanding of how surface characteristics (e.g., ridge spacing and height) and development of specific denticle morphologies differ across and within shark species. But few studies have investigated the extent to which denticles vary within a species through ontogeny, with only a few anecdotal remarks in the literature. Here we use micro-CT and gel-based profilometry to investigate how the three-dimensional (3D) morphology and surface topography of denticles changes as sharks grow. 3D models and surfaces were used to assess denticle scaling throughout ontogeny of demersal leopard sharks (Triakis semifasciata) ranging in size from 0.07 to 1.2 meters. Initial results suggest that throughout ontogeny, denticle surfaces are changing, resulting in a more than 3-fold difference in crown size, as well as differences in surface roughness due to the presence of additional surface ridges. By combining 3D and 2D measurements (e.g., volume, surface area, crown length and width) with topological surface data (e.g., roughness and kurtosis) we can hypothesize how shark skin interacts with the surrounding environment as these animals grow.

766 Journie Gaeta, Veronica Martinez-Acosta

Changes in Myelin Compaction During Neural Regeneration in Lumbriculus variegatus.

Myelination has been described in some annelids as ‘vertebrate-like,’ compact in structure, made up of tightly associated layers. Using transmission electron microscopy, we investigate myelin compaction associated with the giant interneurons found in the ventral nerve cord (VNC) of Lumbriculus variegatus. Lumbriculus is an excellent regenerating model that is capable of whole-body regeneration, including its nervous system. A conserved feature of all annelid nervous systems is the presence of three giant neuronal fibers that run the length of the body, positioned just beneath the dorsal surface of the ventral nerve cord (VNC). These three giant fibers undergo changes in diameter over the course of regeneration. This change in diameter is marked by notable changes in compaction of the myelin layers associated with each giant nerve fiber. In this study we measure the distance between layers at 12hr, 24hr, 72hr and 1-week post-amputation. Lateral giant fibers have an average distance of 14.2 nm, 13.1 nm and 33.7 nm between layers measured in anterior non-regenerating, posterior non-regenerating, and posterior regenerating worm fragments respectively. Medial giant fibers have an average distance of 10.8 nm and 15.6 nm for posterior non-regenerating and posterior regenerating worm fragments. Further characterization of myelin composition found in the Lumbriculus giant fiber system is needed to fully understand how these alterations in myelin compaction affect recovery of function in regenerating worm fragments.

62 Holland Galante, Anuj Ghimire, Britt Heidinger, Timothy Greives, Rebecca Young, Emily Elderbrock, Jeffery Kittilson, Jacob Campbell

Is mitochondrial copy number predictive of metabolic rate and growth in developing house sparrows?

Metabolism and energy production, including energy products like ATP which are primarily produced in the mitochondria, are essential for cellular functions and expected to underlie development. Energy production is often estimated using whole organism metabolic rate; however, this technique is costly and restrictive when studying free-living species, thus less invasive methods of assessing mitochondria regulated traits are needed. Mitochondrial copy number (mtDNAcn) from both field and laboratory blood samples is indicative of mitochondrial abundance and energy production capacity but the degree to which it is predictive of whole organism metabolic rate and related to growth is unknown. Here we investigate whether mtDNAcn is repeatable, related to whole organism metabolic rate, and predictive of post-natal growth rate in free-living house sparrow (Passer domesticus) nestlings. Blood samples were collected from early and late stages of growth to assess mtDNAcn repeatability and flow respirometry was performed to determine whole organism basal metabolic rate. We predict that chicks with higher mtDNAcn will have increased whole organismal metabolic rate along with more rapid post-natal growth compared to chicks with lower mtDNAcn. These data will enhance our understanding of the physiological mechanisms that influence post-natal growth in free-living birds, and the degree to which mtDNAcn can be used to predict whole organism metabolism in ecological studies.

976 Megan Gall, Glenn Proudfoot

Masked Thresholds and Critical Ratios of Northern Saw-whet Owls (Aegolius acadicus)

Animals rarely acquire and use acoustic information in perfectly quiet and anechoic environments. However, most behavioral and physiological investigations

of auditory processing occur under exactly these conditions. For nocturnal hunters like Northern saw-whet owls (Aegolius acadicus), even low levels of natural noise are likely to raise auditory thresholds, interfere with acoustic detection and localization, and ultimately reduce prey capture success. Here we investigated the effects of acoustic noise on the auditory thresholds of Northern saw-whet owls. We found the even low levels of noise, typical of relatively quiet forests, were sufficient to increase auditory thresholds across a range of frequencies. The signal to noise ratio required for detection of the sound (i.e. critical ratio) was relatively constant across frequencies from 0.5-6 kHz, regardless of the noise level. However, critical ratios deviated from this pattern at 8kHz. These data suggest that increasing levels of noise will impact the ability of Northern saw-whet owls to detect and localize prey items acoustically, in turn affecting hunting success in noisy conditions, as has been demonstrated previously.

1494 Dominique Gallery, John Rippe, Mikhail Matz

Cryptic corals: investigating genetic divergence and environmental adaptation

Coral reefs are vital to the health of oceans and support approximately 25% of marine biodiversity. As anthropogenic stressors increase in frequency and duration, coral populations will continue to decline causing a reduction in genetic diversity. Compounding the challenges of maintaining genetic diversity in coral species is the increasing evidence that many nominal species have cryptic genetic structure. Cryptic genetic structure, also referred to as ecomorphs, occurs when populations do not have complete genetic isolation, but introgression between ecomorphs is limited or rare. Four ecomorphs, primarily separated by depth, have been described in Montastraea cavernosa, a gonochoristic broadcast spawning coral in the Florida Keys. This study aims to determine how adaptive regulatory evolution contributes to ecological specialization across colony age, habitat, and ecomorph. We identified individual colonies as either juvenile, e.g., colonies less than 3 inches in diameter post-settlement before a competent reproductive stage, or adult; e.g., colonies greater than 30 inches in diameter capable of reproduction. We characterize how high genetic divergence impacts gene expression and hypothesize that genes with large genetic divergence will have increased gene expression divergence. Furthermore, we investigate if juvenile colonies have increased transcriptomic plasticity to adapt to their local environment compared to adult colonies.

1428 Jacquelyn Galvez, Z. Jack Tseng

Damming evidence for morphological consequences of artificial barriers in riverine steelhead trout

Artificial damming of freshwater rivers influences many aspects of stream ecology. Human-made dams can create barriers to upstream breeding and rearing habitats of anadromous fishes and can limit gene flow between such populations. Studying fish populations impacted by damming provides a unique opportunity to study the downstream effects of these dispersal limitations, and has potential to reveal how damming influences the evolutionary trajectory of populations—possibly in exposure to different selective pressures and/or buildup of reproductive isolation—and how endangered fishes cope with anthropogenic environmental changes. In this study, we conducted a morphological comparison of above- and below-dam samples of anadromous steelhead trout, Oncorhynchus mykiss, using 2D geometric morphometrics analysis of lateral body shape. Preliminary results demonstrate that above- and below-dam specimens have minimal overlap in morphospace. Principal components (PC) analysis of shape data suggests that above-dam individuals are wider in the snout and head region with a shorter body, whereas below-dam individuals are narrower in the head region with a wider, longer body. Overall, below-dam individuals appear to have a more streamlined body shape; discriminant function analysis statistically supports clusters apparent in the PC morphospace. These results lead us to propose functional hypotheses for how muscle mass and movement may differ between above-dam (traditionally freshwater resident) and below-dam (traditionally anadromous/migratory) trout populations.

1385 Mandy Game, Frank Smith

Orthodenticle is required for the expression of both r-opsins and c-opsins in tardigrades

In many bilaterians, the gene orthodenticle (otd) regulates the development of eyes. Otd's role in regulating opsin genes during eye development in both protostomes and deuterostomes has contributed to the debate about whether the ancestral bilaterian had eyes. In the eyes of vertebrates and other deuterostomes, c-opsins function as the visual opsins, while in the eyes of protostomes, r-opsins perform this role. Although, it is clear that otd regulates visual opsins broadly across Bilateria, whether otd regulates non-visual opsins in protostomes has not been thoroughly explored. In order to understand more about the evolution of the regulation of opsin genes in Bilateria, we explored whether otd regulates both r-opsins and c-opsins in the tardigrade Hypsibius exemplaris, a microscopic protostome. Using Hybridization Chain Reaction in-situ, we characterized the expression patterns of two r-opsin genes and three c-opsin genes in H. exemplaris. Each opsin gene was expressed in a distinct pattern in the head of H. exemplaris. One of the r-opsins we investigated was strongly expressed in the eyes of H. exemplaris, suggesting a visual role for this gene. We then used RNA interference to target expression of otd. We found reduction in both r-opsin and c-opsin gene expression levels with this treatment. These results support a model in which otd regulated both r-opsins and c-opsins in the last common ancestor of Bilateria.

1176 Kaelyn Gamel, Henry Astley

Using Inverse Dynamics to Quantify Joint Mechanics of Underwater Walking in Axolotls

Underwater walking (UW) was the predecessor to terrestrial walking in the water to land transition. The difficulty of recording ground reaction forces (GRFs) from underwater walkers have limited empirical investigations, limiting our knowledge of the mechanics of this form of locomotion. Investigating single leg GRFs underwater can give insight into the mechanical loads and contributions of joints and whether UW forelimb or hindlimb driven. The vertical loads the joints may experience are predicted to be minimal due to buoyancy, but the animal must generate substantial propulsive forces to overcome drag. To examine the biomechanics of UW, we will use a modified underwater force plate to gather single leg GRFs from axolotls (Ambystoma mexicana). We synchronize limb kinematics and force data to calculate joint moments, work, and power. Tracking limb joints using a coordinate system relative to each joint with GRFs allows the calculation of moments using inverse dynamics at all limb joints over a cycle. Preliminary data suggest forelimb medial-lateral and braking forces are greater than hindlimb forces, whereas hindlimb propulsive forces are greater than forelimb. This in conjunction with past results suggests, the axolotl is hindlimb driven and stabilizes with the forelimb and body impacts. Future analysis will quantify relative joint contributions.

834 Alissa Ganley, Ian Bartol

Turning abilities of Sepia officinalis and Sepia bandensis hatchlings

Throughout their lifespan, cuttlefishes turn to capture prey, avoid predators, and navigate complex environments. The ability to turn effectively is especially important during early ontogenetic stages when predation pressure is high and effective prey capture strategies are critical for survival. However, surprisingly little is known about turning performance and dynamics of young cuttlefish. In this study, we collected kinematic and velocimetry data from cuttlefish, S. officinalis and S. bandensis hatchlings/early juveniles (∼0-30 days old) to assess their turning capabilities. A total of 150 turns were considered. Using in-house MATLAB routines, angular velocity, length-specific turning radius, jet velocity, jet length-to-diameter ratios, and angular impulse were determined. The cuttlefishes exhibited a wide range of turns, both in the arms-first and tail-first orientation. During turning sequences, S. officinalis used shorter but higher velocity jet pulses than S. bandensis, with S. officinalis showing a trend in greater jet angular impulse. Despite differences in jet properties, both cuttlefish completed turns of similar length-specific turning radii regardless of orientation; however, S. officinalis routinely completes faster turns. The results of this study indicate that a higher length-to-diameter ratio jet may restrict S. bandensis' speed of turning, but they manage to complete turns with the same tightness as S. officinalis.

946 Kenneth Garcia, Daniel Powell, Elise Martin, Alexandra Miller, Grace Bukowski-Thall, Patsy Dickinson

Flexibility of cardiac ganglion does not correlate with complexity of feeding in 3 species of crab

Central pattern generators (CPGs) are neural circuits that control motor behaviors by generating rhythmic firing patterns without the need for rhythmic inputs. In decapod crustaceans, a CPG in the cardiac ganglion is responsible for controlling the heartbeat, while CPGs in the stomatogastric nervous system (STNS) control movements of the foregut. Numerous amines, amino acids, and peptides modulate these neuronal circuits, allowing them to flexibly generate a variety of outputs. The large number of modulators (upwards of 30) identified in the stomatogastric system led us to ask why so many modulators are present. Previous studies have shown that the modulatory capacity, a measure of the extent to which a circuit is modulated, is greater in the STNS in species with broad diets than in the STNS of a specialized feeder, the kelp crab Pugettia producta. We hypothesize that this correlation reflects the evolutionary need for flexibility, and therefore would be restricted to the feeding circuits. We therefore compared responses of the cardiac ganglion CPG in three majoid crabs (Pugettia producta, Libinia emarginata, and Chionoecetes opilio) to the same neuromodulators tested on feeding-related circuits. We show that CG responses across species do not correlate with the animal's diet, supporting the hypothesis that modulatory capacity is related to the need for flexibility in the motor output of a given circuit/species rather than on phylogenetic relationships among those species.

201 Daniela Garcia-Cobos, Diego Gomez, Brandon Hedrick, Rachel Keeffe, Patricia Brennan

Coevolution of male and female genitalia in Helicops pastazae using 3D morphometrics

Squamates have great variation in male genital morphology that is often used as a taxonomic trait. Variation in female genitalia is known, but is less well studied. Here we report on out observations of the shape of the genitalia in adult female and male H. pastazae, a semiaquatic neotropical snake. We collected 42 adult specimens (22F, 20M), and made models of the lumen of the vagina, and inflated and removed both male hemipenes before preserving them in formaline 10%. Vaginal shape is significantly associated with body size: in smaller females the connection between the procotodeum and urodeum is closed, whereas in larger females, the connection opens, often is a single side opens first. The apical portion of the hemipene has close correspondence with the shape of the urodeal chambers, while the rest of the hemipene remains in the proctodeal chamber. The hemipenes in larger males are covered in long thin hard spines that penetrate the vaginal wall. Unlike previous work in Nerodia, vaginal allometry was positive. The coevolution in M/F shape is evident, and histological elaborations in the vaginal wall may mitigate damage by the hemipene spines.

371 Guillermo Garcia-Costoya, Karla Alujevic, Akhila Gopal, Michael Logan

Predicting ectotherm responses to climate change by quantifying shifts in thermal landscapes

Human activities have led to drastic changes in thermal environments worldwide, an especially relevant change for ectotherms. As environmental temperatures become both warmer and more unpredictable, climate change is likely to affect ectotherm populations both directly, through the interaction between the local thermal environment and organismal thermal tolerance, and indirectly, through effects on competitors, predators, parasites, and prey. A major goal of modern ecology is to accurately predict how this complex web of changes will impact and potentially harm ectotherm populations. Nonetheless, most climate change models offer predictions based on changes in the "average" characteristics of a population or thermal environment, despite the fact that the game of ecology is usually played by multiple species in a spatiotemporally complex arena. Here we examine how the thermal environment influences space use in populations of western fence lizards (Sceloporus occidentalis) across an elevational and competition gradient in the Great Basin Desert. We used infrared drone photogrammetry to construct highly precise 3D thermal representations of each site, which we combined with mark-recapture data to map the distributions of individual S.occidentalis and other competing lizard species over space and time. We then used these data to parametrize a model predicting habitat use shifts in space and time based on IPCC projections. Our study reveals how key ecological processes interact to affect the fate of wild ectotherms under climate change.

769 Sarah Gardner, Polly Campbell

The effect of genotype on the prenatal gut microbiome in the house mouse

In mammals, the microbiome was historically thought to establish in the postnatal period after exposure to the maternal vaginal tract. However, recent evidence in mice suggests that offspring are exposed to maternal microbes during gestation, in part via the placenta. Adult gut microbiota are sensitive to changes in the environment, however genotype can also influence the diversity and abundance of microbes in a given tissue. Importantly, no study to date has tested for an effect of genotype on the prenatal microbiome. To determine the effect of genotype on embryonic gut seeding in the house mouse (Mus musculus domesticus), four crosses were generated from two wild-derived inbred strains of M.m. domesticus. We collected tissue samples ($n = 5$ litters/genotype) from the placenta and embryonic gut, as well as a suite of maternal samples including the oral cavity, blood, gut, and vaginal tract. Microbial DNA was then extracted from each sample and sequenced (V4 region of the 16S rRNA gene). The effect of litter genotype on microbial diversity and abundance in the embryonic gut were analyzed using linear mixed models. The results of this experiment will indicate whether the initial seeding of the prenatal microbiome is strictly a maternal effect or if paternal genotype can influence initial community composition of the embryonic gut.

733 Isabella Garino-Heisey, Rylee Vigil, Wesley Rancher, Victor Gonzalez, John Hranitz, Thomas Tscheulin, Theodora Petanidou

Different thermal tolerances of summer-acclimated bees in a diverse island community

Understanding the range of thermal tolerances by members of a community is critical to predict the community's potential response to climate change. Bees are important pollinators of plants and community-wide perspectives on the thermal tolerances of individual species provides valuable insights into how climate change will impact individual species and affect ecological services by the bee community. We assessed the lower and upper thermal tolerance of more than 70 bee species (30 genera in 5 families) on the Greek island of Lesvos, a hotspot for bee diversity. We assessed the influence of body size (intertegular distance), hairiness (hair length), social behavior, and nesting guild. We found that across all bees, cold tolerance increases with increasing body size and hair length. Heat tolerance was not influenced by either morphological feature. Although highly social bees, such as honey bees and bumble bees, were as heat tolerant as solitary bees, they were able to tolerate lower temperatures. Twig-nesting bees, such as small carpenter bees, were more heat tolerant than ground- and cavity-nesting bees. This work demonstrates differential thermal sensitivities across bee species, highlighting the importance of improving our understanding of bee biology and ecology to better predict their responses to climate change.

905 Kathleen Garland, Alistair Evans

A Universal Model of Growth Describing the Evolution and Development of Theropod Beaks

Vertebrate beaks show a remarkable diversity of forms epitomized by birds and non-avian theropods. While studies have attributed beak morphology in birds to selective pressures such as foraging behaviour and diet, few have investigated how the underlying developmental mechanisms influence and constrain beak shape across the clade. Here we present the power cascade model, which may be used to describe the growth and form of a wide range of pointed structures such as teeth, claws and beaks. In the theropod beak, the power cascade is a log-log linear relationship that describes the expansion of the beak radius from the tip to the base. To test our model, we measured beak shapes across 131 families of extant birds and non-avian theropods and found that 92% followed the power cascade model ($r^2 > 0.95$). We were then able to use ancestral state reconstruction methods to test when the power cascade pattern may have arisen during the multiple instances of theropod beak evolution. Furthermore, by plotting the power cascade slope and aspect ratio parameters, we are also able to generate a morphospace that describes the beak shape of all extant birds and non-avian theropods. Within this morphospace, we can then explore how beak shape is grouped by other variables such as phylogeny and ecological functions.

188 Kelsey Garner, Cari Hickerson, Carl Anthony

Assessment of Repeatability and Behavioral Syndromes in Eastern Red-backed Salamanders

Behavioral syndromes are suites of behaviors that are correlated across contexts and are comprised of behaviors which are repeatable within individuals through time. Behavioral repeatability and correlates have potential fitness consequences at both the individual and evolutionary scale. However, few studies have examined these processes in terrestrial amphibians. We examined the repeatability of three commonly studied behaviors (boldness, exploratory tendency, and neophilia) in two genetically distinct clades (Northern, Ohio) of Eastern Red-backed Salamanders (Plethodon cinereus). The unique and extensive distribution of the Northern clade suggests that differences in behavioral traits may contribute to the historical dispersal success of these individuals. We tested the following hypotheses in the laboratory: (1) Both clades would exhibit repeatable behaviors; (2) Boldness, neophilia, and exploratory tendency would be positively correlated, suggestive of a behavioral syndrome; and (3) The Northern clade would repeatably exhibit bold, neophilic, and exploratory tendencies consistent with dispersing across a large range. We found strong repeatability of boldness and exploratory tendency but not neophilia. However, we found little evidence to support the presence of a behavioral syndrome. Contrary to our prediction, the Northern clade was less exploratory, neophilic, and bold than the Ohio clade. We postulate that dispersal phenotypes were lost through evolutionary time and emphasize that ecological pressures may have been primary drivers of range expansion.

1069 Austin Garner, Andrew Moura, John McCormack, Carla Narvaez-Diaz, Alyssa Stark, Michael Russell

Hyposalinity negatively impacts sea urchin locomotor performance and tube feet kinematics

Sea urchins are key benthic herbivores capable of drastically altering intertidal and nearshore community structure. They are considered stenohaline and only tolerate slight deviations from normal salinity ($\sim$ 32‰). Global climate change produces extreme climatic events (ECEs) in coastal areas, inducing periods of hyposalinity from increasing frequency and magnitude of storms. Sea urchins use tube feet, muscular hydrostatic extensions of their water vascular system, for locomotion, yet if or how hyposalinity affects locomotion remains unclear. We examined locomotion and tube feet kinematics of the green sea urchin (Strongylocentrotus droebachiensis) under three salinity conditions ranging

from normal (32‰) to moderate (22‰) and extreme (16‰). We also assessed the potential for hyposalinity acclimation by repeatedly exposing sea urchins to 22‰ and 16‰ seawater. Sea urchin locomotor performance and tube feet kinematics are negatively impacted by hyposalinity, particularly at 16‰. Despite repeated exposures, sea urchin locomotor performance did not improve over time, suggesting that acclimation is limited. Our findings demonstrate that ECEs present significant challenges to these key marine herbivores and highlight the importance of studying acute stressors induced by global change.

261 Caitlin Garrett, Kelsie Pos, Allyson Evans, Patricia Hernandez

Comparison of Pharyngeal Morphology in Invasive Asian Carp

Since their first releases into U.S. rivers half a century ago, Asian carp have threatened freshwater ecosystems from the Mississippi River basin through the Great Lakes. Silver, bighead, grass, and black carp all feed on different prey, from extremely small particles to aquatic plants and molluscs. While individual aspects of the trophic anatomy of these fishes have been studied, this is the first study to describe and compare pharyngeal musculature across species. Here we describe the pharyngeal bones and associated muscular architecture of each species, compare relative muscle masses, investigate their fiber types, and create two- and three-dimenstional visualizations of these morphological features. We use dissection and computed tomography to compare bony and muscular elements, as well as histological techniques to further characterize pharyngeal muscles. The following muscles were dissected out and weighed: levator arcus branchialis 5, retractors os pharyngeus superior and inferior, transversus ventralis, and pharyngocleithrals internus posterior and exterior. We found that the levator was the largest pharyngeal muscle by relative mass in most species, while the inferior retractor was the largest in black carp. Interestingly, previous research indicates that this latter muscle is also largest in common carp, suggesting that this architecture may be better suited for generalized diets. We examine these differences in a functional context to determine the role of pharyngeal anatomy in these fishes' status as successful invaders.

586 Ayane Garrison, Ibrahim Waheed, John Long, Candido Diaz

Modeling the Microscale Morphology of Moth Wings

The wings of a moth consist of a follicle-covered surface lined with thousands of detachable microscales. One of the many hypotheses about their adaptive value is that these scales evolved as a defense mechanism against the glue droplets of orb-weaving spider webs. When a moth comes into contact with an orb-web, their scales flake off, effectively freeing them. As an exception to this norm, spiders of the subfamily Cyrtarachninae are moth specialists whose glue flows especially well on moth wings, penetrating the surface of the scales and gluing them to the prey's base cuticle. We are generating a series of comparative models with varying scale arrangements, surface topographies and pitting them against variable glue types for microfluidic analysis. In doing so, we hope to gain a comprehensive understanding of how spiders' glue spreads across different areas of the moth, as well as the physical interactions between varying moth and spider species and their respective scales and glues. To create our models, we first use auto-fluorescence confocal microscopy to image various wing surfaces and individual scales. We then virtually reconstruct and analyze the acquired z-stacks using Fiji, before uploading them into Fusion 360 and combining our individual surface and scale components to create a fully formed 3D model. This research is supported by the National Science Foundation project, #2031962 to CD and JL.

1736 Samantha Gartner, Mark Westneat

Elastic skull ligaments and the biomechanics of the parrotfish bite.

The biomechanics of the fish skull has been well studied, with extensive research on kinematics, muscle function, modeling and hydrodynamics. Connective tissues such as tendons and ligaments are critical to musculoskeletal function, yet ligament properties are not often studied in cranial systems. Here, we aim to test the material properties of ligaments in parrotfishes and wrasses to explore their function. We investigated the material properties of three cranial ligaments (coronomaxillary, operculohyoid, and interoperculomandibular) across 8 parrotfishes and 2 related cheiline wrasses, using tensile tests to measure ligament load, strain, resilience, and elastic (Young's) modulus (E). The central finding of this study is that parrotfish cranial ligaments are highly elastic, showing high strain (up to 60% of resting length) with low breaking strength (up to 12 N) compared to close relatives. Modulus E in parrotfishes is low (50-80 MPa), reflecting the extensibility at relatively low forces of cranial connective tissues. Strain in parrotfishes was up to 60% of resting length, while elasticity (biomechanical resilience) in parrotfishes is high (85-95%) suggesting substantial energy return. Parrotfishes appear to have springs in their skulls, which can help to dampen forces and store energy. Ligamentous springs in fish cranial linkages, and elastic tissue mechanisms more broadly among vertebrates, may change the way we analyze the biomechanics of rhythmic as well as rapid explosive feeding events in vertebrate skulls.

722 Kayla Garza, Juan Daza

From symplesiomorphy to synapomorphy: The case of the stapedial foramen in Lepidosaurs

The stapes is a middle ear bone in tetrapods that was likely derived from the fish hyomandibula, although some authors claim that the mammalian stapes is derived from other parts of the hyoid arch. This claim has major implications for the homology of the perforate condition of the stapes, which is known in many fossil tetrapods, mammals, and some extant reptiles (geckos, dibamids and some amphisbaenians along their ontogeny). When the stapes is perforated, it carries the stapedial artery (at least this is the case in living forms). Researchers largely agree that the stapedial foramen of early tetrapods is homologous with those of living forms, and that this might not be homologous with the foramen in the hyomandibula of fish (which carries a branch of the facial nerve), although the distribution of this trait in the tetrapod tree of life seems to indicate convergence between mammals and squamates. In addition to this, is generally accepted that the stapedial foramen is the ancestral condition in reptiles (being present in forms like Youngina and Captorhinidae). In much advanced squamates,

1661 Richard Gawne, Michael Levin

Using Tissue Chimeras to Probe Regenerative Patterning and Physiological Controls in Planaria

The regenerative abilities of planarian flatworms have been widely studied for decades, with particular attention being paid to the genetic mechanisms involved in the establishment of head/tail identity. In contrast, relatively little is known about the biophysical mechanisms, tissue-tissue interactions, and physiological factors that contribute to regeneration, esp. with regards to complex characters such as the head. We elucidate some of these higher-level contributions to the regenerative process through the construction of intra- and inter-specific planarian chimeras that induce abnormal tissue-tissue interactions; specifically, we test the ability of tissue communication to override the genetically determined morphological defaults in the absence of RNAi or transgenesis. Using grafting techniques, we test whether fragments of donor tissue from double-headed worms can serve as an 'organizer' that converts wild-type worms into double-headed animals. We then examine the relationship between genomes and anatomical outcomes by quantitatively characterizing head shapes arising from chimeric animals containing cells from diverse species of planaria with distinct wild-type head morphologies. To determine whether patterning errors resulting from chimeric tissue interactions have broader physiological consequences, we measure the growth rates and compare the metabolic profiles of wild-type and chimeric worms. These studies aim to uncover the higher-level costs of incorrect patterning, and determine whether alternative morphologies produced through perturbations to the regenerative process have cascading effects that impact other ontogenetic and life history events.

1821 Jennifer Gay, Evelynne Dangcil, Jacqueline Nacipucha, Todd Mowery

An animal model of preterm infant exposure to the neonatal intensive care unit environment.

Introduction: According to the World Health Organization, approximately 15 million children are born prematurely each year. Many of these infants end up spending days to weeks in a neonatal intensive care unit (NICU). The auditory system of infants that are born prematurely are often exposed to noise and light levels that affect auditory development.Methods: We have developed a rodent model of NICU exposure. We used the Mongolian gerbil (Meriones unguiculatus) as our model organism, which has a low frequency human-like audiogram and is altricial. Here eyes are opened on the day of ear canal opening and animals are exposed to the NICU-like environment throughout the critical period of auditory development. After the animals mature into adults (∼PND 86) whole cell recordings were carried out from auditory cortex brain slice preparations. Excitatory and Inhibitory receptor properties, as well as intrinsic cellular measurements (F/I curves) were collected from these animals and compared to normally reared control animals. Results: After NICU exposure we observed an imbalance towards inhibition with lowered synaptic excitation. We also found reduced cellular firing properties. Conclusion: NICU-like exposure to light and sound permanently altered the cellular and synaptic properties of the auditory cortex. This preliminary result suggests that preterm infants in the NICU may have their auditory thresholds decreased to compensate for the loud environment.

601 Hannah Gellert, Daphné Halley, Zackary Sieb, Jody Smith, Greg Pask

Microstructures at the Distal Tip of Ant Chemosensory Sensilla

Ants and other eusocial insects emit and receive chemical signals to communicate important information within the colony. In ants, nestmate recognition, task allocation, and reproductive distribution of labor are largely mediated through the detection of cuticular hydrocarbons (CHCs) that cover the exoskeleton. With their large size and limited volatility, these CHCs are believed to be primarily detected through direct contact with the antennae during behavioral interactions. Here we first use scanning electron microscopy to investigate the unique morphological features of CHC-sensitive basiconic sensilla of two ant species, the black carpenter ant Camponotus pennsylvanicus and the Indian jumping ant Harpegnathos saltator. These basiconic sensilla possess an abundance of small pores typical of most insect olfactory sensilla, but also have a large concave depression at the terminal end. Basiconic sensilla are enriched at the distal segments of the antennae in both species, which aligns with their proposed role in contact chemosensation of CHCs. A survey of these sensilla across additional ant species shows varied microstructures at their tips, but each possess surface textures that would also increase sensory surface area. These unique ant chemosensory sensilla represent yet another example of how specialized structures have evolved to serve the functional requirements of eusocial communication.

1391 Bradford Gemmell, Sean Colin, John Costello

Hydromechanical Properties of Metachronal Swimming in Polychaetes

Free-swimming polychaetes are widespread in marine environments. These animals employ a unique form of swimming whereby the metachronal wave is coupled to a bending body wave. This body wave is unique among swimming animals in that it travels in the same direction as the animal's swimming direction. However, we currently lack a mechanistic understanding of this unusual form of locomotion. In this study we use a combination of high-speed, high-resolution video and particle image velocimetry (PIV) to quantify kinematics and fluid dynamics for three species of swimming polychaetes, spanning two orders of magnitude in size. We find that in all species, flows generated by metachronal waves of parapodia dominate while typical flows associated with body bending is absent. However, the parapodia are less flexible than propulsive structures in other metachronal swimmers. This creates a localized, but substantial upstream flow during the recovery stroke. Using body bending, the recovery stroke can occur mostly beneath the bulk flow from the power strokes, resulting in minimal inference while the subsequent power stroke can benefit from the pressure field generated during recovery. These results may have important implications for future vehicle designs that incorporate metachronal locomotion.

1253 Jacob George, Haley O'Brien, Holley Flora, Holly Woodward

Just Dunk It?: Observing Hard and Soft Tissue Interactions in Anoles

Understanding morphology and interactions of tissues at microanatomical levels is essential to interpreting form-function relationships. Traditional histological methods observe hard and soft (with decalcification) tissues independently. This leaves knowledge gaps from the lack of direct observation of hard and soft tissue interactions at minute scales. Anoles are small squamates with hyoid apparatuses (skeletal elements connecting the oral cavity and pharynx) modified to support protrusible dewlaps. We histologically imaged the delicate anole hyoid apparatus, a structure difficult to isolate due to its complex, primarily cartilaginous, jointed musculoskeletal elements. Here, we describe our technique for embedding, sectioning, and staining hard and soft tissues together without significant pre-processing. We applied two embedding methods to our specimens. The first was embedding entire specimens in epoxy before cutting thin sections from the craniocervical region; the second was isolating the ventral craniocervical region prior to embedding and cutting. Generated thin sections were stained with toluidine blue to observe soft tissues, and cartilaginous and ossified elements. Following these embedding and staining protocols, we were able to discern chondrocytes and fibroblasts, distinguish between hyaline cartilage, fibrocartilage, and bone, recognize cartilage in varying stages of remodeling, and identify previously unobserved interfaces between muscle and cartilage. These results demonstrate that non-traditional protocols can be utilized in histological observation, particularly in cases of sites of tissue interaction with applications in developmental, evolutionary, functional, and clinical contexts.

1448 Andrew George, Sara Yeo, Nalini Nadkarni

The STEM Ambassador Program – Bridging Science and Society

The imperative for scientists to engage more directly and effectively with the public has become increasingly important to science and society. The NSF-funded STEM Ambassador Program (STEMAP) teaches scientists, engineers, and other academics to design, implement, and evaluate innovative public engagement events as foci for building relationships with communities and promoting open-minded exchange between scientists and diverse members of the public. A major goal of STEMAP is to provide researchers with the skills to nurture relationships that increase the accessibility of science and scientists to community groups that face physical, legal, and financial barriers to accessing traditional public science venues (e.g., museums and zoos), such as rural, senior, and incarcerated populations. STEMAP trainees, known as "Ambassadors", receive comprehensive training in identifying, contacting, and building relationships with scientifically underserved community groups to design activities tailored to each group's needs and interests in the venues where these groups already gather. Ambassadors are guided to reflect on their personal and professional interests and experiences to identify and connect with community groups gathered around shared interests, circumstances, or experiences. STEMAP has trained over 200 scientists, who in turn have formed relationships with and provided scientific programming for over 70 community groups nationwide. STEMAP techniques and examples, and opportunities for involvement in future trainings will be discussed.

1833 Rebecca German, Christopher Mayerl

Biology at Birth: Introduction to the Symposium

Infancy is a perilous time for any organism, with significant changes as individuals move from the protected maternal environment to the outside world. Massive anatomical, behavioral, and physiologic changes start at birth, and continue through being a juvenile, with implications for adult survival, success, and fitness. This symposium will highlight the importance of understanding infancy from an integrated perspective, and how infancy can shape an individual's future. Our goal is to bring together researchers across various life science disciplines for conversation, collaboration, and interaction across boundaries as a way of promoting novel and innovative research at this specific moment of development. We will examine infancy through multiple physiologic/comparative perspectives, under three general topic headings: (1) how the prenatal environment shapes infant phenotype (e.g., maternal effects); (2) general infant physiology and development; and (3) the longitudinal impacts of infant experiences on phenotype and performance. Speakers will cover these topics across multiple physiologic systems (including neurological, cardiovascular, musculoskeletal, digestive, endocrine) and multiple model species (humans, pigs, sheep, rodents). We hope that the presentations and discussions among individuals representing the three topic headings will galvanize interactions and cross-fertilizations. This in turn will promote new and integrative work on the both the underlying normal physiology and the specific pathophysiologies that characterize infancy.

933 Jace Gertz, Allison Davis

The brave and the bold: effects of pollution on boldness behaviors in fish

Forever chemicals, microplastics, pollution–terms that frequent our headlines and accompany research detailing their effects on the human body. However, when it comes to other animals, the focus is on whether pollutants are present or how they affect the organisms at high levels. It is vital for us to understand how pollutants affect animal behavior at low exposures since the accumulation of small changes can still lead to a large disruption in the ecosystem. In this study, we are interested in the effects of a chemical pollutant–4-tert-octylphenol–on the boldness behaviors of a common freshwater fish, sailfin molly (Poecilia latipinna). Octylphenol is a main ingredient in common detergents and emulsifiers and is known to have estrogenic effects at high levels. While its use has been banned or managed since the late 1900s, octylphenol can still be found in most waterways at lower concentrations. It is currently unknown how these lower concentrations affect aquatic life. Here, we expose a treatment group to 0.41 ug/L (a biologically relevant level) and compare boldness and neophobia behavior between the exposed and control groups. Both increased or decreased boldness and exploration can drastically affect an organism's foraging patterns or predator avoidance. Understanding the behavioral changes that stem from low-level pollution enables us to predict shifts and protect aquatic organisms in this rapidly changing world.

1188 Mafdy Ghaly, Kelsey Beavers, Whitney Mann, Laura Mydlarz

Variation of antibacterial response is linked to disease susceptibility in Caribbean stony corals

Climate change has been well linked to the rise in coral disease outbreaks. Disease outbreaks cause significant decline in many keystone coral populations leading to decrease in overall biodiversity of the reef ecosystem. While forecasting disease outbreaks has improved, there is still a lack of understanding for species specific susceptibility to disease. We hypothesize that more susceptible species have a lowered ability to combat pathogens including growth inhibition and biofilm formation. In this study, seven stony coral species were exposed to white plague disease (WPD) and stony coral tissue loss disease (SCTLD) coral fragments and proteins were used to assess activity against growth and biofilm assays of the coral pathogen, Vibrio coralliilyticus. Initial data show lowered antibacterial and antibiofilm activity in corals with higher disease susceptibility. The survival of corals among reef ecosystems are critical to overall function and it is imperative to continue investigating mechanisms of disease susceptibility for better conservation efforts.

446 Francesca Giammona, Miriam Ashley-Ross

Jumping up that hill: How Kryptolebias marmoratus locomotes under various conditions

Amphibious fishes are notable for the ways in which they move on land. Some amphibious species, such as Kryptolebias marmoratus, accomplish this by performing tail-flip jumps. This jump is a two-stage movement, where in Stage 1 the anterior of the body curls over the tail, and in Stage 2 the tail pushes off the ground to initiate a jump. Many studies that focus on tail-flip jumps in K. marmoratus use tests on non-compliant, flat surfaces. However, in the wild this species must often traverse over land that is soft and prone to deformation, such as mud, peat, or sand. They must also jump up inclines that can range from 8?-16?. Individuals likely cope with these conditions by altering kinematic aspects of their jumps to produce effective movement. This study aims to determine which kinematic variables K. marmoratus changes when jumping on these different substrate types. First, fish underwent jump trials on microbeads of different grain sizes, mimicking substrate conditions from fine to very coarse sand. Second, fish jumped up inclines ranging from 5?-20?. With both sets of trials, the duration, velocity, and acceleration of Stages 1 and 2 were measured, as well as aspects of body curvature and jump take-off. Kinematic differences revealed by this study will inform past, present, and future K. marmoratus locomotor studies with applicability to wild fish.

245 Samantha Giancarli, Michael O'Connor, Matthew Bonnan

Actively foraging lizards build more robust humeri than similarly sized ambush predators

Blob and Biewener (1999), as well as Sheffield et al. (2011) hypothesize that the safety factors of a tetrapod's limb bones are reflective of metabolic energetic strategy–that is, low energy throughput tetrapods will build more robust limb bones to avoid metabolically expensive fractures. An obvious alternative is that very active animals will build heavier bones to resist more frequently applied stresses. To test this hypothesis in lizards, we analyzed CT and microCT scans (both newly scanned and obtained from MorphoSource) of lizard humeri representing both active foragers and ambush predators (i.e. high and low energy throughput, respectively). After making 3D models in Slicer, we used the Segment Geometry module to measure cross-sectional area, second moment of area about major and minor axes, and polar moment of inertia at the midshafts of these humeri. All of these measurements scale allometrically with body size (humeral length is used as a proxy), with differences in both allometric slope and intercept between active foragers and ambush predators. Contrary to the original hypothesis, active foragers appear to build more robust humeri than ambush predators of a similar body size. We hypothesize that this is due to more routine stress on the bones of active foragers, given their more frequent movements.

989 Brendan Gibbs, Clark Morgan, Steven Longmire, James Liao

Swimming kinematics and energetics of wild red drum under ecologically relevant flows

Locomotory performance is intimately tied to the properties of an environment. This is especially relevant for fish as fluids moving over the physical environment can create complex flow regimes. Despite this, swimming performance has largely been analyzed in uniform flow which may not be consistent with the conditions animals evolved in. We set out to determine how movement through ecological flows may alter fish swimming. First, acoustic telemetry of a wild marine teleost (Sciaenops ocellatus; $n = 43$) was used to inform our laboratory swimming treatments. Tagging data revealed that red drum primarily populate intracoastal inlets characterized by oyster reefs and mangrove habitats. Inlets are dynamic tidal environments with wide flow velocity fluctuations (20cm/s-120 cm/s), therefore swimming kinematics and energetics ($n = 5$; 37.7 ± 1.3cm) were tested under the following flow speeds: 22cm/s, 61cm/s and 100cm/s. Each flow speed was tested under three conditions: in uniform flow, and behind 2-D and 3-D bluff bodies to simulate mangroves and oyster reefs. We used DeepLabCut to reconstruct body midlines from a trained neural network. Turbulent flows behind bluff body treatments altered swimming kinematics compared to uniform flow. For example, tailbeat frequency (Hz) behind a bluff body (100cm/s; 2-D = 15.99 ± 0.34; 3-D = 14.728

$\pm$ 0.39) was significantly lower than in uniform flow (23.65 $\pm$ 0.35). Swimming in unsteady flows also drastically lowered energetics (100cm/s; laminar MO2 = 372.6; 2-D MO2 = 68.1; 3-D MO2 = 94.4). Our data indicates that the conditions fish face in the wild are critical to understand an ecologically accurate cost of locomotion.

1220 Miranda Gibson, Estefanía Rodríguez, Christopher Meyer, Benjamin Titus

Ecological diversification in the clownfish-hosting sea anemone Heteractis magnific

Tropical coral reefs harbor levels of biodiversity that are rivaled only by tropical rainforests yet do so in an area that encompasses only 0.1% of the global seafloor and in a setting with few hard barriers to dispersal. Evolutionary explanations that are overwhelmingly reliant on allopatric speciation are increasingly thought to be a poor fit for explaining the origin of tropical marine biodiversity on this scale. Exploring the processes by which tropical marine species diversify ecologically, where physical isolation is not a pre-requisite for reproductive isolation, will help shed light on the relative contribution of sympatric and allopatric diversification to global levels of marine biodiversity. To explore this question, we collected tissue samples of the magnificent anemone Heteractis magnifica, one of the most abundant and charismatic clownfish-hosting sea anemone species, from three distinct coral reef habitats in the Maldives and Moorea, French Polynesia. Using restriction site-associated DNA sequencing (RAD-seq) we demonstrate strong population genetic structure by reef habitat zone, possibly even rising to the level of cryptic species.

1127 Matthew Gifford, David Adams, Casey Brewster

Effect of warming nights on the energy budget and persistence of a locally imperiled lizard

It is well recognized that warming associated with global climate change will have far reaching implications for life on earth. Changing species distributions, alterations of phenology and daily activity periods, and changes to environmentally sensitive physiological functions have been demonstrated. Work also indicates that the effects of climate change on organisms varies across different spatial and temporal scales. Observed temperature increases are distributed asymmetrically across the diurnal cycle, where daily minimum temperatures are increasing at a faster rate than daily maxima. Thus, nighttime temperatures might have a particularly important effect on animal physiology and population persistence. In ectotherms, warming temperature at night should increase energy expenditure altering the energy budget. Such changes to organismal energetics might result in changes to life history characteristics that transmit up to the population level. We developed a spatially-explicit bioenergetic individual based model for the Eastern Collared Lizard to explore the consequences increasing nighttime temperature on a species already locally imperiled due to habitat alteration. We developed this model to explore potential changes in energy expenditure and life history due to habitat alteration, and to inform ongoing mitigation and reintroduction efforts for the species in Arkansas.

440 Erin Giglio

Using pose estimation to identify differences in movement across sex and neurodivergence in mice

Quantifying and describing animal behavior without imposing pre-determined human categorizations is a perennial problem. This is especially true in cases where internal states or motor behaviors express themselves in ways that are not immediately to human observers or do not align well with existing paradigms. Pose estimation, which tracks the location of body points over time in video, offers a wholly computational approach to classifying behavioral changes. Here we use SLEAP, a free and species-agnostic pose estimation library, to understand how freely moving mice of different sexes and neurotypes translate their contexts into physical movement and therefore behavior. We ask how mice of both sexes with and without a deletion associated with neurodivergence in humans (16p11.2 deletion) respond to dopamine injections when released into an open enclosure. How do different brains convert changes in internal status into external behavior?

1510 Amandine Gillet, Katrina Jones, Eric Parmentier, Stephanie Pierce

Detecting backbone regionalization patterns in extant cetaceans

The land-to-water transition during the evolution of cetaceans (whales, dolphins and kin) is characterized by a shift from limb-based to axial-based locomotion. This deep re-organization of their body plan had a major impact on vertebral morphology and function. Relative to other mammals that show distinct vertebral shapes subdivided into numerous regions, the cetacean vertebral column appears more homogeneous in shape and de-regionalized, with regional boundaries obscured. It has been suggested that either the typical number of regions are present but hard to detect due to homogenization, or regions have been reconfigured or lost entirely, linked to Hox gene repatterning. Here, we investigated backbone regionalization patterns in extant cetaceans using segmented regression analysis, a maximum likelihood approach that detects the number and location of regions based on vertebral morphology. Despite apparent homogenization of the backbone, numerous morphological regions are still detected in the cetacean spine. The greatest number of regions is found in the "caudal" region, with three–five regions present, while two–four regions are identified in the anterior part of the backbone (thoracic and lumbar). Interestingly, the degree of regionalization is positively correlated with vertebral count, thus suggesting the backbone of species with higher vertebral counts might be more functionally heterogeneous. Together, our results illustrate that cetacean backbone regionalization is complex and highlight the key role "caudal" vertebrae play in supporting axial-based locomotion.

1419 Celina Gilmore, Z. Jack Tseng

A 3D Printing Approach to Modeling Mechanical Behavior of Vertebrae for Functional Analyses

Bone functional morphology is partly defined by its mechanical properties, although most fossil specimen biomechanical analysis is limited to linear indices of digital simulations. We used microcomputed tomography to examine the trabecular bone microarchitecture of the thoracic vertebrae in a domestic cat specimen. The compressive strength of five isolated vertebral bodies of the thoracic region was measured using a mechanical testing frame. The compressive test consisted of force-displacement testing to determine Young's (elastic) modulus and the strength of the individual bony thoracic specimens and 3D printed models. Overall, the estimated modulus values were statistically similar between PLA models and bone, whereas the estimated yield strength values are statistically different between PLA models and bone. This study aimed to propose a new approach for quantification of mechanical properties by comparing 3D printed "lattice-like" trabecular structures and actual cancellous trabecular bone. The analysis of the elastic modulus and yield strength of the PLA and bone demonstrates informative but general mechanical behavior using printed models to replicate biological specimens under compressive stress. The following steps will include the evaluation of printed PLA structures at different gradient infill densities to better match bone behavior. Although limited to small sample size, these tests provide assessments of the viability of a physical modeling approach to understanding the functional morphological implications of vertebral body variation in the fossil record.

30 Benjamin Glass, Angela Schmitt, Kelsey Speer, Jill Ashey, Ariana Huffmyer, Hollie Putnam, Katie Barott

Cnidarian sperm motility is pH-dependent and influenced by parental exposure to ocean acidification

For broadcast spawning marine invertebrates, gametes are directly exposed to seawater prior to fertilization, presenting unique challenges for these species as climate change continues to drive rapid ocean warming and acidification (OA). In particular, the activation of sperm motility is a key process during broadcast spawning that is likely to be sensitive to future OA due to its dependence on sperm internal pH (pHi). Yet, sperm motility is poorly understood in cnidarians, a group that includes many broadcast spawners of utmost ecological and societal importance. We characterized foundational aspects of sperm physiology relevant to performance under global change in two cnidarians: the coral Astrangia poculata and sea anemone Nematostella vectensis. Ultrastructures of sperm showed that multiple mitochondria power motility, which was confirmed to be activated via the canonical, pH-dependent sAC-cAMP-PKA pathway. Upon finding that sperm motility in these species is pH-dependent, we then investigated the impacts of parental exposure to OA (pH 7.4 vs. 7.72) on sperm performance and associated fitness outcomes. Exposing N. vectensis anemones to low pH during gametogenesis resulted in decreases in male and female fecundity, but increases in egg size, sperm mitochondrial membrane potential, and fertilization success. Overall, this work indicates that sperm performance in broadcast spawning cnidarians is likely to be heavily impacted by future OA, and identifies parental effects as an avenue for cnidarian acclimatization to future global change.

296 Jordan Glass, Jon Harrison

Hot bees lift loads without warming or increasing metabolic rate

All ectotherms exhibit thermal performance curves, which are thought to determine maximal, temperature-specific performance. Maximal flight metabolic rate for unloaded honey bees flying in variable-density air peaks at flight muscle temperatures of 39°C, suggesting capabilities should decline at higher or lower muscle temperatures. We studied the effect of air temperature (20, 30, and 40°C) and nectar loads (0-75% of unloaded weight) on body temperatures, metabolic rates, and water-loss rates during flight of honey bees, Apis mellifera. Flight muscle temperatures and metabolic rates of flying bees increased linearly with increasing nectar load without changes in water-loss rates at air temperatures of 20°C and 30°C. Bees flying at these air temperatures achieved maximal thorax temperatures of 38-40°C, suggesting that demands of loading are met by increasing muscle temperature toward optimal. However, when flying at air temperatures of 40°C, evaporative water loss increased exponentially with load, allowing flight muscle temperatures to stabilize around 46°C regardless of nectar load. Remarkably, bees with flight muscle temperatures of 46°C were able to carry heavy nectar loads without increasing flight metabolic rate. Thus, increases in the efficiency of conversion of metabolic to mechanical power enabled this bee to exceed achieve load-lifting performance beyond the thermal performance curve limits for metabolism. This research was partially supported by USDA 2017-68004-26322.

1453 Lani Gleason, Florian Fekete, Richelle Tanner, Wes Dowd

Divergent transcriptomic and proteomic signatures of plasticity in an intertidal mussel

Responses of organisms to environmental change can be quantified at multiple levels, including the genome, transcriptome, and proteome, but these levels might provide different information. We conducted paired transcriptomic and proteomic analyses of the intertidal mussel Mytilus californianus after manipulation of its environment. Treatments included field-acclimatization, common gardening in a benign environment, and subsequent placement at either high- or low-intertidal sites that varied in intensity and duration of stress exposure. Globally, the two methods similarly identified plasticity across treatments. However, by analyzing 1519 gene products shared between the two datasets, we observed stark divergence between treatment-driven shifts in transcript and protein abundance patterns. For example, transcripts for molecular chaperones tended to be upregulated in the outplant high treatment, but the corresponding proteins were not significantly elevated. In several instances transcripts and proteins moved in opposite directions in a given treatment comparison. Furthermore, modules of gene products were either positively or negatively correlated with biochemical measurements on the same tissues depending on whether we considered transcript or protein abundances. Possible explanations for these discrepancies include time lags or other molecular means of decoupling transcript expression from expression of the corresponding protein, but in certain environmental contexts these discrepancies appear less common. Thus, care is warranted when interpreting expression data, particularly in ecological/evolutionary studies. Proteomic resources from this study will enable targeted follow-up experiments.

216 Kimberley Glenn, Alexis Lindsey, Mike Norris, Kaitlyn Murphy, Daniel Warner

Habitat Use of Hatchling Lizards Across Different Environments

How animals use their habitat is influenced by numerous factors and can have important fitness consequences. Habitat use of the brown anole lizard is well documented, but most studies focus on adults, rather than hatchlings, and rarely assess how habitat is used in different environments. Our study aimed to understand movement and habitat utilization during early life stages. To address this objective, brown anole eggs were collected from a captive breeding colony and incubated under conditions mimicking nest environments on shaded and open islands at our field site in Florida. Post-hatch, marked lizards were transported to the field and released at a specific location on either a shaded island (dense overhead canopy) or an open island (little vegetation). We quantified thermal data, shade cover, ground cover, vegetation type and height across a fine-scale grid on each island. Recapture efforts and visual surveys enabled us to record the location and perch height/type of each hatchling. Preliminary observations indicate that hatchling dispersal is relatively low on the open island, resulting in a high localized density in one area. In contrast, hatchlings on the shaded island dispersed relatively evenly across the entire island. Overall, this study will show how juvenile lizards utilize their habitat in differing environments and will be helpful in predicting how this invasive species might impact native organisms.

1774 Sam Glenn, Mitchell Ford, Arvind Santhanakrishnan

Morphological characterization of wing shapes of tiny insects

The bristled wings of numerous species of tiny insects such as thrips (Thysanoptera) and fairyflies (Hymenoptera) show remarkable diversity in shape, ranging from teardrop-shaped to long, slender profiles. We aimed to document the interspecific diversity in forewing shape of thrips and fairyflies. Wing shapes and geometric characteristics (chord, wingspan, wing area) were measured from published forewing images of thrips and fairyflies in ImageJ. Principal component analysis was performed on wing geometries of 13 species of thrips and 28 species of fairyflies. The three primary axes of variation were found to be linearly correlated ($p << 0.01$) with: 1) wing area ($R2 = 0.95$); 2) leading-to-trailing edge area ratio ($R2 = 0.71$), where the wing planform was divided into two regions on either side of a line connecting the wing root to wing tip; and 3) aspect ratio ($R2 = 0.49$). Body length was linearly correlated ($p < 0.05$) with wingspan and wing area in 10 species of thrips and in 8 species of fairyflies. While wing area directly impacts aerodynamic force generation, the effects of aspect ratio and leading-to-trailing edge area ratio on tiny insect flight are unknown. We hypothesize that wings with high aspect ratios could be useful for active control and stabilization during passive dispersal, while low aspect ratio wings with larger leading-edge areas could augment lift production by enhancing leading edge vortex formation during flapping flight.

1248 Ashley Glover, Harshada Sant, Sarah DeAmicis, Kriti Dhiman, Alexzander Cook, Chigozie Sumani, Adeline Southard, Brandon Drescher, Yaron Meirovitch, Richard Schalek, Yuelong Wu, Jeff Lichtman, Paul Katz

A connectomics approach to determine the neural architecture of the chemosensory system of the nudib

Although gastropod molluscs have been important for neuroscience, little is known about their chemosensory system's neural architecture. We took a connectomics approach to determine the neuronal architecture and connectivity in the rhinophore ganglion (RhG), which sits at the base of the rhinophore, the chemosensory appendage, in the nudibranch, Berghia stephanieae. The RhG contains around 9000 neuronal somata, almost twice as many neurons as the rest of the brain. We serially sectioned an entire RhG at 33nm thickness and completed imaging of about half of the sample of 2175 sections at 4nm lateral resolution. The RhG had a variety of regions including distinctive clusters of somata, neuropil, and axon tracts. We segmented and made 3D reconstructions of a few neurons in this dataset. Most of these neurons spanned the entire length of tissue from the middle of the RhG to the connective with the cerebral ganglion. We identified potential local interneurons and projection neurons. Some neurons had distinctive electron-dense granules. Most neurons in this dataset are filled with vesicles of different sizes and many branch extensively in the RhG. We segmented two non-branching axons that spanned throughout the tissue, bypassing the RhG. Machine learning algorithms will be applied to automatically segment all the cells to provide a first draft of the connectome. A complete connectome of this enigmatic ganglion will provide insights into its structural organization.

1518 Anna Godfrey, Erik Zornik

Vocal responses of male Xenopus borealis to conspecific and heterospecific pairing

Social communication is temporally dynamic, shaped by the identities, locations and internal states of each individual. A goal of our lab is to understand the sensory stimuli and neural mechanisms that orchestrate dynamic behaviors. Male Xenopus borealis produce a wide range of vocalizations that vary dynamically with social context. While some of the environmental conditions and sensory cues that regulate vocal patterns in male X. borealis have been described, the fine-scale temporal dynamics have not been explored. We performed audio and video recordings of male X. borealis paired with male and female conspecifics and heterospecifics (X. laevis and X. petersii) in overnight trials. While the call types produced matched those previously described, the amount of calling varied significantly within and between experimental conditions. Ongoing analyses are aimed at quantifying the precise timing and reliability with which social cues influence behavioral dynamics. Results from these and future studies may lead to new hypotheses about the neuronal mechanisms by which vocal control circuits are modulated to coordinate complex and dynamic social interactions.

947 Matthew Godino, Elyse Wick, Matt Steffenson

The effect of apiculture stressors on the immunological response of Italian honeybees

Colony collapse disorder (CCD) has caused widespread death of honeybees worldwide, but the exact causes are not understood. Many scientists however agree that pathogenic threats most likely contribute to CCD. Due to the integral ecosystem role that bees fulfill; it is important to understand how honeybees respond immunologically to different factors to better inform practices to combat CCD. The goal of this project was to quantify the immunological cost of two different beekeeping approaches to better understand how beekeeping practices can affect bees' susceptibility to CCD. Two colonies were maintained, one with an internal plastic foundation on their frames, and one without. The frame foundation provides structural support for the creation of honeycomb. Frames with no foundation are utilized by beekeepers to harvest beeswax, however beeswax is more energetically costly for colonies to produce, thus potentially causing energetic stress that may affect the colony's ability to fight pathogenic threats. We collected bees from each colony and extracted their hemolymph to quantify their basal immunological protein levels to determine if frames with no plastic foundation resulted in the colony being less able to combat pathogens. Data analysis is ongoing, but we predict that bees from colonies with a plastic foundation will have higher levels of intracellular immunological proteins, and thus will be more capable of successfully fighting off immunological threats.

349 Tyler Goerge, Donald Miles

Heat hardening influences boldness behavior expression in tree lizards, Urosaurus ornatus

Rising temperatures and extreme weather events threaten ectotherm populations worldwide. The increasing severity and intensity of heat waves are dangerous for ectotherms in hot climates, where individuals are already operating near their upper thermal limits (CTmax). When CTmax is exceeded, performance breaks down and mortality occurs. To survive heat waves, ectotherms can increase CTmax by up-regulating heat-shock proteins in a process called heat hardening. However, heat hardening has been demonstrated to reduce preferred body temperature and locomotor performance in lizards, which represent maladaptive responses to a warming environment. If heat hardening compromises the expression of other behavioral traits, its potential as an adaptive plastic response to warming climates may be compromised. Here, we investigated the influence of heat hardening on boldness behavior within a population of the tree lizard (Urosaurus ornatus). We measured boldness behavior as latency to emerge from a refuge after a simulated predation attack before and after a heat hardening response. We found that heat hardening, induced by warming individuals to CTmax, increased boldness behavior in U. ornatus. Boldness in males was more impacted than in females. To our knowledge, this is the first study that demonstrates behavioral ramifications of heat hardening and highlights the importance of behavioral and physiological interactions when considering population persistence in warming climates.

725 Kayla Goforth, Catherine Lohmann, Kenneth Lohmann

Recognition of site-specific magnetic fields by sea turtles: use of dual magnetic parameters

Sea turtles possess a magnetic map sense, meaning they can obtain positional information from Earth's magnetic field. Turtles can sense two magnetic parameters that vary predictably across the globe: intensity (strength) and inclination (the angle field lines make with Earth's surface). Together these parameters create unique magnetic signatures in most oceanic locations. Yet how turtles recognize magnetic signatures, whether both parameters are indispensable, and how precisely turtles can differentiate between similar magnetic signatures, remain unknown. Using an established behavioral assay, sea turtles were conditioned to discriminate between two magnetic fields representing actual geographic locations; turtles were fed in one field and not fed in the other. In an initial experiment, conditioned turtles were tested in fields in which the geomagnetic parameters were mismatched: i.e., the inclination angle of one field was paired with the intensity of the second field or vice versa. In a subsequent experiment, turtles were exposed to magnetic fields in which the inclination angle differed from that of the conditioned field by one and two degrees. Turtles responded to the conditioned field more strongly than to 'mismatched' fields or to fields in which the inclination angle was altered. Taken together, the results suggest turtles use both inclination and intensity to identify the magnetic signatures of locations, and can detect differences of one degree of inclination or less.

563 Luke Gohmann, Gregory Demas, Cara Wellman, Jessica Cusick

Maternal microbiome and stress remodel dendrites in prefrontal cortex in Siberian hamster offspring

Maternal stress and disruptions of the maternal microbiome during development can have organizational effects on the development of brain and behavior of offspring. We have shown that these maternal manipulations have sex-dependent effects on offspring aggressive behavior. Given that the prelimbic cortex is sensitive to stress and may play a role in modulating social behaviors, we investigated how maternal stress and disruption of the microbiome during pregnancy can affect offspring neural development in the prelimbic cortex in Siberian hamsters, Phodopus sungorus. Pregnant hamsters were exposed to either a broad-spectrum antibiotic, social stress, combined treatments, or no manipulation (i.e., control). Adult offspring (PND 107-115) were euthanized, brains were stained using Golgi histology, and apical and basilar dendritic lengths of pyramidal cells in the prelimbic cortex were quantified. Our data indicate that maternal stress and microbiome manipulation have a sex-dependent effect on offspring dendritic morphology. Maternal stress increased apical dendritic length in female offspring relative to controls. Conversely, male offspring with maternal antibiotic treatment exhibited significantly longer apical dendrites than control offspring. Furthermore, female offspring appeared to exhibit increased variability in apical and basilar length across all treatment groups relative to male offspring. Thus, maternal stress and disruption of the microbiome interact to produce lasting changes in prefrontal cortex of offspring. Such changes may contribute to the behavioral effects of these manipulations.

1596 Akshata Gole, Yueming Sun, Alexandre Palaoro, Kostya Kostya

Feeding behaviour and wetting characteristics of live hawkmoths

Hawkmoth' s feeding organ, proboscis, varies in size from a few millimeters to several centimeters allowing them to explore a broad variety of food sources. Long-tongued hawkmoths typically hover over flowers when feeding, therefore, the time of proboscis dipping and withdrawing from nectary tube per pickup of maximum amount of nectar is important characteristic of the feeding process. The more nectar per dip the greater energy reward. Therefore, the more wettable the external surface of proboscis, the greater volume of nectar the hawkmoth acquires. While analysis of proboscis wettability of flying insect is challenging, feeding of constrained live hawkmoths can be studied in detail. These experiments demonstrate very important feeding features that allow to shed light on the mechanism of fluid uptake. We describe a new experimental setup enabling to measure dynamic contact angles that water makes with proboscises of live hawkmoths. We studied 60 individuals distributed across 16 species of hawkmoths and two species of butterflies and found that hawkmoths belonging to the same subfamilies either macroglossinae or sphinginae have similar contact angles. We observed and classified different modes of drinking suggesting that hawkmoths with proboscises much longer than their body size develop special mechanisms for liquid uptake.

185 Ming Gong, Eric Tytell, Yordano Jimenez

Dorsal and ventral asymmetries in tail motion during vertical maneuvering in largemouth bass

Generally, fish rely on their tails to generate thrust. Many fishes have tails that are morphologically symmetrical along the vertical axis, but functionally asymmetrical in swimming. For example, they can control the dorsal and ventral lobes independently to produce asymmetrical tail shapes, and presumably asymmetrical forces, during maneuvers. Some previous studies also applied both two-dimensional and three-dimensional methods and found that cartilaginous fishes can bend and rotate their tails to generate torques that counteract the torques generated by the bodies. But few studies have examined the 3D kinematics of vertical maneuvering in ray-finned fishes. In particular, we hypothesized that fish would move the dorsal and ventral lobes of their caudal fins asymmetrically during vertical maneuvers. To test this hypothesis, we recorded high-speed videos of upward, downward, and horizontal swimming in largemouth bass, Micropterus nigricans, from two views, which we analyzed in three dimensions with DeepLabCut. During upward swimming, there were more tail beats with the dorsal lobe leading, while during downward swimming, there were more tail beats with the ventral lobe leading. We are analyzing the correlation of asymmetric tail motion with body angle, angular velocity, and vertical velocity.

50 Jazcenya Gonzalez, Terence Leach, Gretchen Hofmann, Kit Yu Karen Chan

Marine heatwaves reduce gamete quality of the sea urchin, Strongylocentrotus purpuratus

Anthropogenic climate change has increased the frequency and intensity of marine heatwaves (MHWs), which are characterized by abnormally high sea surface temperatures lasting five or more consecutive days. To date, various studies have considered the biological consequences of these MHWs with a focus on adult mortality in marine species. To better understand how these events alter future populations, we sought to examine the role of MHWs on gamete quality and their transgenerational impacts. Using the keystone urchin species Strongylocentrotus purpuratus, we investigated changes in male and female gamete qualities after prolonged exposure (4 weeks) to elevated temperatures (+6°C, mimicking the "blob" observed across the northeastern Pacific Ocean from 2014-2016). Sperm concentration, protein concentration, and motility decreased after experiencing the MHW condition. While egg size appeared to be unchanged, the jelly egg coat thickness dramatically reduced under the MHW condition. Such a decrease in target size, combined with slower sperm speed, imply a lower chance of fertilization for these broadcast spawners. Direct fertilization assays will be used to further assess this prediction. As MHWs become more prevalent with anthropogenic climate change, our results illustrate an intense legacy effect: even if the adults survive elevated temperatures, reduction in gamete quality has negative consequences for population dynamics.

282 Raquel Gonzalez, Paul Johnson, Morgan Brizendine, Nathan Whelan

Genetic diversity, gene flow, and population structure of the endangered Alabama Pearlshell mussel

Alabama Pearlshell, Margaritifera marrianae, is a federally endangered freshwater mussel species endemic to the Murder Creek and Sepulga Rivers in south Alabama. This mussel has been extirpated from over 75 percent of its historical range as a result of anthropogenic habitat deterioration. However, aside from occurrences and host fish relationships, little is known about the species, in particular its molecular ecology. Genetic data can be used to better understand basic biology of Alabama Pearshell and to determine genetic impacts of historical species decline. Genetic data are also important for management efforts to prevent loss of genetic variation and preserve natural genetic structure. We used a genomic approach (3RAD) to generate molecular data to assess genetic diversity within the current range of Alabama Pearlshell. Analysis of population genetic structure suggests that gene flow is mostly limited to within drainage systems and is likely restricted by migration of the host fishes. Our findings also indicate higher genetic diversity and less inbreeding within populations than what we expected given the highly imperiled nature of the species. Notably, our genomic data do not indicate a recent bottleneck, which conflicts with apparent species decline that has been observed through traditional surveys. Future life history research and continued population monitoring is needed to determine how Alabama Pearlshell is maintaining high genetic diversity and avoiding inbreeding depression.

771 Christopher Gonzalez, David Plachetzki

Phylogenetic Focusing: a Novel Approach to Gene Family Phylogenetics

The growing availability of metazoan proteomic sequence data has substantially improved phylogenetic assessments of gene family evolution. However, what sequence data is included when constructing a phylogeny greatly impacts the final result, and the exclusion of informative sequences can lead to incorrect conclusions about tree topography, gene loss or gain events, and gene family evolution. To address the risks of data exclusion, we developed a program called Phylogenetic Focusing. PhyFocus reduces these risks by first conducting a highly permissive search of species' proteomic data using user-provided query sequences from multiple gene families, then constructing a gene tree for each species. Each species' gene tree is next "focused" by extracting the subtree representing the gene family of interest. Finally, the subtree sequences are concatenated, filtered for quality via HMMR and alignment editing, and used to construct the final gene family phylogeny. The PhyFocus approach can thus help improve phylogenetic assessments of gene family evolution, and is being developed as a publicly available package.

1254 Lizbeth Gonzalez, Louie Yang

Can aphid excretion serve as restoration for native vegetation?

One of the major threats to California's native vegetation is the spread of invasive grasses, which pose environmental concerns like wildfires. Exotic annual grasses are among the first aboveground vegetation to establish after a disturbance because they can quickly absorb available nutrients like nitrogen, which is in competition between plants and their microbial soil community. The addition of soil carbon typically reduces soil nitrogen availability via microbial immobilization. However, conclusions vary about carbon addition as an application for restoration of native vegetation. We investigate the natural input of carbon that comes from the oleander aphid, Aphis nerii. High densities of aphids excrete visible amounts of a sugary substance called honeydew. We will test whether the naturally occurring amount of honeydew on Asclepias fascicularis, is enough to change the soil nitrogen concentration in the soil. We hypothesize that the addition of naturally occurring honeydew will fuel the microbial community, thereby reducing the original concentration of soil nitrogen. If honeydew reduces nitrogen availability, we will further investigate whether these changes affect the growth of a locally common exotic annual grass, Bromus tectorum. We hypothesize that a significant decrease in the soil nitrogen concentration could decrease the growth of Bromus tectorum, making native species more competitive. If there is no effect, it might be concluded that honeydew does not have enough carbon to feed the microbial community.

1269 Anabarbara Gonzalez, Maria Alcivar, Karla Alujevic, Leah Bakewell, Guillermo Garcia-Costoya, John David Curlis, Noah Gripshover, Akhila Gopal, Samir Gulati, Renata Pirani, Daniel Romero, Claire Williams, Kelly Wuthrich, W. Owen McMillan, Michael Logan, Christian Cox

Temporal dynamics of ectoparasite infection during island colonization in Anolis lizards

Parasites can negatively impact the fitness of host individuals, limiting their expansion into new habitats. However, organisms sometimes lose their parasites when they colonize novel environments. This so-called "enemy release" may permit successful invasion. While enemy release has been documented in many taxa, the temporal dynamics of this phenomenon in the time period immediately following colonization is much less understood. We translocated populations of slender anole lizards (Anolis apletophallus) from the mainland to islands in the Panama Canal. All populations of transplanted lizards initially had trombiculid mites present. While most islands did not have any resident anoles (one-species islands), one island had an existing population of Gaige's anole (Anolis gaigei; two-species island), a competitor of slender anoles. After recapturing lizards only a few weeks after translocation, we found that mites were already completely absent from slender anoles on one-species islands, and they remained absent for five generations after population establishment. However, the slender anoles transplanted to the two-species island retained their mites and were still infected after five generations. Our study confirms that enemy release can occur extremely rapidly and then persist for several generations, but only when competitors are not present. This suggests that the diversity of the invaded community can affect the probability of enemy release and may have implications for invasion dynamics.

1844 Paul Gonzalez, Andreas Baxevanis

Conserved non-coding elements evolve repeatedly around homeobox genes in cnidarians, molluscs, arthropods and vertebrates

Conserved non-coding elements (CNEs) are short DNA sequences located outside of protein-coding genes that can remain under purifying selection for up to hundreds of millions of years. Studies in human and other vertebrate genomes have revealed that most CNEs carry out regulatory functions. Notably, many of them are enhancers that control the expression of homeodomain transcription factors and other genes with crucial roles in embryonic development. As a result, they are particularly relevant for the evolution of animal body plans. However, very little is known about CNEs outside of the vertebrates. To further our knowledge of CNEs in other parts of the animal tree, we conducted a large-scale characterization of CNEs in more than 50 genomes from within three of the main branches of the metazoan tree: Cnidaria, Mollusca, and Arthropoda. We identified hundreds of thousands of CNEs and reconstructed the temporal dynamics of their appearance in each lineage; we also determined their spatial distribution across genomes. We demonstrate that the proximity of CNEs to homeodomain genes is a shared feature of metazoans that evolved repeatedly and independently in lineages as distantly related as sea anemones, snails, insects, and mammals. We show that most homeodomain-linked CNEs are organized in syntenic cis-regulatory modules that maintain distance and order over large evolutionary timescales, presumably reflecting constraints on the local genomic regulatory architecture.

1623 Perla Gonzalez-Moreno, Quan Tran, Michele Nishiguchi

How to get rid of your neighbor: Type VI secretion system (T6SS) between conspecific V. fischeri

Symbioses between sepiolid squids (Cephalopoda: Sepiolidae) and the bioluminescent bacterium Vibrio fischeri serve as a model to examine the dynamics of host colonization. Multiple strains of V. fischeri are present in seawater, yet only a few successfully colonize and dominate squid light organs. Since the light organ represents a haven for bacterial replication, multiple factors have led to competition for this niche. Therefore, we examined whether T6SS-facilitated intraspecific competition may regulate the diversity and spatial distribution of V. fischeri strains found within the light organ of Euprymna. The T6SS is a molecular syringe that delivers toxic effectors to targeted competitor cells and can be regulated by changes in pH encountered within the host. Candidate T6SS-encoding strains were coincubated with T6SS-deficient strains isolated from Indo-West Pacific host populations. Five T6SS-candidate strains exhibited a lethal phenotype against competitor strains under neutral pH conditions. We subsequently examined whether pH affects T6SS expression in our lethal strains during this competition. Lethal strains had distinguished T6SS expression levels when experimentally evolved to different pH conditions compared to their ancestor. Results imply that lethal strains can extirpate potential competitors during host colonization and adapt to express T6SSs under host-specific cues (pH). Thus, the T6SS may serve as a major driving force in regulating the diversity and spatial distribution of symbiont strains found within the light organ of various host populations.

734 Shauntara Good, Chase Mason, Hannah Stanford

Evaluating the toxic effects of common sunflower terpenes using Vanessa cardui

Terpenes are small organic compounds found in all plants that serve a wide range of functions, including chemical defense against insect herbivores. The relative composition of terpenes varies widely across species, but also across plant organs and among genotypes within a species. The tissues of cultivated sunflower (Helianthus annuus) are dominated by three volatile monoterpenes: alpha-pinene, sabinene, and limonene. To investigate the chemical defense function of these three monoterpenes, we assessed the toxicity of these compounds in the thistle caterpillar Vanessa cardui (Lepidoptera: Nymphalidae). This species was selected as our model herbivore given its cosmopolitan distribution, polyphagous lifestyle, and importance as a pest of field crop sunflower. A standardized poison-food technique was employed, where larva were reared on artificial diets adulterated with doses of single terpenes as well as combinations. Larva were checked daily for mortality until chrysalis formation, with pupa moved into netboxes until adult emergence. Single-terpene diets were used to assess LD50s, while combination diets were used to determine whether these abundant terpenes act additively, antagonistically, or synergistically when present together as in plant tissue. Better understanding the activity of endogenous plant phytochemicals against insect pests informs breeding efforts for improved host plant resistance. Improving plant resistance to pests through changes in tissue terpenoid concentration or composition can contribute to agricultural sustainability through reduced pesticide use.

197 Jessica Goodheart, Abegail Bigasin, Rose Fiorenza, Deirdre Lyons

Identifying putative nematocyst sequestration genes in the nudibranch Berghia stephanieae

The intracellular uptake and storage of structures from one organism inside another is fundamental to eukaryotic origins, and multiple lineages have evolved to sequester such structures secondarily from their prey. Most groups evolved such interactions for metabolism (e.g., dinoflagellate endosymbiosis in cnidarians), but few have done so for defense. The processes of recognition and storage of sequestered cells is well characterized in cnidarian-dinoflagellate symbiosis, but little is known about sequestration in organisms that sequester defensive structures like cnidarian nematocysts. We investigated genes that may be involved in nematocyst sequestration in the nudibranch Berghia stephanieae, well known for its predation on the anemone Exaiptasia diaphana. During digestion in Berghia, Exaiptasia nematocysts move into a structure called the cnidosac in the Berghia ceras, where they are phagocytosed and stored by cells called cnidophages. We performed differential expression analyses between the distal ceras (where the cnidosac is located) and the proximal ceras and identified 166 upregulated distal ceras genes (71.1% annotated). Using HCR, we find some upregulated genes expressed in the cnidosac of Berghia juveniles, including known phagocytosis receptors that may be used by cnidophages to identify nematocysts. Since Exaiptasia is a well-studied species, the development of molecular tools in Berghia provides a valuable system where both sides of sequestration can be investigated. This work also provides a framework for comparative analyses of convergent intracellular sequestration across eukaryotes.

167 Christine Gordon, James Newcomb

Localization of extraocular opsin in the brain of Berghia stephanieae

Opsin is a protein that interacts with the light-sensitive chromophore, retinal, and is used for photoreception in both eyes and extraocular tissues. Preliminary data from immunohistochemistry (IHC) indicates the presence of extraocular opsin in the brain of the nudibranch Hermissenda opalescens. In this study, we used both IHC and in situ hybridization chain reaction (HCR) to investigate the localization of opsin in the brain of another nudibranch, Berghia stephanieae. With IHC, opsin protein was expressed in neurons throughout the brain, especially in the posterior region of the cerebropleural and pedal ganglia. Opsin mRNA was localized with HCR in similar regions of the brain. These data indicate that both techniques are likely labeling expression of the same gene. Furthermore, the presence of opsin in many neurons of the brain, which sits immediately below relatively translucent skin, suggests that this species of nudibranch may exhibit extraocular photoreception.

382 Andrew Gordus

Untangling the web of behaviors used in spider orb-weaving

Many innate behaviors are the result of multiple sensorimotor programs that are dynamically coordinated to produce higher-order behaviors such as courtship or architecture. Extended phenotypes such as architecture are especially useful for ethological study because the structure itself is a physical record of behavioral intent. A particularly elegant and easily quantifiable structure is the spider orb-web. The geometric symmetry and regularity of these webs have long generated interest in their behavioral origin. However, quantitative analyses of this behavior have been sparse due to the difficulty of recording web-making in real-time. To address this, we have developed a novel assay enabling high-resolution tracking of limb movements and web structure produced by the hackled orb-weaver Uloborus diversus. With a brain the size of a fly's, the spider U. diversus offers a tractable organism for the study of complex behaviors. Using machine vision algorithms for limb tracking, and unsupervised behavioral clustering methods, we have developed an atlas of stereotyped movements used in orb-web construction. The rules for how these movements are coordinated change during different phases of web construction, and we find that we can predict web-building stages based on these rules alone. Thus, the physical structures of the web explicitly represent distinct phases of behavior. In addition to our behavioral efforts, we are also developing biological assays to investigate how this elegant behavior is encoded in the spider's brain.

54 Anjali Goswami, Eve Noirault, Ellen Coombs, Julien Clavel, Anne-Claire Fabre, Thomas Halliday, Morgan Churchill, Abigail Curtis, Akinobu Watanabe, Nancy Simmons, Brian Beatty, Jonathan Geisler, David Fox, Ryan Felice

Attenuated evolution of mammals through the Cenozoic

Placental mammals make up 94% of extant mammalian diversity, with ∼6144 recognized extant species and an immense variation in ecology and morphology. Despite a wealth of data from extant and fossil species, the nature of the placental mammal radiation has remained a contentious topic, with significant uncertainty in the timing of the initial divergence driving continued debate on the tempo, mode, and drivers of placental evolution. Contributing to the uncertainty is the exclusion of fossils from most studies, despite the initial early Cenozoic radiation overwhelmingly involving wholly extinct lineages. Here we present the first quantitative analysis of skull morphological evolution spanning the full breadth of living and extinct placental diversity, with 757 3-D landmarks and sliding semi-landmarks for 322 species representing every extant family and most extinct orders. We conduct these analyses across 1800 evolutionary trees, with divergence estimates binned into sets spanning 5-million year intervals from 100 to 70 million years ago, to constrain the impact of phylogenetic uncertainty on our results. Placental cranial variation is highly concentrated, with only whales and rodents occupying distinct regions. Rates of cranial evolution peak early in placental radiation and generally decline through the Cenozoic. Whales, armadillos, and extinct "ungulate" orders consistently display rapid evolution, while stem placentals, evolve much more slowly than the crown group. Rodents and bats display moderate to low evolutionary pace, demonstrating a dissociation.

1825 Holly Gothard, Carla Hurt

Genomic Resources for Conservation of the Imperiled Hardin Crayfish (Faxonius wrighti)

The crayfish genus Faxonius is a focus for conservation and management efforts. Many Faxonius species are narrowly endemic and vulnerable to habitat loss. In contrast, at least three species are highly invasive across North America and Europe (F. virilis, F. immunis and F. limosus). Faxonius wrighti (Hardin crayfish) is a narrowly endemic, stream-dwelling crayfish native to tributaries in the middle Tennessee River basin; this species is currently being petitioned for federal listing under the Endangered Species Act. Loss of habitat due to agricultural run-off and stream channelization has contributed to population declines. The objective of this project is to provide genomic resources that can inform management and conservation efforts for F. wrighti. We are using whole genome sequencing (WGS) and comparative transcriptome analysis to investigate functional genetic variation. Whole genome assembly of crayfish is challenging due to the high repetitive content of crustacean genomes. We are optimizing a workflow for de novo assembly of crayfish genomes with short-read sequence data. Our multi-tissue transcriptome will be used to annotate the assembled WGS. Differential gene expression across tissues and populations will provide information regarding organ and gene function, as well as functional genetic variation across populations. This project will generate the first WGS assembly for the this diverse and ecologically important genus and will be used to inform conservation genetics studies in related taxa.

809 Madison Gott, Madeline Arrmstrong, Jessica Zehnpfennig, Andrew Mahon

A temporal investigation of sea spider (Pycnogonida) reproduction in the Southern Ocean (Antarctica)

Pycnogonids (sea spiders; Chelicerata), are a group of globally distributed benthic invertebrates placed in ten families and over 1300 described species. Approximately 20% of known sea spider species are found in the Antarctic and sub-Antarctic waters with over 200 of those species being endemic to the Southern Ocean region. Outside of one family, pycnogonids show exclusively paternal care after eggs produced by the mothers are glued to the male ovigerous legs and remain attached to the male through the different developmental stages until they reach the appropriate size and fall/crawl off the male. From collections spanning five research cruises to the Southern Ocean including the Western Antarctic Peninsula, the Bellingshausen, Amundson, northern Weddell, and Ross Seas regions,

we present information related to reproductive collections and covariate collection information (location, depth, collection date, etc.) from >1400 samples. We note observations of males carrying offspring and compare that with covariate data (location, date of collection, depth, etc.) to investigate the temporal nature of this reproduction and to determine if there are differences in the general timing of the reproductive characteristics. Our data present a comprehensive overview of sea spider developmental processes from large regions of the waters surrounding Antarctica.

1751 William Gough, Max Czapanskiy, Matthew Savoca, Elliott Hazen, William Oestreich, James Fahlbusch, Jeremy Goldbogen

Energetic Tradeoffs for Foraging and Migration in Large Whales

Long-distance migrations are one of the most energetically challenging behaviors observed within the animal kingdom. Animals migrate to track the seasonality of food sources or move between spatially distinct foraging and breeding habitats. Large body sizes, such as those seen in baleen whales (Mysticeti), are one adaptation allowing for migrations across vast distances. As capital breeders, mysticetes must also rely on the energy from a defined feeding season to last them throughout the year. Consequently, maximum migratory distance should be a function of energy gained during the feeding season. Using empirically-derived estimates of foraging and swimming energetic intake and costs for mysticetes of varying body sizes, we calculated the energy gained during a foraging season as well as the energy subsequently used during migration. For a successful foraging season, the energetic cost of migration only amounts to ∼20% of foraging season energy intake across body sizes, while a poor foraging year could result in exorbitant migratory costs of ∼100% or more. We also found that migratory costs are dependent on total distance, duration, and swimming speed. Combining a theoretical model with satellite tracks of individual whales, we determined that longer migrations are more costly and occur at higher speeds than shorter migrations. In a rapidly changing ocean, small differences in the distance, duration, and/or speed of a migration could have major impacts on individual fitness.

184 Gregory Grabowski, A'Tearea Boggan, Jolani Perez

Carbonate anhydrase activity localization and pH modeling in GI segments in the Roach: Gromphadorhin

Carbonic anhydrase (CAH) plays a key role in the conversion of carbon dioxide into bicarbonate and protons. Its enzymatic-localization using the Hansson's technique demonstrated CAH activity within small tracheal airways, throughout the ceca, and in clusters of cells in the lower midgut and intestine. Protons from the ceca are responsible for acidification of the crop, whereas bicarbonate neutralizes this acid and contributes to the alkalinization of the lower GI tract. Fluorescence stereo-dissecting microscopy was performed in situ using a lipophilic dye to establish the anatomical juxtaposition of these structures at a macroscopic level, as well as re-affirm microscopic relationships indicated by Hansson's technique. Systemic pH regulation appears to be driven by carbonic anhydrase (CAH) in the intertwining of airways and Malpighian tubules forming a mass confined by the curvature of the midgut; whereas close association with the ceca and lower GI regions may provide the cecal acidifying protons and lower gut alkalinizing bicarbonate, respectively. This is substantiated by hemolymph increased alkalinity with acetazolamide by retaining bicarbonate, whereas the pH along the GI tract became neutral with acetazolamide. It appears that close proximity of airways to the ceca and midgut supply carbon dioxide that is converted into protons and bicarbonate, and specific ion transporters, as yet to be identified, shuttle either into the gut lumen generating the characteristic pH of the segments.

143 Matti Gralka, Shaul Pollak, Otto Cordero

Fundamental metabolic strategies of heterotrophic bacteria

Through their metabolism, heterotrophic microbes drive carbon cycling in many environments. These microbes consume (and produce) hundreds to thousands of different metabolic substrates, begging the question of what level of description is required to understand the metabolic processes structuring their communities: do we need to account for the detailed metabolic capabilities of each organism, or can these capabilities be understood in terms of a few well-conserved carbon utilization strategies that could be more easily interpreted and more robustly predicted? Based on the high-throughput phenotyping of a diverse collection of marine bacteria, we showed that the fundamental metabolic strategy of heterotrophic microbes can be understood in terms of a single axis of variation, representing their preference for either glycolytic (sugars) or gluconeogenic (amino and organic acids) carbon sources. Moreover, an organisms position on this axis is imprinted in its genome, allowing us to successfully predict metabolic strategy across the bacterial tree of life. Our analysis also unveils a novel and general association between metabolic strategy and genomic GC content, which we hypothesize results from the difference in C:N supply associated with typical sugar and acid substrates. Thus, our work reveals a fundamental constraint on microbial evolution that structures bacterial genomes and communities and can be leveraged to understand diversity in functional terms, beyond catalogs of genes and taxa.

1130 Michael Granatosky, Melody Young, Nicolas Flaim, Edwin Dickinson

Unusual phalangeal proportions improve grasping potential in birds, mammals, and bioinspired design

Among tetrapods, digital proportions are highly constrained in a large-to-small proximodistal gradient. However, some mammals and birds have broken this pattern, elongating the distal phalanx and shortening its proximal counterpart. The convergent morphology among these distantly related taxa suggests an as of yet unknown biomechanical advantage to this configuration. We collected linear measurements of phalangeal length, width, and depth along digital ray three from a sample of birds and mammals and estimated force production at each of the interphalangeal joints. Further, we developed a set of bioinspired robotic rays that mimic our morphological measurements. Peak forces were collected at the midpoint of each phalanx within these robotic rays. Distal elongation of the penultimate phalanx and shortening of the proximal phalanx is associated with scansorial and raptorial birds and suspensory non-primate mammals. Shortening the proximal phalanges increases the force generating potential of extrinsic digital flexor muscles at more proximal interdigital pads, but not the claw tip. As such, we propose that shortening the proximal phalanges evolves when high grip forces are required. Assuming the legitimacy of this hypothesis, elongation of the penultimate phalanx has no influence on the force generating potential of digital musculature. Instead, such elongation serves to maintain overall ray length to accommodate for the short proximal phalanges.

1156 Michael Granatosky, Melody Young, Edwin Dickinson, Daniel Tanis, Aleksandra Ratkiewicz, Christopher Hanna, Allen Currier, Felix Kong, Clyde Webster

The Onset of Beak and Tail Use are Triggered by Changes in Substrate Orientation in Parrots

Parrots (Order: Psittaciformes) are unique among tetrapods in practicing a tripedal gait pattern powered by the exaptation of the cranio-cervical system into a third limb. However, it is unclear what conditions elicits onset of this gait pattern. In this study, we explore the influence of substrate orientation on the gait characteristics of rosy-faced lovebirds (Agapornis roseicollis) and cockatiels (Nymphicus hollandicus). Each species was filmed moving across five substrate orientations (0-90° and 45-85°, respectively). The tail was integrated into the locomotor cycle at 45° for both species. The use of the tail became ubiquitous for cockatiels at steeper angles, but lovebirds lifted their tail often coinciding with the swing phase of each limb. Beak use increased as substrate-orientation became steeper and was ubiquitous during 90° climbing in lovebirds. For both species, gait characteristics changed in a predictable manner to improve stability (i.e., slower speeds, shorter strides, and greater duty factors) at steeper orientations. These data show that tail and beak use are decoupled from each other. The inclusion of the tail first arises at lower inclinations to assist in pitch-back prevention during climbing, while the beak appears to start out more as a stabilizing grappling hook at ∼65° and does not power the locomotor cycle until true vertical ascent.

393 Jesse Granger, Sönke Johnsen

Collective Navigation as a Solution to Noisy Navigation and its Vulnerability to Population Loss

Many animals use the geomagnetic field to migrate long distances with high accuracy; however, research has shown that individual responses to magnetic cues can be highly variable. Thus, it has been hypothesized that magnetoreception alone is insufficient for accurate migrations, and animals must either switch to a more accurate, localized sensory cue as they near the end of their journey, or integratetheir magnetic sense over time. Here we suggest that magnetoreceptive migrators could use collective navigation strategies to migrate using only the Earth's magnetic field. Using agent-based models, we show that collective navigation allows for high-accuracy migrations. We compare this strategy to both time-integration and the use of a more accurate, local cue, and demonstrate that collective navigation is the most successful strategy of these three for animals with noisy navigational abilities. Finally, we explore the impact of population loss on animals relying on collective navigation. We show that as population density decreases, a greater proportion of individuals fail to reach their destination and that a 50% population reduction can result in up to a 37% decrease in the proportion of the individuals completing their migration.

476 Isabella Gravante, Audrey Hurt, Rachel Pepper, Brett Klaassen-van-Oorschot, Vermilion Villarreal

Morphologic Differences in Bird's Nest Fungi as a Predictor for Dispersal Behavior

The dispersal mechanics utilized by flora are interesting to the evolutionary history of their reproductive success. Several species of plants and fungi use a type of dispersal dubbed "splash cup dispersal", wherein an organism harnesses the kinetic energy of falling rain to launch its propagules distances many times the size of the parent organism. The mechanics of splash cup dispersal have been studied in bryophytes, but less work has been performed on fungal species. Fungal genera Nidularia use rain-activated dispersal to launch packets of spores, called peridioles, impressive distances. These species present with differing phenotypes, such as cup shape, texture, and peridiole shape.Our research attempts to discern what effects, if any, these phenotypical differences have on dispersal results: height of ejection, distance of ejection, and velocity. The setup utilised a pump controlled by a micron adjuster to release water drops at a range of impact locations. We then filmed the impact of the droplets with a high-speed camera. Cups were modeled from live fungi, and 3D printed. Results have shown to be different from conical cups of $\frac{1}{2}$ the size, with minimal correlation between dispersal results and impact location. Internal cup texture had no effect on dispersal, while round peridioles dispersed further than lenticular peridioles of the same volume and density. Additionally, we present a simple mathematical model that predicts dispersal from initial conditions.

1467 Katelyn Graver, Jordanna Sprayberry

How do bumblebees use visual versus olfactory information from flowers at different spatial scales?

Bumblebees are essential pollinators; utilizing sensory information to locate flowers while foraging, including visual and olfactory cues. Unfortunately, climate change and human activity have impacted the sensory signals they use to forage for floral resources. Thus, a comprehensive understanding of how they use floral sensory signals to find resources is a crucial component of conservation efforts. The majority of existing research exploring the relationship between visual and olfactory floral cues is performed at local spatial scales. This research is thus highly applicable to understanding floral selection, but an incomplete understanding of floral cue-use during search is still poorly understood. This study uses a wind-tunnel paradigm to investigate how the bumblebee Bombus impatiens uses visual versus olfactory information from flowers at local and distant spatial scales. This will allow us to establish a more thorough understanding if and how cue use changes as foraging bumblebees transition from floral search to floral selection.

1420 Lily Gray, Harry Siviter, Felicity Muth

Does chronic flupyradifurone exposure impair bumblebee memory?

Bees are important pollinators of crops and wildflowers and, as such, their recent decline presents a threat to both global food security and ecosystem biodiversity. A leading factor contributing to bee losses is the use of systemic insecticides such as neonicotinoids, which cause sub-lethal effects on bee behavior and reproduction, with consequences for pollination. While novel insecticides are increasingly being used in place of neonicotinoids, these act via the same pathway and as such may have similar sub-lethal effects. Since neonicotinoids are known to have a number of effects on bee foraging, learning and memory, here we addressed whether the novel insecticide flupyradifurone has similar consequences. Specifically, we addressed whether flupyradifurone affected bees' ability to remember a color association, a behavior relevant to successful foraging. Data collection is ongoing, but we believe our results will both help us better understand how flupyradifurone affects bees, and, more broadly, the protocols useful in addressing how other pesticides affect bee behavior.

1495 Marcelle Gray, Sarah Foltz

Interactions Between Land Use Type, Nest Predators, and Parental Behavior in Cavity Nesting Birds

Nest predation is a threat to the breeding success of many avian species. Predation pressure can vary depending on the predator community in the breeding area as well as the resources available to those predators. We studied anti-predator responses of tree swallows (Tachycineta bicolor), eastern bluebirds (Sialia sialis), and house sparrows (Passer domesticus), all cavity-nesting species that use artificial boxes and breed simultaneously in southwest VA. We used motion-triggered trail cameras to monitor nests for predation attempts and presence of potential predators in the nest box area. In addition, we observed the nest defense behaviors of parents associated with each nest during thrice-weekly nest-monitoring box checks. Specifically, we counted the number of overhead flights and dives and recorded whether or not parents also performed beak clicks and/or alarm calls during a 1-minute period coinciding with our check of the nest box. Nest boxes monitored during this study were located at two different sites: 1) a working farm and adjoining farm-turned-nature-conservancy and 2) a residential neighborhood. Data analysis is ongoing. We predict that the parents who experience a higher rate of predator visits will be more aggressive than those who see fewer predators. We also predict that the predator community at the two sites will be different in species composition and quantity.

163 Mia Greco, Marosh Furimsky

The Effect of Embryonic Exposure to Ibuprofen on Visual System Development

Ibuprofen is an over the counter non-steroidal anti-inflammatory drug (NSAID) commonly used to reduce fevers and relieve pain. The use of NSAIDs during pregnancy is debated, as studies have shown an association between prenatal drug exposure and an increase in premature births. Because of this, use after 32 weeks gestation is not recommended. Ibuprofen is a potential oculotoxin and is suspected to alter retinal blood flow during development. It inhibits cyclooxygenase (COX) enzymes, which function in synthesis of prostanoids. Prostanoids are cellular lipid mediators produced by the retina early in development to regulate blood choroidal and retinal blood flow. Because of this, COX activity is high in immature eyes. Due to ibuprofen's role as a COX inhibitor and COX's regulatory role in ocular blood flow during development, the effect of embryonic exposure to ibuprofen on eye development was investigated. Transgenic line zebrafish were exposed to varying concentrations of ibuprofen at 20 hpf. Utilizing microscopy and sectioning and staining techniques, images, measurements, and samples were obtained for assessment of overall morphology, eye diameter, and retinal cell proliferation and vasculature. A decrease in eye diameter along with decreased pigmentation of the eye was observed between embryos exposed at higher concentrations in comparison to the control. This study could provide useful information to the field of developmental biology and to physicians in their recommendation of ibuprofen usage during pregnancy.

310 Patrick Green, Daniel Sankey, Thomas Collins, Faye Thompson, Michael Cant

Short-term mating resources drive contest success in banded mongoose (Mungos mungo) warfare

When animals compete over limited resources, the individual that values the resource more usually wins. In contests among groups, however, different group members may value the same resource differently, and this value may change over time. Therefore, it can be unclear what motivates groups to fight. Here, we test how multiple resources influence intergroup contest outcomes in banded mongooses, a cooperatively breeding mammal that engages in violent intergroup fights. Many banded mongoose contests start when estrus females lead male group-mates to territory boundaries, starting fights with rival groups during which females mate with rival group males. Other fights occur directly over territory access, while still others are raids of a group's den that can result in the death of pups. We predicted that group success in intergroup conflict was related to the number and estrus status of females, the location of the fight, and the number, age, and sex ratio of the group's pups. Our preliminary analysis revealed that only female estrus status affected outcomes. When the focal group's females were in estrus and the rival group's were not, the focal group won 76% of the time. Focal groups had only a 40% chance of success when both groups, or neither group, had estrus females. Our results suggest the main factor motivating intergroup contest effort in banded mongooses is male defense of immediate mating resources.

509 Kiirah Green, Greg Rouse

Six new Lacydonia (Lacydoniidae, Annelida) species from the Pacific Ocean and Caribbean Sea

Lacydonia with 15 named species, is the single genus of Lacydoniidae, within the diverse clade Phyllodocida. Despite the low known diversity, Lacydonia has been recorded in almost every ocean basin and has a wide bathymetric range, from 10 m to over 5000 m. For this study Lacydonia samples were available from shallow-water Mediterranean, Caribbean, and Californian sites, as well as from deep-sea eastern Pacific methane seeps and wood falls. Using morphological and DNA data, this study supports the erection of six new species in addition to contributing new DNA evidence for two known species (L. miranda and L. hampsoni). This greatly expands the diversity of the group. Lacydonia hampsoni is shown to have a wide distribution from Oregon to Costa Rica. Several species were found at the same Costa Rican methane seeps. Habitat evolution and biogeography of Lacydonia is also discussed.

608 Todd Green, Tamar Goldblatt, Jeffrey Ng, Saqib Chariwala, Paul Gignac, Akinobu Watanabe

Do the cranial casques of cassowaries function as vocal resonators?

Vocal communication is common among Aves. Calls may vary in frequency, amplitude, and means of anatomical production between groups. Cassowaries (Casuarius) produce among the deepest of avian calls, with near-infrasonic components as low as 32 Hz. Booming vocalizations are critical for cassowaries in maintaining territories and attracting mates, though the process by which these sounds are produced is unknown. Cassowaries are not equipped with a tracheal cleft and vocal sac like their sister group, emus (Dromaius novaehollandiae). In lieu of these, cassowary cranial casques have been implicated as a source of sound resonation. For resonation to occur, a large enough patency for a vibrating column of air to pass between the nasal sinuses and internal casque (endocasque) is needed. Gross dissection of adult cassowary heads does not support a connection; however, due to the delicate nature of the internal casque trabeculae, the process of dissection could damage such passageways if present. To non-destructively investigate this matter, we used μCT imaging to visualize endocasques and nasal sinuses of an ontogenetic series of southern cassowaries (Casuarius casuarius; n = 18). Across ontogeny, we did not observe a patency large enough (diameter ? 2.0 mm) between cavities to satisfy the criteria for casque vocal resonation. Our data indicate that other anatomical structures are responsible for deep vocalizations in cassowaries, suggesting future studies focus on other potential casque functions.

879 David Green

Evolutionary, developmental, and functional perspectives on human and ape shoulder morphology

Most considerations of primate scapular morphology have focused on the association between form and function, but recent work has also highlighted morphological attributes shared among modern humans and African apes. These findings grant insight into the nature of their last common ancestor, but such hypotheses are tenuous in the absence of corroborating fossil evidence. Complete hominin scapular fossils are rare, and some of the better-preserved specimens of Australopithecus and Homo erectus happen to be from juvenile individuals. Accordingly, an ontogenetic perspective of hominoid scapular shape is required to analyze these specimens in the proper context. In this investigation, broad scapular blade attributes aligned gorillas and chimpanzees with modern humans, as apart from orangutans and gibbons, which corresponds with previously established phylogenetic relationships. Human and H. erectus scapulae also share numerous features (e.g., transverse spine orientation), distinguishing them from apes and australopiths. These morphological differences follow with disparate behavioral regimes seen among extant groups – ape locomotion is quadrupedal and includes climbing, knucklewalking, and arm-swinging, whereas humans primarily recruit their upper extremities for non-locomotor, manipulative tasks. This scapular evidence, in keeping with other apelike features of the Australopithecus skeleton, strengthens the hypothesis that their locomotor repertoire included both climbing and terrestrial bipedalism. These results shed further light on the paleobiology of the last common ancestor and the milieu in which bipedalism evolved within the human lineage.

422 Lauren Gregory, Emily Hung, Atalanta Ritter, Jennifer Brisson

Sending mixed pre- and post-natal environmental signals for a phenotypically plastic trait

Polyphenic traits, or morphs, require precise timing of environmental cues to develop properly. Developmental abnormalities can occur if the morph-determination process is confused by mixed environmental signals. For instance, pea aphids (Acyrthosiphon pisum) can produce winged or wingless offspring depending on environmental crowding density. However, some lines produce wing asymmetric aphids which have only a partial, nonfunctional set of wings. The precise cause of this abnormality is unknown. We investigated whether wing asymmetry was associated with receiving mixed pre- versus post-embryonic environmental signals. We first tested whether post-embryonic environment had any effect on wing morph determination by placing nymphs born from a mother raised in a low-density environment into a high-density environment, and vice versa. Second, we tested whether this mismatch between pre- and post-embryonic environment was associated with more wing abnormalities by scoring how many experimental nymphs were wing asymmetric and of those with asymmetry, what combinations of fore- and/or hindwings were affected. We found no evidence of an association between post-embryonic environment and morph determination, providing confirmation that pea aphid morph determination is a strictly prenatal process. Additionally, wing asymmetry occurred in all different combinations of the wing quadrants, suggesting that fore- and hindwing development are independent processes. This work further informs our knowledge of the developmental process of a phenotypically plastic trait and developmental instabilities within that trait.

931 Neysa Grider-Potter, Ryosuke Goto, Tetsuya Shitara, Yoshihiko Nakano

Neck muscle activity during multiple forms of locomotion in primates

As the intersection between head and trunk, the neck both maintains head stability while simultaneously anchoring the pectoral girdle during locomotor tasks. Head stability facilitates vestibular and ocular feedback required for safe, efficient locomotion but forelimb use during locomotion is variable. Here, we predict that 1) forelimb-dominate locomotor modes will require greater neck muscle activity than hindlimb-dominated modes and 2) increases in extrinsic neck muscle activity will correspond to increases in activity of the intrinsic neck muscles. We collected fine-wire electromyographic data during forelimb-assisted and hindlimb dominated locomotion in Macaca fuscata and Hylobates lar. Electromyographic data were collected from trapezius and sternocleidomastoid (extrinsic neck muscles) as well as splenius capitis and rectus capitis posterior (intrinsic neck muscles). Muscle activity data were compared intraspecifically between the forelimb-assisted modes of locomotion (brachiation and quadrupedalism) and hindlimb-dominated bipedalism using linear mixed models.Muscle activity varied significantly between locomotor modes in both species and, as predicted, extrinsic muscle activity is greater during forelimb-assisted modes than during bipedalism. In addition, sternocleidomastoid activity is significantly, positively correlated with splenius capitis suggesting that increases in extrinsic neck muscle activity due to forelimb-dominated locomotion necessitates corresponding increases in intrinsic neck muscle activity. Thus, we might expect differences in musculoskeletal morphology due to locomotor mode in order to accommodate functional variations.

242 Christopher Griffin, Neil Pezzoni, Romain Pintore, Randall Irmis, Nathan Smith, Alan Turner, Adam Marsh, Sterling Nesbitt

Early theropod hindlimb morphology evolved via shifts in ontogenetic timing

Early dinosaurs possess high anatomical and histological variation throughout ontogeny. Conspecific individuals at similar body sizes may possess disparate ontogenetic ages and character states, muddling basic taxonomy and phylogenetic reconstruction. The Late Triassic dinosaur Tawa hallae is key in reconstructing dinosaurian relationships. We integrated quantitative morphological analysis and bone histology to study the ontogeny in a sample of Tawa hallae femora (n = 36) from the Hayden Quarry (HQ), New Mexico. Non-metric multidimensional scaling (NMDS) recovered a continuous ontogenetic series. Ontogenetic sequence analysis confirmed high variation in the sample, with sequences that were consistent with the signal recovered in NMDS. Femoral histology of three specimens confirmed that these character state transitions correlate with ontogeny, with one femur possessing signs of asymptotic growth. 3D geometric morphometric analysis indicated ontogenetic signal when performed only on the HQ assemblage. The addition of other early saurischians to the analysis strongly suggested that Tawa femora are anatomical intermediates between herrerasaurids and neotheropods, with immature Tawa femora possessing neotheropod-like features before transitioning into herrerasaur-like anatomy at more mature ontogenetic stages. This is evidence that Tawa and herrerasaurids are non-neotheropod theropods, with the former representing a transition from the more plesiomorphic herrerasaurid anatomy to the derived neotheropod condition. Because neotheropod anatomy is present in immature Tawa femora, this suggests that portions of the neotheropod postcrania evolved via shifts in ontogenetic timing.

582 Noah Gripshover, Charles Watson, Jesse Meik, Lance McBrayer, Patrick Hennessey, Christian Cox

When food fights back: the feeding behavior of specialist and generalist predators on dangerous prey

Prey choice has important consequences for predators, especially when prey is dangerous. Consuming dangerous prey is particularly challenging for limbless, gape-limited predators, such as snakes, since the head must capture subdue, and ingest prey. Centipede eating evolved multiple times within snakes, despite centipedes' powerful forcipules capable of injecting venom into attackers. However, no study has described in detail how snakes may be adapted to choose, capture, and subdue centipedes as prey. We recorded feeding behavior of the flat-headed snake, Tantilla gracilis, a generalist predator and the southeastern crowned snake, Tantilla coronata, a specialist predator of centipedes. We offered multiple prey types during the day and night to test for prey preference and diel patterns of feeding. Both species of snakes preferred to feed at night. Although both species investigated multiple prey types, they only struck at and consumed centipedes. Each species differed dramatically in feeding behavior. In all trials, T. coronata struck, immediately coiled around the centipede, and held on for a prolonged time. Whereas T. gracilis struck centipedes, pinned them, and quickly began swallowing. Centipedes repeatedly bit snakes with their forcipules, prompting body restraint, while being consumed. Finally, we compared skull morphology between species to examine differences possibly related to behavior. Our results show how a specialist predator uses modified behaviors which may increase the ability to consume dangerous prey.

997 Collin Gross, Jay Stachowicz

The role of predators in structuring grazer communities across spatial scales

While the role of species interactions like predation in driving prey community composition, biomass, and behavior are well-known, the impact of predation on prey functional traits and trait-based community assembly is still relatively understudied. Studying how the distributions of traits in communities vary along global gradients can inform how variation in interactions like predation and other factors contribute to the process of community assembly. Using an observational approach spanning 30° of latitude in two oceans, we found that dispersion in communities of peracarid crustaceans associated with eelgrass (Zostera marina) strongly increased with increasing predation pressure and decreasing latitude. We build upon these results at regional and local scales using a combination of regional surveys and a field caging experiment to specifically target the role of predator traits in driving these differences in functional structure across prey communities. By integrating observations and experiments of species interactions and community structure across multiple spatial scales and trophic levels, we can better predict the impacts of community composition on food web dynamics, especially as regional species pools shift with climate change and anthropogenic introductions.

1246 Taylor Grossen, Rachel Cohen

Circannual gene expression across seasons in the green anole lizard (Anolis carolinensis) brain

Seasonally breeding animals must time their reproductive activities with appropriate environmental conditions, and many vertebrate species use day length as one of their primary cues. Similarly, photoperiod regulates daily activity patterns, which are controlled by the cyclic expression of four main genes (PER, CRY, BMAL, and CLOCK) such that Per and Cry dimerize and inhibit Bmal and Clock. When Per and Cry levels are low, Bmal and Clock dimerize and activate Per and Cry expression. Previous studies indicated possible differences of circadian rhythm expression across seasons within rodents, although other vertebrate groups have been largely understudied. To begin to examine a potential role circadian rhythm gene may have on circannual patterns, we are assaying mRNA expression of the core circadian rhythm genes in the green anole lizard (Anolis carolinensis) hypothalamus during two times of year: the breeding and non-breeding seasons. We collected tissue from male and female lizards during the morning, and isolated mRNA from the hypothalamus. Using quantitative PCR, we found that there were no differences in PER1 and CRY mRNA expression across breeding and non-breeding male and female lizards ($F_{1,27}$ 0.071, $n = 7$-10) and are continuing to assay mRNA expression of BMAL and CLOCK. Ultimately, this study provides insight in whether the circadian rhythm system might influence seasonal patterns in a reptilian species.

303 Laura Grossner, Maya Zepeda, Kiri Stauch, laura grossner, Charles Abramson

The Effect of Weight Changes on Cap Pushing Response in Honey Bees (Apis mellifera)

The cap pushing response (CPR) is a learning and memory paradigm that utilizes shaping to analyze different behavioral preferences. Honey bees were trained to a circular platform with a hollow center that housed a 50% sucrose by volume solution. A cap is placed over the hole, one light and one heavy to observe if honey bees would push the cap even with a heavy more aversive object blocking the sucrose solution reward. During the experiment, the weight of the cap was switched every fourth trial out of 16. This experimental set up allowed researchers to look at the switch between caps giving the observer a better idea of the behavioral shift between caps. Distance of caps pushed, and kinetic energy was measured to determine force used while pushing the caps and to observe if there was a change during each of the fourth trials. Results revealed that there was a significant difference in distance pushed between the heavy and light cap, but no difference in kinetic energy used between the two groups. These findings show that honey bees use the same amount of force no matter the weight of the cap, but distance the cap travels is much higher with the lighter cap. The honey bee will push the heavy cap even though it is a more aversive object to gain the sucrose solution reward.

750 Alina Grossweiner, James Townsend, Bradford Gemmell, Sean Colin, John Costello, Kelly Sutherland

Morphometric and kinematic variability underpin swimming performance among three ctenophore orders

Ctenophores are a group of gelatinous marine organisms that maneuver using eight rows of macrocilia called ctenes. The extent to which morphological and kinematic traits account for differences in swimming performance between ctenophore groups – especially considering the diversity of body plans and feeding strategies within the phylum – has been unclear. The goal of this study was to determine the variation of morphological and kinematic traits between three orders of ctenophore, Beroida, Cydippida and Lobata, and to explore how they relate to swimming performance. High-resolution images and high-speed videos were taken at laboratory and field sites in Friday Harbor Laboratories, Washington and Kona, Hawaii or were collected through a literature review. Adult cydippids were smaller than beroids and lobates and, relative to their size, had larger ctenes. Percent propulsive area, created from the ratio of the combined ctene surface area to total body surface area, was over four times greater in cydippids than lobates. Beat frequency predicted swimming speed only in cydippids. Body length weakly correlated with swimming speed for both cydippids and lobates. Beroids were the fastest order based on absolute speed but both beroids and cydippids both outpaced lobates in terms of relative speed. The relationships between morphology, kinematics and swimming are complex and the variability between groups suggests different kinematic profiles or ecological strategies among ctenophores.

1274 Courtney Grula, George Yocum, Julia Bowsher

Regulation of metamorphosis in the solitary bee Megachile rotundata

The physiological regulation of growth and metamorphosis has been well studied in the model organisms Manduca sexta and Drosophila melanogaster, but few studies have determined this life history transition in other insect species. Mothers of the solitary bee Megachile rotundata provision a finite amount of food to offspring, which may influence the physiological basis of the decision to initiate metamorphosis at a critical weight. To determine the regulation and timing of metamorphosis, we starved final instar M. rotundata across a range of weights and observed the timing of metamorphic commitment. After starvation, we measured Juvenile Hormone (JH) titers and genes involved in JH synthesis and response. We also measured genes involved in ecdysone synthesis and response. We found that metamorphic commitment was followed by declines in JH titers, and the upregulation of genes involved in ecdysone synthesis, and genes which are involved in pupal commitment.

1605 Courtney Grula, Arun Rajamohan, Joseph Rinehart

Cryopreservation of Monarch Spermatozoa

The Monarch butterfly, Danaus plexippus, is a migratory insect species that travels thousands of miles annually. D. plexippus was recently classified as endangered by the ICUN, which sparked many efforts to protect the species. Our approach for conservation is cryopreservation. Spermatozoa collected from male monarch butterflies were frozen in a solution containing cryoprotectants and then stored in liquid nitrogen. To determine spermatozoa survival, a subsample of preserved spermatozoa were thawed rapidly and survival was qualified through a live/dead stain. Through cryopreservation, we hope to preserve and store genetic material and viable spermatozoa. To date, this is the first successful cryopreservation of Monarch spermatozoa which sets the foundation to continue cryopreservation in this species.

932 Carsten Grupstra, Kirstin Meyer-Kaiser, Matthew-James Bennett, Maikani Andres, Hannah Aichelman, James Fifer, Alexa Huzar, Annabel Hughes, Hanny Rivera, Sarah Davies

Adaptation to thermal stress in cryptic coral lineages from marginal habitats

A major question in evolution is how plasticity and adaptation interact to influence survival in rapidly changing environments. This question is especially pertinent to reef-building corals, which are threatened by rising seawater temperatures. Recently, cryptic diversity—"hidden" taxonomic diversity that can harbor physiological variation—in marginal habitats has been suggested to underpin thermal resistance in some corals, but the relative contributions of plasticity and adaptation are difficult to disentangle. Here, we investigate adaptive variation in three cryptic coral lineages across environments that vary from typical offshore ("average" temperature, high coral cover) to marginal lagoon (high temperature, low coral cover) habitats in Micronesia. We sampled 90 colonies of the common coral Porites cf. lobata and uncovered that one cryptic lineage dominated offshore habitats (L1), while the other two lineages (L2-3) were more abundant in marginal environments. A thermal challenge experiment demonstrated that the lineages associated with marginal environments (L2-3) exhibited higher thermal resistance than L1 colonies. To disentangle whether this variation was driven by adaptative vs acclimatory mechanisms, we conducted a 6-month reciprocal transplantation experiment between offshore and marginal habitats using adult and juvenile L1 and L2 corals and tested their thermal resistance with a thermal challenge. Together, these experiments provide an exciting opportunity to unravel the contributions of plasticity and adaptation to thermal resistance in Porites cf. lobata and "shed light" on the future of coral reefs.

729 Ethan Guardado, Mary Woodruff, Susanna Tsueda, Kimberly Rosvall

Body mass and brood size interact with thermoregulatory mechanisms in wild nestling songbirds

With longer, hotter heat waves, animals are enduring prolonged heat stress. Animals can combat heat behaviorally by evaporative cooling (e.g., panting), or physiologically by upregulating heat shock proteins (HSPs) to repair cellular damage. However, excessive panting can cause water loss, and prolonged HSP upregulation may itself cause cellular damage. Considering larger bodies and broods may retain more heat, rising heat waves could select for reduced body and brood sizes by virtue of size-dependent thermoregulatory mechanisms. We investigated how mass interacts with HSP mRNA abundance and panting in 12 day-old tree swallows (Tachycineta bicolor). Using air-activated warmers, we experimentally heated nests to 4°C above controls for 4 hours in the afternoon. We video-recorded and quantified panting during the 2nd hour of heating. Later, using qPCR and one chick per nest, we quantified hippocampal HSP90AA1 gene expression because the hippocampus mediates exploration and migration, both vital behaviors for juvenile migratory birds. We found that HSP90AA1 abundance and panting were positively correlated across treatments, suggesting thermoregulatory responses are linked. In heated nests, larger chicks had more HSP90AA1 mRNA. In control nests, bigger broods panted more and had higher HSP90AA1 mRNA. Thus, larger chicks and broods may be more affected by heat. These responses may be beneficial in the short-term, but intensifying heat waves may eventually cause selective pressures against large body and brood sizes.

207 Jeffrey Guasto

Physical mechanisms regulating bacterial transport in porous media

Microbes thrive in marine sediments and saturated soils, where they mediate bio- geochemical processes, biofilm formation, and disease transmission. Swimming bacteria use both random walk and directed motility strategies to explore and navigate these complex environments, which are ubiquitously characterized by intricate porous microstructure and dynamic fluid flows. However, a comprehensive understanding of the microscopic physical mechanisms that regulate the macroscopic dispersal of motile bacteria in porous media remains lacking. We use precise cell tracking and microfluidic model porous media to quantify the transport properties of a model bac- terium (Magnetococcus marinus) and disentangle the effects of motility, microstructure, and flow. In quiescent environments, successive scattering events from solid surfaces rapidly decorrelate the cells' random walks. Effective cell diffusivity decreases with decreasing effective mean free path, which is established as a universal geometrical parameter controlling cell transport across different porosity, pore size, and disorder. For magnetotactic bacteria, preferential cell alignment along a magnetic field significantly hinders their ballistic motility in disordered, but not ordered, media due to accumulation in concave pore structures. Lastly, when directed to swim upstream against an ambient flow, we show that pore-throat constrictions cause magnetotactic bacteria to become hydrodynamically trapped over a broad range of flow speeds, which stifles cell flux regardless of the disorder of the medium.

1368 Christian Guerzon, Derrick groom, Cecilia Doan

Studying the regulation of cutaneous water loss in Calyte anna (Anna's Hummingbird)

Avian species rely on various thermoregulatory mechanisms to maintain body temperature in the face of high ambient temperatures. One such process is evaporative, which results in the loss of heat as water evaporates from the body surface through respiratory (RWL) or cutaneous water loss (CWL) routes. However, the mechanisms and relative importance of these two evaporative routes are not well defined in many avian species. Our goal is to fill in this gap in knowledge by investigating evaporative water loss in the smallest and most energetic birds: the hummingbirds. Our research question is: what is the relative importance of CWL for hummingbird thermoregulation across different temperature regimes, and how is CWL regulated in hummingbirds? We predict that hummingbirds will demonstrate increased CWL in response to increased temperatures, and when administered a beta-adrenergic agonist compared to when given an antagonist. To test this, we captured wild Anna's hummingbirds and measured CWL and RWL using respirometry under different temperature regimes. We want to understand this since high environmental temperatures can be detrimental for small endotherms such as hummingbirds. We also plan to measure CWL following the administration of pharmaceuticals that specifically target the beta-adrenergic sys-

tem. Demonstrating the beta-adrenergic system regulates CWL can provide a foundation for understanding hummingbird thermoregulatory physiology, and small endotherms more broadly.

585 Destiny Guillory, Sarah DuRant, Erin Sauer, Madeline Sudnick

Effect of maternal disease severity on transfer of antibodies to offspring

Individual variation in susceptibility to pathogens can be driven by many biotic and abiotic factors, including parental effects8. Parents provide the foundation for an individual's immune system through genetic inheritance and continue shaping offspring immunity during prenatal and postnatal development12. For example, the vertical transfer of maternal antibodies can differ due to many different nongenetic maternal factors, including environment, disease history, and behavior. Understanding the nongenetic ways parents contribute to offspring will allow us to better understand variation in disease susceptibility among individuals. Here we examine the effect of maternal infection severity on the concentration of vertically transmitted antibodies in the developmental environment (i.e., egg yolk). We collected unfertilized domestic canary eggs from 13 clutches of mothers with prior exposure to Mycoplasma gallisepticum (MG) and 13 naive mothers. Using the yolks from these eggs, we quantified total egg yolk antibodies with an enzyme-linked immunosorbent assay, or ELISA2. We found no significant effect of MG exposure, disease pathology, or MG-load on egg yolk antibody levels. Yolk antibody levels were also not affected by egg yolk mass. Further research is needed to determine whether MG-specific antibodies differed among treatments, whether other factors of maternal disease shape vertical transfer of antibodies, and how vertical transfer of antibodies varies with time post maternal infection.? ?? ?

123 Makayla Guinn, Christiana Kumar, Hussain Abdulla, Justin Elliott, Seth Foster, Frauke Seemann, Carrie Sinclair, Dara Orbach

Effects of salinity on steroid hormones and epidermal integrity in dolphins

Common bottlenose dolphins (Tursiops truncatus) in the Gulf of Mexico (GoM) are important bioindicators of ecosystem welfare and sustainability, inhabiting a variety of environments with variable natural salinities. Prolonged exposure to low saline conditions yields severe skin lesions and an increased risk of fatal secondary infection, raising concerns about current freshwater influx in the GoM from anthropogenically driven stressors like climate change. We assessed the prevalence and severity of skin lesions through images collected from a drone flown over dolphins. Additionally, we plan to assess steroid hormones extracted from blubber biopsies using liquid chromatography coupled with a fusion orbitrap mass spectrometer (LC-MS/MS) in three genetically distinct dolphin populations inhabiting ecosystems with different natural salinities within the GoM (5-15 ppt, 27-30 ppt, 36-38 ppt). Preliminary findings reveal skin lesions may be detectable using aerial images, and LC-MS/MS analysis of archived blubber detected 10 compounds associated with steroid hormone biosynthesis including cortisol, cortisone, corticosterone, and aldosterone. This study is the first to use aerial body images as a proxy for analysis of epidermal integrity in dolphins. This study will also be the first to validate aldosterone, an important regulator of internal salt and water balance and salinity stress, in dolphin blubber. Health data collected can measure dolphin susceptibility to environmental disturbances that alter salinity and induce negative physiological responses, assisting in the conservation of marine life across the GoM.

1186 Alex Gunderson

Disentangling physiological and physical explanations for body-size dependent thermal tolerance

Many consequences of global warming are body size dependent. Consistent with this observation, size-dependent thermal tolerance (SDTT) is often observed within and between taxa. Several hypotheses have been put forth to explain SDTT, most or all of which are physiological: they are predicated on different cellular, tissue, and/or system level responses of large and small individuals to temperature. However, physiological differences are not required for SDTT. In dynamic thermal environments, the rate of body temperature change affects the maximum temperature organisms can tolerate. Therefore, SDTT can also arise due to physical differences between large and small organisms that affect relative rates of body temperature change. Here, I present a framework for differentiating between physiological and physical explanations for SDTT in thermal tolerance experiments. I also present analyses applying the framework at intraspecific and interspecific levels using Anolis lizards as a model system. At both levels, I find no evidence for physiology-based SDTT within this lizard group. This framework is broadly applicable and may be of use for understanding the evolution and ecological consequences of SDTT as the global climate continues to change.

1308 Grace Guo, Santi Tabares-Erices, Irby Lovette, Anusha Shankar

A comprehensive phylogeny of avian torpor with ecological context

Torpor is a fascinating physiological adaptation that allows animals to conserve energy by a controlled reduction of their metabolic rate, body temperature, and other bodily functions in challenging environmental conditions. This phenomenon has been observed in a variety of avian species spanning 13 different families, representing a diverse array of habitats, diets, and other aspects. We are collating data from the existing torpor literature to create a comprehensive database of the species that exhibit torpor. We are using Ruf and Geiser's review (2015) as a starting point and have added 80+ bird and mammal species to the existing database of 215 species so far. We are also adding more physiological and ecological information for each species where the data are available, such as mean torpor bout duration, diet, and mean latitude at which each species is found. Our goal is to assess torpor within a phylogenetic framework across avian species while taking into account ecological factors. This review and analysis of torpor lends itself to expanding our understanding of the evolution of torpor, and perhaps of endothermy, by revealing patterns of daily torpor use in birds in the context of evolutionary relatedness and ecological constraints.

1318 Alexandra Gurgis, Jessica Goodheart, Rebecca Varney, Todd Oakley, Gabriella Wolff

The Minute Brains of Sea Fireflies: Evidence of Ancestral Mushroom Bodies

Ostracods are uniquely positioned within the pancrustacean phylogeny to provide insight into arthropod brain evolution. One of the oldest known crustaceans in the fossil record, ostracods are the most speciose members of Oligostraca, a clade sister to all other pancrustaceans. Despite their phylogenetic significance, knowledge of ostracod neurobiology is extremely limited, with nothing known about the adult brain. Investigating ostracod neuroanatomy is essential to unraveling questions about pancrustacean brain evolution. One current question of interest is when did mushroom bodies originate? Mushroom bodies are well-established as centers for learning and memory in insects, but the discovery of these in mantis shrimps suggests they are conserved across Pancrustacea. In this study, we used synchrotron micro-tomography, 3D reconstruction and immunohistochemistry to examine the brain morphology of the ostracod Vargula tsujii (Myodocopa, Cypridinidae). Here, we present the first model of an adult ostracod brain. Staining with a known mushroom body marker, anti-DC0, provides evidence for the existence of mushroom bodies within this taxa.This research expands our limited knowledge of ostracod neuroanatomy, allowing a more accurate reconstruction of the ancestral pancrustacean brain.

957 Roi Gurka, Asif Nafi, Daniel Weihs

On an adaptation of the Reynolds number to aquatic locomotion

The Reynolds number, which describes the relative importance of viscous and inertial contributions is commonly used to analyze forces on fish and other aquatic animals. However, this number is based on steady, time-independent conditions, while all swimming motions have a periodic component. Here we apply periodic flow conditions to define a new non-dimensional group, which we name the "Periodic Swimming Number, P", which rectifies this lacuna. This new non-dimensional number embodies the periodic motion and eliminates the arbitrariness of choosing a length scale in the Reynolds number for Body-Caudal-Fin swimming. We show that the new number has the advantage of compressing known data on fish swimming to two orders of magnitude, suggesting that the fluid-fish interaction is better described by P. In addition, we demonstrate that using P separates the fish species based on their locomotion modes. This shows the importance of considering not only inertia and viscous forces but also the time-dependent contribution to the forces.

1799 Christine Guzman, Kurato Mohri, Hiroshi Watanabe

The role of Neurexins in the early evolution of the nervous system

In the nervous system, chemical signaling occurs either via volume transmission of neuropeptides, or synaptic transmission of 'classical' chemical transmitters. It is hypothesized that during early evolution of animals, the diffusion-driven peptidergic signaling was the major mode of cell-cell communication. Later on, a faster and more targeted synaptic signaling was needed, as animal bodies and behaviors increased in complexity. But it remains largely unclear how the synaptic machinery evolved. One crucial event was the establishment of cell-cell contacts to specify and stabilize the communication between cells. In this study, we investigated Neurexins (Nrxns), a family of core presynaptic cell adhesion molecules, using the non-bilaterian model Nematostella vectensis. A series of gene expression and structure analyses indicated a non-neural origin of Nrxns. Functional analysis of the epithelial (classical) Nrxn in N. vectensis revealed its major role in cell adhesion. Neural Nrxns, named delta-Nrxns, are distinctly expressed in neuronal cell clusters that exhibit both peptidergic and classical neurotransmitter signaling abilities. Knockdown of delta-Nrxns resulted in abnormal behaviors of N. vectensis polyps, involving muscle contraction. Interestingly, the knockdown of the neuropeptide-precursor gene co-expressed with delta-Nrxns did not show the same behavioral abnormalities, reflecting an independent role of delta-Nrxns from peptidergic signaling. Pharmacology experiments suggested that delta-Nrxns are required for synaptic signaling. This study provides insights into the ancestral non-neural function of Nrxns and may explain how and why they were employed in the synaptic machinery of the ancestral nervous system.

165 Travis Hagey, Alaina Dawkins

Toepad shape allometry and evolution across Hemidactylus geckos

Gecko toe pads are a novel innovation allowing species to use their habitat in unique ways. Pads evolved multiple times in lizards and likely multiple times within geckos. One such suspected independent origin is at the base of Hemidactylus geckos. All Hemidactylus species have adhesive toepads, with most species having multiple pairs of lamellae, although some species have some or all undivided lamellae with multiple clades presumably reverting to narrow, underdeveloped and/or undivided pads. We sought to investigate and quantify morphological and evolutionary patterns across Hemidactylus, to better understand how adhesive pads evolve and diversity through time. Using a geometric morphometrics approach we correlated toe pad morphology with body size. Interestingly, our results suggest a consistent lamellae size across species, regardless of toepad area or lamellae number. When we considered lamellae configuration (divided vs undivided), our results couldn't detect differences in toepad shape between divided and undivided toe pads, yet we suspect species with divided pads likely have relatively wider and shorter adhesive areas, while species with undivided pads likely have narrower and longer pads. These results anecdotally fit our observations of undivided species. Lastly, using a node height test, comparing standardized phylogenetic independent contrasts through time, we found a significant model of late burst evolution, suggesting evolution of toe pad shape has been speeding up in the Hemidactylus genus.

640 Madeleine Hagood, Joseph Alexander, Marianne Porter

Exotendon or not? Mechanical anisotropic behavior of shark skin

Shark skin is hypothesized to act as an exotendon, altering swimming performance among species. In the skin, dermal denticles are embedded in the dermis, and collagen fibers form an elastic meshwork. This network stretches along two distinct axes of stress (longitudinal, anteroposterior; hoop, dorsoventral), transmitting tensile forces along the body during swimming. Previous work has shown that shark skin behaves anisotropically, stiffening along the hoop orientation, and that denticles and collagen fibers impact mechanical properties. We quantified the mechanical properties of shark skin, and the impacts of the collagen fiber network and dermal denticle density among species to test the exotendon hypothesis of shark skin. From 18 species (6 families), we dissected skin between the two dorsal fins and created grids (5×5cm). Using stereoscopic microscopy, we quantified the denticle density and collagen fiber angles for each skin square with ImageJ. Four pieces from each grid (2/orientation) were tested in tension until failure at a 2 mm/s strain rate on an Instron E1000. We generated stress-strain curves for each test and calculated the mechanical properties. We found significant differences in stiffness among species between testing orientations; skin tested along the hoop orientation was significantly stiffer than skin tested in the longitudinal orientation for all 18 species. These data support the exotendon hypothesis, and provide consistent species-wide information about shark skin mechanical behavior.

1191 Ella Halbert, Joanna Reinhold, Megan Roark, Sierra Smith, Katherine Stroh, Cameron Siler, David McLeod, Chloe Lahondere

Culex territans and its role in transmitting Batrachochytrium dendrobatidis to frogs

With amphibians in decline worldwide, in part because of pathogens such as the chytrid fungus Batrachochytrium dendrobatidis (Bd), it is critical to understand any potential threats to their populations. Culex territans is a mosquito species that feeds almost exclusively on frogs and has the potential to transmit pathogens, such as giant anuran trypanosomes and ranaviruses. However, its role in transmitting other pathogens such as Bd is unknown. Interestingly, mosquitoes can harbor fungus, and Cx. territans takes over 30 minutes to feed which could allow for spore transfer to the frogs' skin. In this study, we aimed to determine the role Cx. territans plays in transmitting Bd and its prevalence at Mountain Lake Biological Station (MLBS, VA). We screened frogs and field-caught, blood-fed mosquitoes for Bd, as well as conducted experimental Bd transmission assays in a laboratory setting. The presence or absence of Bd was confirmed via qPCR. We also identified the hosts the mosquitoes feed on preferentially at MLBS via blood-meal analysis. We found a low prevalence of Bd in the frogs at the station, no field-caught Cx. territans were infected with Bd, and Cx. territans can transmit Bd in a lab experimental setting. Our data also show that Cx. territans feeds mainly on green frogs and bullfrogs at MLBS. This project provides important insight into mosquito-host interactions, as well as amphibian conservation.

824 Matthew Hale, Daniel Nondorf, Christopher Robinson, Henry John-Alder, Christian Cox, Robert Cox

Widespread Dosage Imbalances Reveal Facets of Sex Chromosome Evolution in Phrynosomatid Lizards

Sex chromosomes present a regulatory conundrum because the progressive loss of recombination between nascent X and Y chromosomes drives the loss of genes on Y, disrupting protein stoichiometry and driving deleterious effects in the heterogametic (XY) sex. Numerous mechanisms have evolved to compensate the expression of X-linked genes relative to autosomes and to balance expression between sexes. However, in the Eastern Fence Lizard (Sceloporus undulatus), transcriptomic data revealed that many X-linked genes are consistently expressed at roughly 2-fold higher levels in females than in males, regardless of age or tissue. This pattern of female-biased expression on X was conserved across 9 other phrynosomatid species spanning 4 genera, suggesting a widespread lack of dosage balance for X throughout this lineage. Further, an inferred autosomal translocation to X in one Sceloporus species has apparently resulted in the novel acquisition of consistent female-biased expression by dozens of formerly autosomal genes. We see no evidence in S. undulatus that X-linked genes are expressed at lower levels than autosomal genes in males. Rather, in females, X-linked genes are expressed at higher levels than autosomal genes. Collectively, our results indicate that male-female imbalances in the expression of X can persist even in the presence of male dosage compensation, suggesting that the secondary evolution of regulatory mechanisms in females may be necessary to restore balanced expression of X between the sexes.

844 Matthew Hale, Daniel Nondorf, Christopher Robinson, Henry John-Alder, Christian Cox, Robert Cox

Evolutionary reversals in sex-biased expression of gene networks underlying growth in spiny lizards

Sex-biased expression of the genome is usually required for the development and maintenance of sexual dimorphism. Therefore, changes in the direction or magnitude of sex-biased gene expression are predicted to contribute to evolutionary shifts in sexual dimorphism. We tested this prediction by characterizing the development of sex-biased gene expression across ontogeny in the liver transcriptomes of two lizard congeners that differ in the direction of sexual size dimorphism (female-biased in Sceloporus undulatus, male-biased in S. jarrovii). Sex differences in autosomal gene expression were minimal in neonates and maturing juveniles of each species, but pronounced in reproductive adults, which exhibited thousands of sex-biased genes in each species. When combining species, we found 2248 autosomal genes with conserved sex bias in expression in adults (main effect of sex, no sex-by-species interaction) and 881 autosomal genes with reversed sex bias (sex-by-species interaction, no main effect of sex). In addition to pronounced reversals in sex bias for key growth-regulatory genes (IGF1, IGF2), we found frequent reversals within gene networks selected a priori for their roles in growth (GHR-Jak/STAT), nutrient sensing (mTOR, AMPK), and energy homeostasis. Collectively, we show that many aspects of sex-biased gene expression can be reversed between congeners, and we identify candidate genes and pathways in which we predict similar regulatory changes to accompany other evolutionary reversals in sexual size dimorphism across the spiny lizard phylogeny.

1620 Madison Hales, Aradhya Rajanala, Christopher Pierce, Ram Avinery, Isaiah Taylor, Mingyuan Zhu, Philip Benfey, Daniel Goldman

Visualizing root response to shifting gravity in real time and three dimensions

Plant roots use a variety of active sensory response behaviors to generate their paths within substrates. These behaviors, called tropisms, influence the root's growth trajectory in the presence of light (phototropism), touch (thigmotropism), and gravity (gravitropism).

How these tropisms react to time-varying stimuli or interact with other growth behaviors like circumnutation is not well understood. To address this, we developed an automated, programmable, rotating plant growth chamber that utilizes an optically transparent gelzan solution as a model substrate. The system provides time-varying gravitational stimulus and captures the real-time growth of a living root. From multiple camera views of the root over time, we reconstruct the root's full growth trajectory in three dimensions. We tracked the growth of rice (O. sativa) roots (typical diameter ∼0.2 mm) rotated between 0 and 90 degrees with respect to gravity, at frequencies from 0.0625 to 6 cycles/hour with both square and sine wave stimulus profiles. We compared how the root tip growth trajectory followed the gravity vector at different stimulation frequencies. Results indicate that administering consecutive stimuli on a short time scale (5 minutes) results in an integrated growth response, while consecutive stimuli on a longer time scale (8 hours) results in discrete tropic responses. We present a full three-dimensional reconstruction of growth trajectories in both regimes, and discuss how transient stimulus effects growth response and circumnutation in all directions.

101 Wouter Halfwerk, Ralph Simon

Acoustic camouflage drives body size evolution in a predator-prey arms race

Body size is an important trait in predator-prey dynamics and can rapidly evolve under an arms race scenario. Nocturnally active Lepidoptera hunted by echolocating bats are strongly restricted in body size, as bigger moths return stronger echoes. Here we determined whether moths can escape this size-dependent predation risk by increasing their acoustic camouflage through ultrasonic absorptive body scales. We used an automated setup to 3D scan moth specimen from the same community for their acoustic properties. Comparing shaved versus intact specimen we found a clear reduction in target strength, although the effect strongly depends on frequency range as well as body size. The stealth coating provided by sound absorptive body scales can reduce prey detectability up to 365 cubic metres and is in particular beneficial to larger species. The level of acoustic camouflage did not covary with other anti-predator traits, such as ultrasonic ears and thus appears to be an all-round anti-predator strategy. Acoustic camouflage through stealth coating thus allows moths to escape from the allometric relationship between size and detection risk, thereby enabling species to evolve larger bodies.

1401 Margaret Hall, Ruxandra Dane, Angel Olivares, Shirinithi Kalai, Alexandrea Miller, Dominik Valdez, Justin Georgi

Comparative anatomy of the Brachial Plexus in Mammals

The brachial plexus is an important network of ventral rami responsible for innervating the forelimb. Whereas the clinical importance for surgical interventions has been extensively researched in humans, broad comparative analyses across mammals of the patterns of innervation supplied by brachial plexuses have yet to be conducted.In order to further investigate the pathway and conservation of the roots and terminal branches of the brachial plexus, we compared our dissections of two macaques, one female and one male, with the available literature on primates, including humans, and non-primate mammals. We found that the roots contributing to the brachial plexus commonly found in humans (C5-T1) are conserved throughout species with the additional C4 or T2 contribution in some mammals. Furthermore, the terminal branches ulnar and musculocutaneous nerves are the most conserved whereas the axillary, radial, and medial nerves are the most variable. We propose that the brachial plexus is largely conserved across mammals but with interspecific variably concentrated among terminal branches supplying developmentally dorsal forelimb muscles. We suspect that this evolutionary conservation of roots, and some terminal branches, of the brachial plexus is embryological in origin.

1630 Kayla Hall, Adam Summers, Cassandra Donatelli

Flappy, flouncy fins: swimming kinematics of the spotted ratfish (Hydrolagus colliei)

Chimaeras are an ancient lineage of cartilaginous fishes distinguished by their large wing-like pectoral fins which they use to swim throughout the deep seas. Chimaeras are capable of oscillatory swimming: flapping flight, and undulatory swimming, or fluttering of the fins, when hovering or station holding in slow currents. Similar to their large pectoral fins, the pelvic fins of chimaeras are equally prominent. The relationship between these two sets of fins, and the reliance on the rest of the body to aid in swimming is unknown. To determine full-body swimming kinematics of the spotted ratfish (Hydrolagus colliei), we swam H. colliei ($N = 4$) in a flume with speeds ranging from 0.1-0.5 body lengths per second (BL/s). We point-tracked videos to determine pectoral fin, pelvic fin, tail beat frequencies and amplitudes, also the position of the dorsal fin spine allowed us to calculate body pitch. At low speeds, H. colliei uses both sets of fins to hover, where the pelvic fins flutter up and down, perhaps in response to vortices shed by the pectoral fins, while the dorsal fin and spine mimic are upright. At high speeds, H. colliei transitions to pectoral flapping flight with no movement of the pelvic fins, quick bursts of body undulation, and the dorsal spine tucks down, becoming streamlined.

1711 Robert Hall, Sean Schoville, Yi-Ming Weng

Genetic Diversity and Infection Pattern of Spiroplasma in the Beetle, Nebria Ingens Species Complex

Insect endosymbionts have been found in more than half of insect species. The roles these microorganisms play in their host could vary from parasitism to mutualism but have not been well explored due to the high diversity of insects and their extremely heterogeneous life histories. In general, common endosymbionts, such as Wolbochia and Spiroplasma, could be beneficial by increasing the number of host offspring, or by increasing the resistance against other parasites. Conversely, endosymbionts can cause male killing processes or post-mating cytoplasmic incompatibility in offspring, which could negatively impact host populations. Here we aim to understand the role of Spiroplasma sp. NR in their host, the Nebria ingens species complex, by scanning the prevalence of infection, genetic diversity, and geographic distribution. Initial results show a relatively high (57%) and geographically widespread infection rate of Spiroplasma throughout the Nebria ingens species complex. Both host and microbe populations show a similar trend of gradual genetic divergence across geographical space, but Spiroplasma appears to have longer dispersal distance. Also, findings show Spiroplasma in sympatric species of Nebria at different altitudes. Our next step will be to utilize Local PCA, sNMF functions, and geographic distribution to elucidate their genetic structures. The ongoing research utilizes population genomic variation of all species, including the beetle mtDNA, to identify inheritance patterns and assess the ecological role of Spiroplasma in this insect host.

1306 Kaley Hallmark, Ching-Wen Tan, Jared Ali, Rudolf Schilder

Larval history effects on migrant Monarch butterfly flight energetics and longevity

The Monarch butterfly (Danaus plexippus) has a complex, migratory life history that spans the north american continent. A single, long lived migratory generation travels 3000-4000 km southwards every fall, followed by a successional brood recolonization northward through several reproductive cycles during the spring and summer. Seasonal environmental changes in photoperiod and temperature cause differences in wing morphology and reproductive investment between migratory and breeding monarch generations. However, how such cross-generational plasticity in these and other pertinent traits may affect migratory success in this species is still largely unknown. To illuminate this issue further, we generated monarch migrants on two larval host plants, under laboratory settings known to induce migrant phenotypes. Here we present data indicating that while adult monarch energetics did not show plasticity in response to these treatments, adult longevity varied significantly with rearing conditions. We will discuss these outcomes in the contexts of monarch overwintering and conservation strategies.

547 Shayne Halter, Blair Wolf

Torpor Use as a Mechanism to Spare Fat in Migrating Hummingbirds - Variation Among Species

Migrating hummingbirds routinely replenish their energy supplies at temporary stopover sites along their flight routes. While at these sites, several species are known to use nocturnal torpor to facilitate rapid increases in body fat to fuel continued movements. Our study assesses body conditions of four species of hummingbirds (rufous, broad-tailed, calliope, and black-chinned) at a stopover site in southwest New Mexico, and their use of torpor to conserve energy. We used a quantitative magnetic resonance (QMR) scanner to measure fat and lean masses in 772 individuals. We performed respirometry trials on 78 individuals to assess use of torpor as a function of fat mass. Our preliminary analysis shows little torpor use in rufous hummingbirds, while broad-tailed, calliope and black-chinned hummingbirds made extensive use of torpor. On average, normothermic rufous hummingbirds lost 12.3% of their body mass during a 12-hour night. In contrast, torpid black-chinned, calliope and broad-tailed hummingbirds lost between 7.9% and 9.3% of their body mass over the same 12-hour period. Rufous Hummingbirds had higher mean evening body masses than the other three species. Torpor use within and among species appears to increase as both body mass and fat mass decrease. Our results suggest that lighter black-chinned, calliope and broad-tailed hummingbirds routinely use nocturnal torpor to supplement fat gain at the stopover site, while rufous hummingbirds with higher body masses tend to remain normothermic.

527 Adriana Halvonik-Sanchez, Adriana Omaña-Angulo

Variation in the Functional Feeding Groups of Fish in a Tropical Lowland Rainforest of Costa Rica

Anthropogenic disturbances in freshwater ecosystems have consequences on species composition and on the relative abundances of fish from different trophic groups. One example of these alterations is the removal of riparian vegetation as a means to create pastures, which can change the environmental conditions of rivers and in turn affect fish community composition. We can evaluate the responses of river ecosystems to environmental changes by assessing fish assemblages and the factors controlling their distribution. We hypothesized that the assemblages of functional feeding groups of fish along Río Puerto Viejo (Sarapiquí, Costa Rica) vary depending on the proximity to pastures. We selected four river pools, two next to pastures and two 50-100 m away. We evaluated habitat quality and measured environmental factors including periphyton coverage percentage, canopy cover, organic matter, depth, temperature, and current speed. Consistent with our prediction we found assemblages of functional feeding groups of fish vary depending on their proximity to pastures. There was a higher density of algivores next to pastures, but higher densities of herbivores, insectivores, and detritivores away from pastures. These differences occur because fish assemblages depend on the physical characteristics of the rivers they inhabit and changes in these characteristics may modify fish community composition. We concluded that assessing assemblages of functional feeding groups of fish is a valid complementary measure of river quality and level of anthropogenic alteration.

233 Leandra Hamann, Hendrik Herzog, Christian Grünewald, Alexander Blanke

Suspension feeders as biological models for bio-inspired filters to reduce microplastic emissions

Based on 18 ecological and technical parameters, we systematically reviewed 35 particle separation mechanisms of suspension feeders, identified structure-function patterns, and estimated their potential to develop a bio-inspired filter module to reduce microplastic emissions. We selected ram-feeding fishes for an in-depth analysis based on their ability to use cross-flow filtration, process large volumes of water, retain particles in a similar size range, and their inherent cleaning mechanism. In particular, we studied the gill arch system of five species within Clupeiformes and Scombriformes using optical microscopy, μCT, and videography to determine relevant filtration parameters. Our results show differences in gill raker morphology, filtration area, and mesh size, indicating two cross-flow filtration variations: Scomber scombrus and Rastrelliger kanagurta (Scombriformes) seem to use surface structures and mucus as adhesive material to increase particle retention, whereas Clupea harengus, Sardina pilchardus, and Engraulis encrasicolus (Clupeiformes) use a solely mechanical separation mechanism. We abstracted the morphological traits of the clupeid filters into parametric models to study fluid dynamics and particle behaviour in a flow tank and with numerical simulations. In a test environment, the developed filter reached a filtration efficiency of 80%. Through an iterative process, we will further optimise these filters to fit the technical requirements of washing machines as a point source of microplastics and further increase the retention rates.

728 Christina Hamlet, Lisa Fauci, Eric Tytell

Neuromechanical modeling of proprioceptive feedback effects on spinal injury recovery in lampreys

Some vertebrate spinal injuries can result in partial or complete loss of locomotor ability. While this loss is often permanent in mammals, some non-mammals, such as lampreys, can regain swimming function in certain circumstances. Though much is known about this phenomenon, the exact mechanisms of recovery are not well-understood in many cases. One hypothesis/conjecture is that amplified proprioceptive (body-sensing) feedback can allow an injured lamprey to regain functional swimming even if the descending signal is lost. We employ a multi-scale, integrative, computational, neuromechanical model of an anguilliform swimmer fully coupled to a viscous, incompressible fluid to examine the effects of amplified feedback on swimming behavior. Our results show, in some cases, feedback amplification below a spinal lesion is sufficient to partially or entirely restore normal swimming behavior.

1105 Alyssa Hamm, Ally Angst, Kashish Khanna, Joshua Gross

Cranial form and sensory-skeletal integration: Variation and constraint as a function of eye loss

The spatial colocalization of sensory neuromasts and bones in fish has long been appreciated in the classic literature. Our recent work suggests neuromasts are osteoinductive and mark positions of primary ossification for intramembranous bones around the eye. In this region, neuromasts positioned too closely to one another result in bone fusion. Here, we examined putative constraints in a developmental model by scoring the spectrum of fusion in a natural fish system, Astyanax mexicanus. We anticipated that eyed surface-dwelling morphs would show normal bones, while eyeless cavefish would display identical patterns of fusion. Interestingly, we discovered substantial variation in this developmental logic based on morphological analyses of ∼200 specimens of surface fish and three different cavefish populations. Eyeless cavefish showed a broad spectrum of fusion across the left-right axis, but patterns of fusion were specific to each population. Constraint was also evident as two bones (SO2 and SO3) never fused in any population. Surprisingly, surface fish had fusions, but they occurred very infrequently. This work suggests bone fusion patterns are mediated by neuromast positions but are constrained by the architecture of the skeletal orbit. One source of fusion variability may be differing rates of eye regression. Future studies will clarify the genetic, developmental, and molecular basis of this natural example of sensory-skeletal integration.

514 Victor Han, Gerhard Magnus, Junling Xing, Yueping Zhang

Diversity of cellular morphology and physiology of Purkinje cells in the adult zebrafish cerebellum

This study was designed to explore the functional circuitry of the adult zebrafish cerebellum, focusing on its Purkinje cells and using whole-cell patch recordings and single cell labeling in slice preparations. Following physiological characterizations, the recorded single cells were labeled for morphological identification. It was found that the zebrafish Purkinje cells are surprisingly diverse. Based on their physiology and morphology, they can be classified into at least three subtypes: Type I, a narrow spike cell, which fires only narrow $Na+$ spikes ($<$ 3 ms in duration), and has a single primary dendrite with an arbor restricted to the distal molecular layer; Type II, a broad spike cell, which fires broad $Ca2+$ spikes (5–7 ms in duration) and has a primary dendrite with limited branching in the inner molecular layer and then further radiates throughout the molecular layer; and Type III, a very broad spike cell, which fires very broad $Ca2+$ spikes ($\geq$ 10 ms in duration) and has a dense proximal dendritic arbor that is either restricted to the inner molecular layer (Type IIIa), or radiates throughout the entire molecular layer (Type IIIb). The labeled axon terminals of these Purkinje cells end locally, as reported for larval zebrafish. The present study provides evidence that the corresponding functional circuitry and information processing differ from what has been well-established in the mammalian cerebellum.

971 Jiawei Han, Hans Hofmann

Comparative Transcriptomics of the Subpallial Amygdala across 12 Species of Vertebrates

The mammalian amygdala is a key node in the social decision-making network, an evolutionarily ancient system of fore- and midbrain nuclei involved in evaluating social stimuli, cognitive and affective processing. Given its central role in these processes, dysfunction of the amygdala is associated with many psychiatric disorders. Here, we use phylogenetic comparative analyses to reconstruct the gene expression evolution of the (subpallial) extended medial amygdala and to ask whether gene co-expression modules dysregulated in psychiatric disorders are evolutionarily conserved or unique to the lineage leading to humans. We first collected subpallial amygdala transcriptome datasets ($n = 351$ individuals) for twelve vertebrate species – representing mammals, birds, squamate reptiles, and teleosts – and compared them to those of the hippocampus and its non-mammalian homologs, suggesting that brain region transcriptomes are relatively similar across vertebrates. Next, we reconstructed ancestral subpallial amygdala transcriptomes for vertebrates, amniotes, mammals, and primates, which allowed us to identify evolutionary conserved "core transcriptomes" of the subpallial amygdala and its putative non-mammalian homologs. We then identified the gene co-expression modules that are either evolutionarily conserved or have evolved de novo, including the lineage leading to humans. Ongoing analyses examine the extent to which gene co-expression modules dysregulated in psychiatric disorders are unique to humans. Our novel approach illuminates the evolutionary origins of the molecular mechanisms underlying complex (social) behavior and their vulnerability to dysregulation in psychiatric disorders.

219 Sarah Handy, Karly Cohen, Lauren Simonitis, Matthew Kolmann

Comparative anatomy and evolution of the gizzard in fishes

Gut morphology is related to the food types that organisms can process/digest; for example, the long intestinal tract of many herbivorous characiforms enables nutrient extraction from low-quality food items. The gizzard, a specialized organ of the gut tract, aids in digestion via mechanical reduction by grinding food. Gizzards may compensate for poor or absent dentition, and/or provide an advantage when consuming small, tough food (e.g., some phytoplankton, algae). Gizzards are present in several groups of vertebrates, including archosaurs and fishes. However, questions remain regarding how widespread gizzards are in fishes, and how similar these structures are among different lineages. We investigate the distribution of gizzards across bony fishes to (1) estimate how many times gizzards have evolved across the fish tree of life, (2) determine if aspects of ecology and gut morphology are associated with having a gizzard, and (3) describe gizzard tissue composition in multiple lineages. According to our analyses, gizzards are rare in bony fishes, evolving only twice, and their presence is not clearly related to morphological/ecological factors such as gut length, dentition, or diet type. We find that gizzards are histologically complex and consistently include several tissue types including circumferential and longitudinal smooth muscle, which are indicative of peristaltic activity. Taken together, this evidence supports that gizzards in fishes aid in mechanical reduction of food items, but their relative scarcity, evolutionarily and contemorarily, suggests they are just one of many possible solutions to process complex diets.

800 James Hanken, Zachary Lewis, Ryan Kerney

Lost and found: Lung development in lungless salamanders

Two basic facts about the Plethodontidae, the world's most speciose and diverse family of salamanders, were established a century or more ago. First, they are all lungless. Second, their primary mode of respiratory gas exchange is through the skin and buccopharynx, an arrangement that is enabled by major morphological specializations of cardiovascular anatomy. We have reexamined these claims with the benefit of morphological, molecular and experimental approaches unavailable to early investigators. We find that the evolution of lunglessness is a more nuanced, integrated and complex phenomenon affecting diverse aspects of organismal biology than the one that was originally described and is still widely accepted today: 1) Lungless salamanders are not lungless, or at least not as embryos—transient embryonic lung primordia form but regress before hatching; 2) Lung developmental-genetic pathways are at least partially conserved despite the absence of functional adult lungs for at least 25 and possibly exceeding 60 million years, likely reflecting critical developmental, morphological and functional integration between the heart and lungs in vertebrates generally; and 3) Lungless salamanders express in the larval integument and adult buccopharynx a novel paralogue of the gene surfactant-associated protein C (SFTPC), which is a critical component of pulmonary surfactant expressed exclusively in the lung in other vertebrates. This gene may facilitate extrapulmonary respiration by producing pulmonary surfactant-like secretions outside the lungs.

793 Daniel Hanley, Casey Greenberg

Green light enhances egg recognition in the gray catbird Dumetella carolinensis

Avian brood parasitism is a model system for studying coevolution. In this system, hosts adapt egg recognition abilities based on eggshell features and parasites evolve counter-adaptations in those same features. Eggshell color is the primary cue used by hosts, and although perceived eggshell colors should be affected by variation in light, it is generally assumed that birds compensate for variable light conditions through color constancy. Unfortunately, few studies have tested whether light conditions at host nests alter rejection behavior in wild birds. Here, we address these questions by experimentally parasitizing gray catbird (Dumetella carolinensis) nests with egg models, recording whether the host accepted or rejected these eggs, measuring the reflectance of each host and model egg, and measuring the irradiance at each nest. We found that the perceived color difference between the model and host eggs did not predict rejection. Instead, egg rejections were predicted by each egg model's coordinates within the avian color space, which were directly related to color temperature. Specifically, rejections were more likely in nests where green light made models appear greener. Thus, we demonstrate that catbirds lack color constancy because the catbird's color perception was directly related to the color of light. These findings suggest that nest light conditions may play a vital, and as of yet underappreciated, role in coevolutionary dynamics between hosts and parasites.

1517 Robert Hanna, Tyson Hedrick, Alejandro Rico-Guevara, Diego Sustaita, Kira Delmore

Quantification of multimodal aspects of hummingbird courtship display dives

Hummingbirds are exceptional fliers, as demonstrated by their unique capabilities that include unmatched flapping frequencies, sustained hovering, and maneuverability. These abilities are constantly pushed to their limits during fundamental behaviors, especially courtship, as female preference drives males' dynamic display dives towards their inherent performance limits while also incorporating other signals such as audible tail trills. However, hummingbird flight is difficult to observe in their natural environments and requires a more complex 3D analysis to capture and quantify flight performance effectively and accurately. Thus, the objective of this study is to measure 3D velocities and accelerations during courtship display dives and their synchronization with dive-specific audio components in Black-chinned and Ruby-throated Hummingbirds, as well as putative hybrids between them. Our preliminary results indicate stronger similarities between Black-chinned Hummingbirds and hybrids in their higher maximum velocities, greater variation in their speeds, and synchronization of tail trills. Ruby-throated Hummingbirds seem to be slower on average but show more consistency in their speeds and have a tail trill consisting of two distinct parts. The long-term goal is to understand how these multimodal components differ both within and among species and to identify the key elements of these behaviors that ultimately determine their success in securing mates.

1333 Ryan Hanscom, Jessica Hill, Tyler Marbach, Charlotte Patterson, Jeet Sukumaran, Timothy Higham, Rulon Clark

Using accelerometry to hop into the behavioral classification of a small nocturnal mammal

The miniaturization and affordability of animal-borne accelerometry is emerging as a key tool to quantitatively and continuously monitor and characterize animal behavior. Thus far, using animal-borne accelerometers on smaller, free-ranging terrestrial mammals has been limited due to acquiring observations of natural behavior, biologger mass, and battery life. Merriam's kangaroo rats (Dipodomys merriami; $n = 19$) were fitted with accelerometers and micro-VHF transmitters for ~ 5 days logging at 25 Hz to collect detailed behavioral data and activity levels. Individuals fitted with accelerometers were filmed using an IR spotlight and Sony NightVison Handycam to associate actual behaviors with accelerometry data. The observed behaviors were scored and multiple supervised learning algorithms were tested to classify accelerometry data into 4 behaviors: still, running, walking, and foraging. Individual precision, accuracy, and recall of behaviors varied with our top model. The top model was then applied to all of the free-ranging acceleration data collected, and we found that kangaroo rat behavior and activity budgets varied across individuals. Our study provides a new framework to attach accelerometers to small mammals (< 60 g), conduct behavioral observations of free-ranging nocturnal animals at night, and to characterize the cryptic behaviors of small nocturnal animals continuously and quantitatively.

190 Rebekah Hansen, Alexandra Kingston

Structural properties of the orbital hoods of snapping shrimp may contribute to shock wave dampening

Snapping shrimp (Alpheidae) have a helmet-like orbital hood that dampens the shock waves they produce with their snapping claws. This transparent extension of carapace is thought to redirect energy away from their brains, reducing their likelihood of blast-induced neurotrauma. Along with its morphology, we propose the orbital hood has structural and material properties that contribute to its ability to dampen shock waves. To compare the structural properties of the orbital hood and carapace of Alpheus heterochaelis, we used transmission electron microscopy (TEM) to image the epicuticle, exocuticle, endocuticle, and membranous layers that make up these tissues ($n = 6$). We found the epicuticle and exocuticle of these tissues are similar in thickness and have tightly stacked lamellae typical of crustacean cuticles. However, the endocuticle of the orbital hood is thicker than that of the carapace, the lamellae are wavy in appearance, and stacks of lamellae are sometimes separated by large gaps. We hypothesize these properties increase the elasticity and decrease the density of the tissue contributing to the dampening of shock waves. To continue our work, we will determine the damping coefficient and Young's modulus of orbital hoods and carapace to address elasticity and dampening functions, and use energy-dispersive X-ray spectroscopy (EDX) to compare material composition between these tissues.

1187 Alexandria Hansen

Investigating undergraduate students' engagement in a bio-inspired design course

The world's most pressing problems require interdisciplinary collaborations to solve. Recent calls from the field of biology education advocate for providing students with opportunities to investigate biological problems using knowledge and skills from disciplines such as engineering, computer science, and art (Vision & Change, 2011; 2015; 2018). Bio-inspired design (also called biomimetics or biomimicry) has emerged as a meaningful context to engage students in designing technological solutions for biological problems. However, these types of learning opportunities are exceedingly rare at the undergraduate level (Lent et al., 2021), despite research indicating that this interdisciplinary approach is effective at supporting diverse groups of students in learning science (Hansen et al., 2021). Moreover, scant research has investigated the learning outcomes or design processes of students engaging in bio-inspired design (Hansen et al., 2020). This study describes the creation of a new bio-inspired design course at a large comprehensive university. Using an ethnographic perspective (Green et al., 2012), course assignments, design artifacts, and student reflections were analyzed to document learning and engagement in bio-inspired design projects. Results indicated that students successfully identified a problem in their own lives and used inspiration from nature to design a solution. Further, students appreciated the novelty of the course and took ownership over learning and engagement with technology. Implications for others interested in teaching bio-inspired design courses are shared.

555 Sophie Hanson, William Ray, Arvind Santhanakrishnan, Sheila Patek

Mantis shrimp locomotion: stroke kinematics in a hybrid metachronal system

Many swimming crustaceans locomote using metachronism––the coordinated rowing of multiple swimming appendages by phase-shifting each appendage's movement in time relative to its neighbor. Mantis shrimp (Neogonodactylus bredini) swim with hybrid metachrony meaning that their swimming appendages (pleopods) move with metachrony during the propulsive stroke and then switch to a near-synchronous motion when re-positioning the pleopods for the next bout of metachronal propulsion. Here we examine five kinematic parameters of hybrid metachronism using a rigorous biological dataset (48 swimming events; 10 individuals). We focus on pleopod sweep angle to determine how variation in the spatial movement of each of the five pleopod pairs enables hybrid metachrony of the whole system. We found that sweep angle is lowest in the posterior-most pleopod (P5) and highest in the innermost pleopod (P3). This pattern is consistent across two distinct swimming behaviors: burst swimming and taking off the substrate. Given that other stroke kinematics are near-uniform across pleopods, variation of sweep angle may be key to changing body speed and the transition between a near-synchronous recovery stroke and metachronal power stroke. This study provides insights on hybrid metachronal propulsion in mantis shrimp and further informs our understanding of the incredible coordination of multi-appendage locomotion.

23 Emily Harders, Ryan Paitz

Avian embryos concurrently metabolize and respond to yolk corticosterone

During times of maternal stress, exposure to elevated glucocorticoids can have numerous effects on offspring development. However, embryos can regulate their exposure to maternal glucocorticoids by metabolizing steroids before they reach the embryo. In avian eggs, it has been shown that glucocorticoids are metabolized early in development, but the specific routes of metabolism remain unclear. To investigate this, chicken eggs were injected with either corticosterone or oil on day zero and incubated for four days. Then, the yolk was collected to quantify 31 different steroids using LCMS-MS and the extraembryonic membranes were collected to quantify gene expression using qPCR. We found corticosterone was not detectable after four days of development, but metabolites 5β-corticosterone and 20β-corticosterone were significantly elevated in the corticosterone injected eggs compared to control eggs. We quantified the expression of AKR1D1 (converts corticosterone to 5β-corticosterone) and CBR1 (converts corticosterone to 20β-corticosterone) as well as a potential corticosterone responsive gene, ACOT13, that is involved in lipid metabolism. We found high expression of AKR1D1 and CBR1 on day four, but no difference based on treatment. Interestingly, ACOT13 expression was significantly higher in eggs treated with corticosterone. Overall, we demonstrate chicken extraembryonic membranes are capable of metabolizing and responding to corticosterone. These results highlight the importance of the extraembryonic membranes in mediating the response to yolk corticosterone.

1044 Ryan Hardin, Tonia Schwartz

Telomere dynamics across early life stages in brown anole lizards

Telomere length are key biomarkers for cellular senescence and organismal survival. However, relatively little research has been conducted on the dynamics of telomeres in early life, particularly in reptiles. In this study we focus on telomere dynamics in the early life stages of the brown anole lizard (Anolis sagrei). Telomeres become shortened or damaged by cell division and oxidative stress, and the enzyme telomerase can be activated to rebuild the telomeres. The process of hatching is one of the first physiologically straining events in early life of a reptile. We hypothesize that this early life event may be the first assault on the telomere length, and that telomerase may be activated to repair telom-

ere length post-hatching. Using a qPCR assay, we test whether telomere length changes during the transition from the embryonic stage, within 24-hour of hatching, and to one week of age. Using qPCR, we also determine sex of the embryos and hatchlings to test whether the telomere lengths vary between the sexes. This research furthers the development of the brown anole as comparative model for cross-species analysis of early life events to better understand telomere dynamics across reptiles, mammals, and birds.

338 James Harper, Catherine Caballero

Evolution of Leptin in Avian Aging

Birds are exceptionally long-lived in comparison to other mammals. Recent research suggests that birds exhibit enhanced resistance to the detrimental effects of oxidative damage and maintain higher than expected levels of cellular function as they age. In this research, we focus on a specific protein, leptin, that is an important metabolic regulator. For many years, leptin protein was presumed to have been "lost" in birds due to a lack of expression in adipose tissues and undetectable levels in the blood. However, studies in domestic birds demonstrated that birds have a functional leptin gene with an especially high guanine-cytosine content (∼70%), which hindered sequencing. More recently, the leptin protein has been sequenced in a handful of birds. A series of computational experiments were performed to determine a correlation between bird longevity and leptin divergence. Across the avian species, leptin homologs experienced negative evolutionary pressure and a positive correlation was found between bird lifespans and leptin protein divergence. Future studies will investigate the relationships between leptin receptors and maximum lifespan potentially leading to many useful insights into the aging process.

339 James Harper, Elizabeth Kirkland-Bailey

Effects of Acute Food Restriction on Endoplasmic Reticulum (ER) Stress Response in Nauphoeta cinerea

Food restriction (FR) extends longevity in a variety of invertebrate species. However, the mechanism behind the life-extending effect is still under debate. Stress resistance, or the ability to tolerate and/or survive exposure to noxious stimuli is typically enhanced in long-lived animal models. Here, we examined the effect of FR on the induction of the endoplasmic reticulum (ER) stress response in the speckled cockroach Nauphoeta cinerea. Cockroaches of both sexes were food restricted and their ability to survive an acute heat stress was assessed relative to ad libitum (AL) fed controls. FR individuals were given the opportunity to feed on normal puppy chow for up to 6 hours, three times a week. In addition, we assessed heat shock protein (HSP) activity in homogenates prepared from FR and AL fed individuals after a brief heat shock, and in response to pharmaceutical agents known to induce ER stress. HSPs are a class of chaperone protein and are key mediators of the ER stress response. Finally, the degree of caspase 3/7 activation in individuals from each treatment group was assessed as an indicator of apoptosis, the culmination of ER stress in the absence of the restoration of normal cellular function. This is the first study of FR and its effect on physiological function in speckled cockroaches. Future studies will examine whether FR increases longevity in this species, as well amelioration of.

341 James Harper, Sami Badwan

Does availability impact immune function in speckled cockroaches (Nauphoeta cinerea)?

Life history theory states that organisms are forced into trade-offs among individual life-history traits (e.g. somatic growth vs. reproduction) in order to maximize reproductive potential. In general, these trade-offs respond to various exogenous factors that are indicative of environmental conditions and the likelihood of future reproductive success. As an example, individuals that direct more resources toward reproduction may be small in size due to the redistribution of energy. Here, we evaluated the relationship between life-long food availability and immune function in Nauphoeta cinerea (speckled cockroach) to test the hypothesis that reduced food availability would compromise immune function using a variety of indicators such as antimicrobial peptide production and lipopolysaccharide-induced mortality among populations with differing levels of food availability.

1126 Taylor Harrison, Frank Smith

Investigation of the segment polarity network in the tardigrade Hypsibius exemplaris

Segmentation has facilitated the evolution of the diverse body plans of Panarthropoda. The segment polarity genes engrailed, hedgehog, cubitus interruptus, and wingless show a conserved segmental expression pattern in Arthropoda and Onychophora. However, little is known about this process in Tardigrada. We identified one ortholog of engrailed and hedgehog in the tardigrades Hypsibius exemplaris and Ramazzotius varieornatus. Two orthologs of cubitus interruptus were found. Wingless is not found in the genome of either species. In-situ Hybridization Chain Reaction (HCR) was used to analyze expression patterns in H. exemplaris. Wnt4 and a paralog of Wnt16 were seen in segmental patterns, potentially substituting for wingless in the segment polarity network. Engrailed was seen in stripes at the posterior of each segment at the segment boundary stage and later in the posterior of each limb bud. One ortholog of cubitus interruptus was seen in the anterior of the segment in the segment boundary stage and later in the anterior of each limb bud. Hedgehog was seen in segmental stripes at the limb bud stage only, with its expression overlapping engrailed expression. These data suggest that the mechanism for segment polarity is conserved in the Tardigrade lineage. However, the absence of wingless in our tardigrade focal species and the absence of segmental stripes of hedgehog during early stages of segmentation reveal unique features of segmentation in Tardigrada.

1177 Nathan Harry, Christina Zakas

The Making of A Life History Transition

In an effort to uncover the genetic and regulatory changes that accompany evolutionary transitions in development, we compare gene expression over the course of development for two different larval modes. We study the annelid Streblospio benedicti because there are two developmental and life-history modes within this species. Using RNAseq data gathered from six developmental time points, we explore how the gene expression of the two developmental morphs found in S. benedicti has diverged. We also use crosses between the developmental types to generate F1 offspring. Assessing mRNA expression in F1s allows us to determine how gene and allelic expression patterns change in different maternal backgrounds. We find that most expression differences are heterochronic shifts, and that the occurrence of novel genes in either developmental morph is uncommon. We find that a large proportion (40%) of genes are differentially expressed early in development, but that most gene expression patterns converge around gastrulation. After gastrulation a small number of genes (5%) continue to be differentially expressed through the larval phase, most of which are larger expression differences than earlier in development. By analyzing the allelic expression of F1 offspring, we find that the majority of the expression changes throughout development are due to trans-acting factors. This study provides insight into how novel developmental and life-history programs evolve.

24 Christina Harvey

Longitudinal gust response of a gliding gull

Bird maneuverability is often cited as a source of inspiration for enhancing the maneuverability of modern non-rotary UAV designs. Maneuverability can be quantified by evaluating a flyer's dynamic response to a perturbation (like a gust). To do this, we require information on a birds' aerodynamic and inertial characteristics across all flight configurations. Obtaining this information is challenging because birds can adopt a wide variety of flight configurations by morphing their wing and shape. In previous work, we developed methods to predict the aerodynamic and inertial properties of a gliding glaucous-winged gull (Larus glaucensces) across its full range of the elbow and wrist extension. Here, we used these tools to analyze the longitudinal dynamic response of a gull in steady gliding flight throughout wing morphing. We assumed the small perturbation form of the governing equations of motion with a quasi-steady aerodynamic response and a rigid, non-porous gull model. Our results showed that gulls can trim if the shoulder joint is allowed to move. Gulls can control the natural frequency and damping ratio of their oscillatory response through morphing their elbow and wrist. In addition, the flying qualities for the majority of gull wing configurations would be adequate for a human pilot albeit with a higher workload. Collectively, our results provide insight into the complete longitudinal stability associated with gull flight and inspiration for future supermaneuverable UAVs.

1484 Hazel Havens, Julia Notar, Brian Taylor, Kenneth Lohmann

A role for the central complex in magnetoreception

The arthropod central complex has been implicated in navigational tasks in a wide range of species. This brain region has been shown to reliably encode head direction from sensory cues both in vivo and in simulation. In addition, emergent properties of arthropod behavior have been recapitulated in robotics and simulation by recreating central complex-like processing of realistic sensory information. Many arthropods have been shown to use Earth's magnetic field as a navigational cue, but how magnetic information is processed remains unknown. Previous work has shown that magnetoreception in the Caribbean spiny lobster Panulirus argus is disrupted by transient strong magnetic fields, suggesting that lobsters transduce the field with magnetic material that can be remagnetized. However, what kind of receptor arrangement or neural processing underlies magnetoreception remains unknown in all animals. Here, we test whether central complex-like processing of the magnetic field may explain behavior observed in the Caribbean spiny lobster after exposure to strong magnetic fields. We developed a model of magnetoreception that calculates head direction from the input of realistically noisy magnetoreceptors processed by a neural network based on the arthropod central complex. We then subject this model and spiny lobsters to simulated and real transient strong magnetic fields, respectively. By comparing simulation performance with lobster behavior, we begin to address how effectively central complex-like processing explains the Caribbean spiny lobster's magnetoreceptive behavior.

315 Justin Havird, Chase Smith, Jess Sterling

Mitonuclear discordance, population genomics, and thermal adaptation in the Hawaiian volcano shrimp

Mitochondrial (mt) loci were early markers of choice in phylogenetic and population genetic studies of animals due to their practicality and ease of use. As a result, hypotheses on population structure and phylogenetic relationships of many animal taxa were originally based solely on mtDNA data. The Hawaiian volcano shrimp, Halocaridina rubra, is an endemic, culturally important species found in the coastal ponds that make up Hawaii's anchialine ecosystem. Based on mt-COX1 sequences it was hypothesized that H. rubra is composed of at least eight highly structured, divergent genetic lineages across the Hawaiian Islands. Here, we revisited this hypothesis using 2B-RAD data spanning the nuclear genome from 116 individuals across the islands. Our results support many of the previously identified, highly structured lineages, but also suggest specific cases where mt and nuclear data tell different stories. This may be due to mitonuclear discordance stemming from introgression or incomplete lineage sorting and encompassing adaptive and non-adaptive scenarios. We also find a significant shift in nuclear ancestry at one site after a high temperature event caused by volcanic eruptions in 2018, possibly due to selection for increased thermal tolerance. We suggest H. rubra may be a model system to uncover mitonuclear genetic incompatibilities leading to incipient speciation and conclude by presenting a draft H. rubra genome which will aid future anchialine biological studies.

1110 Abdisalan Hawadle, Andrea Delgado, Mike Nishizaki

The Effects of Temperature and Flow on Respiration in Two Marine Mussels

Intertidal organisms are subject to environmental variations that may influence their physiological performance. As processes such as respiration depend on gas exchange between organisms and their environment, they are potentially affected by water temperature and velocity. In this study, we compare the effects of multiple environmental stressors (temperature and flow velocity) on the respiration rate in two mytilids, the Mediterranean mussel, M. galloprovincialis and the temperate bay mussel M. trossulus. Thermal performance curves (5, 11, 17, 23, and 29°C) for respiration rate were quantified at five different flow velocities (2, 4, 6, 10, 20 cm s-1) in a fully crossed design. Well-defined thermal performance curves were present at moderate to high water velocities, whereas, at the lowest velocity (2 cm s-1) respiration rates remained low across all temperatures. Although Mediterranean mussels displayed higher thermal optima than Bay mussels under moderate flow speeds (4-6 cm s-1), those differences were absent at higher flow velocities (>10 cm s-1). These results highlight the importance of considering hydrodynamic conditions when estimating thermal tolerance in marine mussels.

302 Olivia Hawkins, Duncan Kennedy, Megan Vandenberg, Richard Hoover, Callie Crawford, Todd Clardy, Emily Kane, Cassandra Donatelli

To eel or not to eel: functional diversity of control surfaces in elongate fishes

Elongate fishes are considered to be morphologically conserved and are characterized by long bodies and greatly reduced fins. While several studies have investigated body kinematics during steady swimming, few have investigated fin use, despite evident morphological diversity. Fishes in the sub-order Zoarcoidei (i.e., pricklebacks, gunnels, eel pouts) have a large diversity of caudal fin shapes. To understand how morphological diversity may reflect functional diversity in these fishes, we quantified 2D kinematics of the body and caudal fin during volitional swimming in species with eel-like isocercal caudal fins (Lycodes pacificus), reduced homocercal caudal fins (Xiphister mucosus), round homocercal caudal fins (Pholis laeta), leptocercal caudal fins (Anoplarchus purpurescens), and hemihomocercal caudal fins (Apodichthys flavidus). We find that tail kinematics appear to be more similar across species with morphologically similar caudal fins regardless of phylogenetic relatedness. Additionally, pitch angle during swimming increased with increased tail beat frequency for all species except in L. pacificus. This may be due to differences in the generation of lift forces across species. Differences in the function and use of morphologically diverse caudal fins could explain why elongate fishes show modifications to the common elongate body plan. Future investigation of musculoskeletal anatomy and the use of elongate fish models will be essential to determine functional differences of the caudal fin during swimming in this group of recently derived elongate fishes.

1051 Eli Haynal, Anna Caraveo, Treson Thompson, CJ Brothers

Is Seagrass Wasting Away? Measuring Disease Dynamics in the Salish Sea

Seagrass wasting disease (SGWD), caused by the marine protist Labyrinthula spp., is affecting meadows of the eelgrass Zostera marina in the Pacific Northwest. Labyrinthula invades the tissue of eelgrass causing black or brown lesions and tissue degradation, with eventual plant mortality. We surveyed four eelgrass meadows in the Salish Sea, WA during summers 2019 and 2020 ($n = 10$ per site). Images of eelgrass blades were analyzed for incidence (percent of samples infected) and disease severity (area of blades covered in lesions) using ImageJ. Disease incidence was high (>70%) across all sites and was significantly different between years. Disease severity (5–9%) was significantly affected by both year and site. Labyrinthula abundance was determined using a hand-held Biomeme™ device, enabling quantitative PCR (qPCR) through a thermocycler connected to phone software. Preliminary qPCR results from 14 samples indicate there is no correlation between pathogen Cq values and disease severity. This suggests that pathogen abundance by itself is not an accurate predictor of SGWD severity.

293 Talia Head, Donald Mykles

Comparative analysis of protein kinase G in the decapod crustacean molting gland

Growth in crustaceans requires the periodic shedding of the exoskeleton, a complex physiological process that is regulated by several molecular pathways. Molt-inhibiting hormone (MIH) synthesized and secreted by the X-organ/sinus gland complex (XO) in the eyestalk inhibits the synthesis of the pro-molting hormones, ecdysteroids, by the molting gland (Y-organ, YO). Such inhibition occurs through a cAMP/$Ca2+$-dependent triggering phase, followed by a nitric oxide/cGMP-dependent summation phase in which cGMP-dependent protein kinase (PKG) indirectly inhibits the mTOR-dependent protein synthesis required for ecdysteroid synthesis. Bioinformatic characterization of PKG transcripts from YO transcriptomes in both Gecarcinus lateralis and Carcinus maenas revealed two PKG1 transcripts and one PKG2 transcript consistent with those characterized in mammals and other metazoans. In this study, the response of the YO to PKG activators and inhibitors was quantified by measuring ecdysteroid secretion in vitro for both G. lateralis and C. maenas. Additionally, knockdown of PKG1 in C. maenas using dsRNA was used to determine the effect of cGMP-dependent protein kinase in the YO in vivo. This data confirms the role of PKG as a downstream messenger of MIH to inhibit ecdysteroidogenesis by the YO. Proteomic analysis of phosphoproteins in PKG-inhibited and control YOs using LC-MS will be used to identify possible targets of PKG. Supported by NSF (IOS-1922701 and IOS-1456942).

803 Alyssa Head, Ethan Livingston, Constant Perry, Princeton Vaughn, Eric Gangloff

Let's include the ladies: Do morphology-performance relationships vary between sexes in lizards?

An animal's morphology influences its ability to perform essential tasks, such as sprinting. Variations in habitat structure can cause body morphology to change over time, leading to differences across populations in a species. These divergences across populations with varying establishment histories can be especially important to understand in successful invaders. Further, most conclusions about lizard morphology-performance relationships have been based only on males, leaving unanswered questions about the female sex. To address this knowledge gap, we measured various limb and body dimensions in both male and female common wall lizards (Podarcis muralis) from multiple populations with different establishment histories. We sampled from invasive populations in Ohio, USA (Cincinnati, where lizards have been established for over 70 years, and Columbus, a recently-established population) and native populations at low-elevation and high-elevation habitats in France. We used a multivariate statistical approach to test the hypothesis that morphology varies among these populations and to quantify differences between males and females. In addition, we examined how morphology-performance relationships might differ between sexes by measuring sprint performance on male and female lizards from Ohio. This study thus provides insights into how vertebrates may adapt to novel environments and how selective pressures might shape males and females differently.

1002 Nicholas Hebdon, Alexa Ortega, Lindsay Waldrop

The Curious Case of Snout Design in Canine Olfaction

For centuries humans have kept canines around as companions and workers because they are trainable, and their physical capabilities compliment our own. As our goals became more niche humans began to breed dogs to fill specific roles from hunting and guarding to simply being a cute companion. One of the things dogs are best known for is their remarkable sense of smell. This sense is so prized that humans have developed several breeds trying to emphasize its effectiveness. But what makes dogs so good at smelling things and have we actually succeeded at making them any better at it? In this study we employ geometric morphometrics to develop a shape space of dog skulls. Across a sample group of dogs we observe that, in terms of the skull shape, the overall design is reasonably consistent for "working dogs" and wolves but starkly contrasted by "companion" dog breeds. Using simplified variations of the traits from this shape space we develop a simplified theoretical geometry for use in Computational Fluid Dynamics simulations. We observe that certain traits such as the angle of transition between respiratory and olfactory regions, have disproportionately large effects on olfactory performance and may be unlinked from observed trait focus on human breeding efforts.

291 Brandon Hedrick, Luke Pruett, Gabriel Rivera, Kory Evans, Simon Lailvaux

The Effects of Cranial Asymmetry on Bite Force in the Green Anole (Anolis carolinensis)

Increased magnitudes of skeletal asymmetry have been tied to reduced functional performance in a variety of herpetofauna. Thus far, this has been examined by comparing asymmetry and general performance requirements based on a taxon's ecology rather than with individual performance. To better understand the nuances of the linkage between asymmetry and performance, we examined the magnitude of cranial asymmetry for 40 individual green anoles (Anolis carolinensis), for which specimen-level maximum bite forces were previously determined. Cranial asymmetry was calculated using three-dimensional geometric morphometrics. We used Procrustes distance between reflected landmarks to generate specimen-level magnitudes of asymmetry. We predicted that the anoles that produced the highest bite forces would have the most symmetric skulls. Fluctuating asymmetry accounted for 8% of total shape variation and sexual shape dimorphism drove morphospace occupation. Bite force and cranium centroid size were significantly and strongly correlated; however, bite force and centroid size residuals were significantly correlated with asymmetry magnitude. Our findings indicate that increased asymmetry was associated with higher bite force, contrary to our initial prediction. Based on these results, we hypothesize that the thin cranial bone in anoles may deform following repeated biting events and thus that high bite forces lead to increased asymmetry. Thus, asymmetry appears to not always lead to a substantial decrease in performance.

669 Ashley Heers

Feathers aloft: unexpected performance in developing birds

Birds are well known for their ability to fly, and flight-capable adult birds have many anatomical specializations for meeting the demands of aerial locomotion. Juvenile birds in altricial species typically acquire these specializations close to fledging, and leave the nest with some flight capability. In contrast, juveniles in most precocial species begin navigating their environment with rudimentary anatomies, and may not develop full sized wings or musculoskeletal apparatuses for several months. Here, I explore how juvenile birds achieve high levels of locomotor performance in the absence of flight specializations, by synthesizing work on two groups of precocial birds with very different developmental strategies. Galliforms like the Chukar Partridge (Alectoris chukar) have early wing development, and are capable of flight within weeks. Compared to adults, juvenile chukars have less aerodynamically effective feathers and smaller muscles, but compensate through anatomical, kinematic, and behavioral mechanisms. In contrast, waterfowl have delayed wing development and initially rely on leg-based locomotion. In Mallards (Anas platyrhynchos) and their domesticated derivatives, leg investment and performance peak early in ontogeny, but then decline when wings develop. Galliform and anseriform juveniles thus rely on different mechanisms for achieving high performance in the absence of flight specializations. In conjunction with work in other animals, these patterns indicate that juveniles with developing locomotor apparatuses can achieve high performance through a variety of compensatory mechanisms.

1426 Christopher Heesy, Leigha Lynch

Relative Brain Sizes Are Related to Transitions in Body Plan in Squamates

Evolutionary digit and limb reduction is associated with body elongation in several vertebrate clades, leading to a diverse array of body plans. Limb reduction is notably correlated with relatively smaller brain sizes among squamates. Body elongation in some squamate groups is pleomeristic, which is the developmental increase in presacral somite number that results in additional presacral vertebrae and body wall segments as well as body mass. We suggest that this redistribution of body mass by body plan should also lead to changes in the patterns and levels of innervation of the body wall by the central nervous system. We explored the evolutionary relationship between squamate brain size and body plan using phylogenetic generalized least squares (PGLS) model designs. Relying primarily on data from the literature, we compiled brain and body masses for over 200 squamate species and categorized their body plans by the number of limb pairs, digits, and presacral vertebrae. We found that reductions in limb and digit number are highly correlated to smaller relative brain sizes. We also found that our most explanatory models for relative brain size include digit counts as a factor, suggesting that novel patterns of innervation are required by transitions in fundamental limb morphology. We also suggest that compensatory innervation in limbless and elongate taxa is likely due to greater localized control of body segments by the spinal cord.

1267 Kira Heikes, Mandy Game, Frank Smith, Bob Goldstein

Uncovering the Embryonic Origin of Germ Cells in the Tardigrade Hypsibius exemplaris

During development, cells specialize to diverse roles. One group of cells vital to the fecundity of many organisms is the Primordial Germ Cells (PGCs). Our knowledge of PGC development is limited to a small sampling of the diversity of life, hampering our understanding of the evolution of this important process. The tardigrade Hypsibius exemplaris is an excellent system for exploring the evolution of development because H. exemplaris is a member of the superclade Ecdysozoa, along with two well-studied organisms, the arthropod Drosophila melanogaster and the nematode Caenorhabditis elegans. Uncovering aspects of PGC development in H. exemplaris will provide valuable information to compare with what is known in arthropods and nematodes. To identify the PGC lineage in H. exemplaris, we characterized cell behavior, examined chromatin morphology, and uncovered patterns of conserved molecular markers of PGC fate. We combined these findings with construction of a lineage of the early H. exemplaris embryo and found that the four earliest internalizing cells in H. exemplaris are the PGCs. To explore when restriction of these markers of the PGC fate begins, we examined the temporal dynamics of molecular markers of PGC fate. Taken together, we identified the embryonic origin of PGCs in the tardigrade H. exemplaris. This work provides a foundation for exploration of PGC development in H. exemplaris and of the evolution of PGC development in animals.

1263 Sarah Heissenberger, Sarah DuRant, Maya Tipton, Daniela Kim, Kaja Arusha, Luis Luis, Daniela Rivera, Francisco Bozinovic, Grisel Cavieres, Daniela Vera, Pablo Sabat, Carolyn Bauer

Effects of maternal water restriction on offspring water balance physiology in Octodon degus

Maternal cues are adaptive when the maternal environment "matches" that of the offspring. The potential of maternal water availability during pre- or post-natal stages to influence offspring water balance physiology has yet to be investigated, and could inform conservation as a potential mechanism of enhanced population persistence for species of semi-arid habitats during drought conditions. One such species is the common degu (Octodon degus), a rodent experiencing population declines associated with increasing drought frequency. To determine what stage (pre vs. post-natal) offspring programming is most sensitive to maternal water cues, and whether these cues occur by influencing resting metabolic rate (RMR), evaporative water loss (EWL), or renal morphology during development, we compared four treatment groups: controls received ad libitum water throughout pregnancy and lactation, while water-restricted mothers received 75% of the daily water intake. A third group was restricted 75% during pregnancy, and a fourth 75% during lactation. At weaning, pups were measured via flow-through respirometry to determine RMR and EWL. Urine samples were also collected from pups. A subsample of pups was sacrificed to measure relative medullary thickness (RMT). RMT, EWL, and urine concentrations of offspring were compared to maternal concentrations to identify what stage maternal transmission of water cues may happen. Determination of stage(s) critical to offspring water balance physiology can help target management plans for various species affected by climate change.

164 Devya Hemraj-Naraine, Hernan López-Fernández, Kirk Winemiller, Gyanpriya Maharaj, Donald Taphorn

Habitat structure and ecomorphology of fishes in neotropical blackwater creeks.

Freshwater ecosystems provide habitat for a diversity of aquatic flora and fauna. However, anthropogenic activities like mining and pollution altering aquatic habitats and the ecosystem services they provide. In South America, which hosts one quarter of all freshwater fish species, aquatic habitats are under considerable encroachment from human development. We surveyed nine blackwater creeks tributary to the Demarara River along a major Highway in Guyana to determine whether fish morphology and community structure correlate with habitat characteristics among sites with different degrees of human impact. Twenty-three morphological traits were measured on 3-5 adult specimens of each species. The most abundant species captured across all sites was the characin, Bryconops melanurus. Streams that had a higher presence of macrophytes and aquatic vegetation had higher species diversity, and streams that were impacted by human activities had greater overall fish abundance. Local fish assemblage structure was associated with the type of human disturbance in each watershed and stream. For example, overall fish abundance was positively correlated with food waste, and fish diversity was negatively correlated with pollution from oils or plastics. Additionally, fish morphology was significantly associated with environmental variables, with higher morphological diversity in streams having greater macrophyte coverage. Findings from this study facilitate the prediction of functional changes in fish assemblage structure in response to human activities that alter habitat features.

755 Robert Hendrickson, Maya Groner, Colleen Burge, Chelsea Bergman

Interspecific Transmission of Seagrass Wasting Disease from Pacific Oysters to Eelgrass

In order to feed the growing population of the world in more sustainable ways, aquaculture of marine species is being used to provide for the increasing need for sustenance. The Pacific Oyster, Crassostrea gigas, is an important aquaculture species, and has been introduced into many areas for this purpose, however we lack understanding of their direct interactions with cohabiting species. One such species that commonly coccurs in areas with C. gigas is Zostera marina, eelgrass, which is affected by Seagrass Wasting Disease (SWD) caused by the protist Labyrinthula zosterae (Lz). A laboratory experiment was conducted where Pacific oysters, C. gigas, were exposed to Lz and transferred over to tanks containing naive eelgrass to test if oysters were a vector for Lz. Preliminary data suggest that disease prevalence of directly inoculated treatments and oyster vectoring of disase were similar. Disease severity was also highest in the inoculated treatments, with both direct inoculation and oyster vectoring of disease being high. Overall, the preliminary findings suggest that transfer of oysters from infected waters to non-infected waters may introduce Lz. These findings should be used to inform general aquaculture practices and the management of oyster beds and possibly other farmed shellfish species to protect eelgrass from increasing SWD stress as eelgrass provides numerous ecosystem services.

1481 Allyssa Hennessey, Jacob Lasala

Effects of Incubation Factors on Sea Turtle Hatchlings on the Gulf of Mexico

Over the course of a sea turtle nesting season on the Gulf of Mexico, female sea turtles will lay approximately 3 to 6 clutches of eggs every 10 to 14 days. These females fast during the nesting season, and subsequent clutches of eggs decline in resource quantity over the course of the season. The effect of suboptimal nutrients on the developing hatchlings can influence developing hatchlings' size, body condition (BCI), and possible anomalies in carapacial scutes. Variations to the number of scutes of the carapace of hatchlings are relatively common but understudied. Hatchlings were collected from loggerhead (Caretta caretta) and green sea turtle (Chelonia mydas) nests on three beaches in Sarasota County, Florida from 2020-2022. The vertebral, costal, and marginal scutes were counted and anomalies were documented, along with the hatchling length, width and depth, head width, and mass. Models were run to determine which variables during incubation had significant effects on carapacial scute anomalies. Further, a subset of nests during the 2021 and 2022 seasons had temperature data loggers added to nests. Models were run to identify whether temperature fluctuations had an effect on scute anomalies. We will discuss how factors during incubation can impact hatchling conditions.

206 Marquise Henry, Kayla Harvey, Paul Moore

Investigating the effects of an SSRI on the physiology and behavior of an aquatic species

Pharmaceutical and personal care products are a group of pollutants that have a large-scale impact on aquatic ecosystems. Upon entering aquatic habitats through the discarding of expired drugs or from incomplete metabolic excretion and waste management, these chemicals affect the physiology and behavior of various organisms. Pharmaceutical compounds are created to produce an effect on an organism at a low concentration. As a result, their presence in aquatic habitats can lead to biological effects even at low concentrations. Exposed organisms often show alterations in social interactions, migrations, and behaviors involved in predation. Whit not always lethal, these behavioral changes have the potential to impact populations and ecosystem functioning. Some pharmaceuticals act as selective serotonin reuptake inhibitors (SSRI). In crustaceans, specifically crayfish and lobsters, serotonin has been linked to a suite of stress responses and agonistic behaviors. The crayfish was chosen as the model organism for this study to its well documented behaviors in response to external stimuli, as well as their status as ecological engineers. The goal of this study was to investigate the effects of an environmentally relevant dosage of citalopram, a commonly used SSRI, on the physiology and behaviors of the crayfish Faxonius rusticus. To do so, oxygen consumption, reaction initiation distance, and serotonin concentration following a stressor were observed. Significant results were seen across treatment and time.

861 Amberleigh Henschen, Michal Vinkler, Marissa Langager, Allison Rowley, Rami Dalloul, Dana Hawley, James Adelman

Gene expression associated with disease tolerance depends on host tissue and pathogen virulence

Animals may evolve to both resist and tolerate novel pathogens, resulting in decreased pathogen load or costs of infection, respectively. However, the mechanisms behind these adaptations, especially those associated with tolerance, are not well understood. We explored tolerance mechanisms in house finches (Haemorhous mexicanus) infected with a recently-emerged bacterial pathogen, Mycoplasma gallisepticum (MG). During infections in common environments, birds from populations where MG has been endemic longer have similar pathogen loads but milder conjunctivitis (i.e., higher tolerance) than birds from populations where MG invaded recently or has not been detected. Using RNA-seq data, we compared gene expression in spleens of birds from more- or less-tolerant populations on day three of experimental infection. Our previous work using localized immune tissue (i.e. the Harderian gland) showed more-tolerant birds have fewer differentially expressed immune genes during infection, and thus a potentially more targeted immune response. However, this pattern reversed in splenic tissue, where more-tolerant birds have more differentially expressed immune genes than less-tolerant birds. In addition, when inoculated with a more recent, virulent isolate of MG, birds from all populations had similar numbers of differentially expressed genes, and more differentially expressed genes in common. Thus, compared to less-tolerant individuals, more-tolerant individuals may have more robust systemic immune responses, but milder local immune responses, early in infection. Furthermore, host-pathogen co-evolution may affect these patterns if pathogens evolve increased virulence.

1801 Michael Henshaw, Abbey Kern, Ethan Book, Chloe Smith, Madison Skinner, Emily Kowal, Natalie Longo, Alex Kayfish, Sophia Hamilton

Cold-Tolerance & Supercooling in Northern vs. Southern Phidippus audax Jumping Spiders (Salticidae).

Thermal tolerance fundamentally shapes an organism's biology In cooler regions, individuals must employ a cold-tolerance strategy to limit injury and death from chilling and freezing. The jumping spider Phidippus audax, the Bold jumping spider, is common across much of North America, and faces diverse thermal challenges across its range. Previous work found evidence for differences in size and coloration between populations, and these differences have been interpreted by some as distinct northern and southern forms. We characterized the cold tolerance strategy (SCP; chill-susceptible, freeze-avoidant, or freeze-tolerant) and super cooling point (temperature at which tissues freeze) of spiders from Michigan, Oklahoma & Texas to assess differences. We found that P. audax are resistant to chilling but could not survive freezing and thus have a freeze-avoidant cold tolerance strategy. We also found that they lower their SCP as cooler temperatures develop to as low as -17°C, that spiders from Michigan were more resistant to injury from cold temperatures, and that spiders from Texas were the least able to reduce their SCP. Body size significantly influenced the capacity to resist freezing (i.e., lower SCP) and larger body size in more southern populations from Oklahoma and Texas may help to explain why they were more likely to die when chilled below freezing.

215 Nicholai Hensley, Todd Oakley

Rules for emergent synchrony during bioluminescent behavior of sea fireflies

When individuals within a collective obey simple rules, their individual behavior can synchronize in time and space to form apparent super organisms - from murmurations of birds to dynamic ant colonies. In animal communication, decreasing timing between signals is at odds with information theory that predicts signal overlap should hinder receiver perception of individuals. However, group signals are widespread like in the singing choruses of frogs or crickets. Here we describe a collective bioluminescent signal in marine animals, produced by shallow water luxorine ostracods (Arthropoda; Crustacea), and begin to characterize the parameters that describe variation in these luminescent "waves" as they ripple across the habitat. Using LED playback with ex situ manipulations of male aggregations, and field surveys of in vivo displays, we show that the magnitude and frequency of these bursts are sensitive to the intensity and duration of incoming stimuli, and that such waves characteristically decay in frequency on a weekly timescale coincident with the lunar cycle. This emergent group behavior represents a remarkable case of evolutionary convergence with species of terrestrial fireflies (Arthropoda; Insecta) and is a rare example of synchronous visual displays in arthropods. Future work within and between species of ostracod that differ in their propensity to synchronize may help illuminate the evolutionary pressures that select for collective signaling.

515 Jennifer Heppner, Jenny Ouyang

Does the urban bird get the worm? Supplemental food effects on hormones and morphology

The rapid expanse of urbanized areas has led to global challenges for wildlife. Specifically, insectivorous birds in cities experience diminishing food availability, which leads to slower growth and reduced survival for both nestlings and adults. A potential mechanism mediating these phenotypes is the endocrine system, in which hormonal differences are consistently observed between urban and non-urban individuals. We have previously shown that urban areas contain less natural and nutritious food items for breeding songbirds and that urban adults and nestlings have higher baseline corticosterone levels. Nonetheless, it is unclear if food limitation is the driving factor behind these physiological differences. To examine the effects of food limitation on urban birds, we supplemented urban and non-urban nests of free-living house wrens (Troglodytes aedon) with live mealworms throughout their breeding season. We measured adult and nestling morphology during development and sampled both to quantify baseline corticosterone and testosterone concentrations. By altering their food availability, we reveal the impact of food limitation on shaping morphological and physiological differences across an urbanization gradient. Our results may uncover a mechanism connecting one of the most significant challenges imposed by the urban environment to the decreased fitness of urban birds and give insight for city planners to increase the resources needed for successful wildlife city living.

743 Joseph Heras, Michelle Herrera, Sara Kelley, Alicia Huang, Donovan German

Comparative Transcriptomics of Marine Intertidal (Family Stichaeidae) Prickleback Fishes

Marine intertidal pricklebacks (family Stichaeidae) are best known for dietary diversity, ontogenetic dietary shifts, convergent evolution of herbivory, and multiple invasions into intertidal habitats. There have been multiple studies that provide insight into digestive physiological properties within pricklebacks such as the variation in gut length across species, enzymatic activity, microbial fermentation in the gut, and the sequenced genome of Cebidichthys violaceus. Here, we contribute to the understanding of dietary diversity in pricklebacks by sequencing the pyloric caeca and middle intestine transcriptomes of four intertidal prickleback species: Anoplarchus purpurescens (carnivores, no shift), Xiphister atropurpureus (ontogenetic shift from carnivory to omnivory), Xiphister mucosus and Cebidichthys violaceus, (both exhibit ontogenetic shifts from carnivory to herbivory). From the transcriptomes of the pyloric caeca and middle intestine, we?detected orthologous gene sequences?across the?four?species, annotated the orthologs, and estimated selection with bioinformatics programs. With bioinformatics tools, we detected signatures of adaptive evolution by estimating nonsynonymous and synonymous substitution rates from orthologous gene clusters. We identified candidate genes under positive Darwinian selection with the following gene ontology terms: carbohydrate metabolism, proteolysis, phospholipid, and lipid catabolic processes. Overall, we characterized gut tissues and identified candidate genes under positive Darwinian selection to better understand dietary specializations within marine intertidal fishes.

622 Nina Hernandez, Doris Preninger, Lisa Mangiamele, Diana Flores-Zamudio

Investigating the Effect of Arginine Vasotocin on Multimodal Communication in Foot-flagging Frogs

Arginine vasotocin (AVT) is a neuropeptide in nonmammals that has been found to increase calling effort and cause changes in the temporal or spectral characteristics of male vocalizations in some frog species. Although AVT's role in social signaling is well established, it is unknown whether AVT modulates other communication behaviors, such as visual signaling, in frogs. To address this issue, we investigated whether AVT affects the multimodal display of foot-flagging frogs (Staurois parvus). Like many other frog species, male foot-flagging frogs produce high-pitched vocalizations to advertise their territory. They also compete with other males through physical leg extensions and rotations, a gestural display known as "foot-flagging." Previous studies show that foot-flagging is regulated by testosterone, yet vocalizations appear not to be androgen-dependent. In this study, we tested whether AVT could influence multimodal displays by treating male foot-flagging frogs with saline, AVT, or testosterone + AVT and recording their display behaviors during interactions with another male. For each male, we analyzed the rate of foot flagging and calling, as well as the duration, dominant frequency, and the number of notes in males' vocalizations. We hypothesize that AVT may modulate vocalizations independently of testosterone in foot-flagging frogs. Our results will shed light on whether distinct hormonal pathways regulate different communication signals in multimodal displays.

1632 Alyssa Hernandez, Jessica Sandoval, Michelle Yuen, Robert Wood

Elongated shapes in bio-inspired suction cups resist shear loading on diverse surfaces

Aquatic organisms utilizing attachment contend with unpredictable environments that can dislodge them from various substrates. To counter these forces, multiple species including insects, cephalopods and fish have evolved suction-based organs for adhesion. Disc morphology among these species can be diverse, with some shapes deviating from a standard circle to more elongated designs. Inspired by the disc morphology of multiple aquatic species, we investigated how elongated shapes in fabricated cups can resist shear forces on diverse surfaces. Cups with six different shapes were fabricated using a stiff silicone material. Shapes included a standard circle, ellipses of varying aspect ratios, and irregular designs. To consider the effects of both suction and friction, cups were produced with and without a soft rim. Cups were pressed down using a force-sensing robotic arm, which then sheared them across surfaces of varying roughness and stiffness in dry and wet environments. Additionally, we tested multiple initial loads to evaluate the effects of partial and full adhesion before shear. Because various shapes produced different areas of contact upon adhesion, shear stress was calculated using peak force and disc surface area. In multiple environments, elongated shapes often outperformed the circle design, which suggests contact area stabilizes or increases as the cup is pulled along the surface. To support these experiments, Frustrated Total Internal Reflection was utilized to visualize how contact changes during shear.

297 Obed Hernandez-Gomez, Reuban Oumnov, Isabela Velasquez-Gutierrez, Vanessa Wuerthner, Jessica Hua

Host vs. environmental factors: Which more strongly associates with wood frog microbiota diversity?

Host-associated microbiomes play essential roles in organismal health. While the contributions of host vs. environmental factors in shaping microbiomes have been assessed independently, differentiating their relative contribution remains a challenge. Using wood frogs, we asked: (1) How do immunogenetic factors influence microbiota diversity? (2) Is there a relationship between immunogenetic and environmental factors? (3) If there is a relationship, are host or environmental factors more strongly associated with microbiota diversity? We collected wood frogs from 14 populations that varied in percent natural cover and reared them in the lab. We sequenced egg, gut, and skin samples to characterize bacterial communities. To assess immunogenetic factors, we genotyped the antigen-binding region (exon-2) of the MHC class IIB gene. We found (1) tadpoles with different MHC class IIB alleles (heterozygotes) had higher microbial diversity in the gut and skin compared to tadpoles with single alleles (homozygotes). (2) Percent natural cover was related to immunogenetic factors- heterozygotes individuals were more common in areas with low percent cover and homozygous individuals in areas with high percent cover. (3) When environmental factors are considered in the model, we found associations between microbiota diversity and percent natural cover. However, the relationship between immunogenetic factors and microbiota diversity is eliminated. Collectively, this suggests that in this system, environmental factors of source populations are more strongly associated with the assembly of microbiotas in captivity.

519 Obed Hernandez-Gomez, Lubna Mulla, Vanessa Wuerthner, Jessica Hua

Commonalities in the response of North American salamander skin microbiotas to wildfires and roads

Anthropogenic activities and their environmental effects can disturb natural associations between wildlife and microbial symbionts, in many cases resulting in negative effects to host health. Changes to microbial communities may also differ depending on life stage and natural history. We used two different North American salamander systems to assess how the skin microbiota of amphibians responds to wildfires and proximity to roads. In northern Californian redwood/oak forests, we assessed how recent wildfires affected the skin microbiotas of Taricha sp., Batrachoseps attenuatus, and Ensatina eschscholtzii. In northern Pennsylvania wetlands, we investigated how habitat road proximity influenced the skin microbiotas of terrestrial efts and aquatic adults of Notophthalmus viridescens. We found a positive effect of disturbance (road proximity and recent wildfire history) on the skin microbiota of terrestrial salamanders, suggesting that disturbances in general increase the diversity of bacteria salamanders are exposed to. Habitat disturbances did not significantly alter natural differences in microbiota composition among age classes or among different host species; however, we did see a reduction in the relative abundance of bacteria associated with defense against fungal pathogens in salamanders inhabiting disturbed habitats. Our study found similarities in the amphibian skin microbiota response to habitat change between two different ecosystems. In addition, our results highlight the need to consider the effects of roads and increased wildfire regimes/intensities on wildlife-associated microbiotas and animal health.

603 Oscar Hernandez-Reyes, Daniel Guerra, Megan Wise-de-Valdez

Shade Coverage and Mosquito Abundance Across Neighborhoods of Different Socioeconomic Status

In the U.S., socioeconomic status (SES) of neighborhoods has been associated with mosquito abundance. However, determining which aspects make a neighborhood most suitable for mosquito breeding is difficult. Some studies report that low-income areas have more mosquitoes due to excessive discarded water-filled containers, while others suggest that high-income neighborhoods have more mosquitoes due to shade coverage and regular yard watering. We asked whether tree shade coverage differed among neighborhood SES and whether shade influences mosquito abundance. We conducted this study in San Antonio, TX, the 7th largest city in the U.S. and one of the most economically segregated. San Antonio is home to mosquito species known to vector West Nile, Zika, and Dengue viruses. Each week, from June-August, 2022, mosquito traps were placed at randomly selected homes across 6 neighborhoods. The neighborhoods were classified by income and shade coverage using U.S. Census Data and LIDAR derived using ArcGIS, respectively. Our data show that neither shade coverage nor mosquito abundance differs among high-, moderate- and low-income neighborhoods. However, in a predictive model, when shade and income factors are combined, there is a stronger correlation with mosquito abundance, but it was not significant. These findings indicate that, unlike in other large cities, shade coverage is not associated with neighborhood SES in San Antonio, TX, and that shade alone might not be a big contributor to mosquito abundance.

1566 Nicholas Heslep, Njaratiana Raharinoro, Richard Lawler, Roshna Wunderlich

Locomotor energetics and development in wild Verreaux's sifaka (Propithecus verreauxi)

Arboreal primates are typically altricial, exhibit long juvenile periods, and use dynamic locomotor behaviors that can be challenging and risky. Sifaka (Propithecus verreauxi) have particularly slow life histories for their size, with long juvenile periods, protracted reproductive careers, and long life spans. They exhibit rapid craniodental development, weaning around 5-6 months, but their postcrania develops relatively slowly, reaching adult proportions about age 3-4 and adult body mass around age 8. Slow somatic growth poses potential mechanical challenges for juvenile sifaka who use thigh-powered vertical clinging and leaping to follow group members during travel. We examined mechanical and energetic costs of movement in developing sifaka. We instrumented 8 wild sifaka (3 yearlings, 3 subadults, 2 adults) in 4 social groups with inertial sensors measuring tri-axial acceleration for 1.5-8 weeks and collected simultaneous continuous behaviors on focal pairs. We quantified overall dynamic body acceleration (ODBA), number and magnitude of peak accelerations, percentage active time, leap counts, and activity budgets across ages. Yearling sifaka exhibit higher ODBA, higher and more peak accelerations, and more activity than subadult or adult sifaka ($p < 0.05$). With absolutely shorter hindlimbs, yearling sifakas need to produce higher accelerations and expend more energy during locomotion than adults. We discuss these results in the context of life history theory, development, and the socioecology of slow-growing group-living juveniles that must move in the same habitats as adults.

1513 Gabriel Hessler, Jason Davis

A dirty planet: the effects of anthracite on varying invertebrate gut biomes

Extreme metabolic adaptations can be found not only in overtly or obviously hostile environments, but also within species occupying unusual niches. A growing human population has forced a demand for energy taken from coal, the mining of which produces behind a large amount of pollution. Coping with this pollution has proven to be a difficult technological challenge, but perhaps solutions can be found by studying the microflora of organisms that have had to evolve to survive in coal-heavy environments. In this project, we sought to determine whether or not insect species such as banded crickets (Gryllodes sigillatus) and dermestids (Dermestes maculatus) could survive the ingestion of anthracite and explore the modulation of this consumption by their gut microflora. Cell cultures were taken from the guts of dermestids and crickets, along with a control insect, the Madagascar hissing cockroach (Gromphadorhina portentosa), and incubated inside a broth solution containing anthracite dust to determine the change, if any, in cell growth. Nanodrop spectrophotometry allowed us to observe whether or not

the anthracite was being metabolized by the gut flora or simply being ignored by measuring the wavelengths of light absorbed. Our results have demonstrated that anthracite does not negatively affect cell growth from any of the species noted and provide evidence suggestive of the metabolization of anthracite in our experimental groups.

1529 Ross Hibbett, Lucien Tsai, Vanessa Bartling, Paco Navarro, Mark Ilton

Biological springs are most efficient when subjected to equal loading and unloading rates

Two of the primary roles of biological springs in animal locomotion are for energy conservation and power amplification. For energy conserving movements, energy is cyclically stored and recovered from elastic structures (e.g. tendon) at similar rates to minimize the muscle work. On the other hand, power amplified movements slowly store and quickly release elastic energy at asymmetric rates. Comparing these two different roles of elastic biological materials, we hypothesize a trade-off between the asymmetry of the loading/unloading rate of the material and its efficiency in releasing elastic energy. We test this trade-off by performing mechanical property measurements at various rates, using a tunable synthetic material that allows us to control the potential stored energy of the system. We find that elastic materials are most energy efficient when they are subjected to equal loading and unloading rates. Any asymmetry between the loading and unloading rate imposed on the material causes it to dissipate additional energy. These findings are consistent across a variety of materials, amounts of deformation and rates, which suggests that there might be a connection between the function of biological springs in energy conserving movements and their underlying material properties.

943 Tobin Hieronymus, Patricia Sanchez-Montejo, Caleb Oleson, Bret Tobalske

Blocking feather muscles activity in vivo in fowl (Gallus gallus) with 6-hydroxydopamine

Birds possess a network of dermal smooth muscles that influence feather position. These muscles are innervated by noradrenergic autonomic nerves, and play a role in shifting plumage for display, thermoregulation, and potentially flight. Despite the functional importance of this system, experimental investigations have been hampered by difficulties in measuring and manipulating smooth muscle in vivo, especially when compared to skeletal muscle. Our goal in the present study was to improve understanding of smooth muscle function in determining external wing morphology. We have adapted an existing approach using 6-hydroxydopamine to block noradrenergic signaling as a novel means of knocking down smooth muscle function in the distal head of expansor secondariorum (mnES), a smooth muscle belly that runs from the humerus to the proximal secondary flight feathers. In our initial experiments ($n = 2$ individuals), a set of four 3.6 mg/kg doses was sufficient to completely block feather movement caused by contraction of the distal head of mnES elicited by direct nerve stimulation. In contrast repeatable feather movements were exhibited in a contralateral sham injection control. The effect was localized to an ?1 cm radius, as evidenced by continued response from the adjacent proximal head of mnES on the treatment side. This approach provides a means to conduct localized loss-of-function experiments to uncover the roles of autonomic feather position control in avian biology. NSF IOS EAGER 1838688.

366 Avery Hiley, Greg Rouse

Phylogenetics of Lepidonotopodinae and mitochondrial gene order rearrangement in deep-sea scaleworms

Within Polynoidae, a diverse family of marine scaleworms, the subfamilies Macellicephalinae and Lepidonotopodinae are comprised of deep-sea species. Lepidonotopodinae is a clade inhabiting chemosynthetic-based environments, such as methane seeps, hydrothermal vents, and organic falls. Contrary to Sanger sequencing, which was used in the most recent Lepidonotopodinae phylogeny, next-generation sequencing has drastically reduced the cost and time for DNA sequencing. Genome skimming is a common tool utilized to sequence millions of fragments of genomic DNA in parallel, spanning the target genome, which can be used to bioinformatically assemble mitogenomes with high read coverage and resolution. In this study, newly sequenced skimming data for 31 deep-sea scaleworms was utilized to assemble mitogenomes, which exhibited extensive gene order rearrangement events compared to shallow-water relatives. Furthermore, inclusion of skimming data for additional already known Lepidonotopodinae species allowed for the increased coverage in DNA data and representation of taxa necessary to create a more robust phylogeny using 18 genes, as opposed to the six genes previously used. The results showed that the previously recovered paraphyly in Lepidonotopodium, Levensteiniella, and Branchinotogluma could be resolved with the erection of five new genera; the reduction of Branchinotogluma into a monotypic genus; the expansion of Lepidonotopodium to in-

clude Levensteiniella plicata; the expansion of Levensteiniella to include Lepidonotopodium okinawae and Lepidonotopodium cf. riftense; and the expansion of Branchipolynoe to include six free-living Branchinotogluma taxa.

183 Geoffrey Hill, Matthew Powers, Ryan Weaver

Color displays produced by metabolized red carotenoids are inherently honest signals

Numerous studies have documented that red coloration that results from the deposition of red ketocarotenoids serves as an honest signal of condition. In those studies, individuals with redder or more chromatic color displays perform better. In most animals, red carotenoid pigments are produced via the C4-oxygenation (ketolation) of yellow dietary pigments such as lutein. While the pattern of red coloration signaling condition is well established, the mechanisms that underlie such honest signaling remain contentious. The genic capture hypothesis proposes that sexual selection on an ornament like red coloration leads to the "capture" of genetic and phenotypic variation in condition; condition dependency evolves under the influence of sexual selection. An alternative hypothesis proposes that selection focuses mate choice on traits that are inherently condition dependent. We tested whether red keto-carotenoids are inherently condition dependent by studying the red copepod Tigriopus californicus. Given the primitive visual system of copepods, it is unlikely that these zooplankton can perceive red, and behavioral trials confirm no mating preference for red. Thus, red coloration is not under sexual selection. Nevertheless, experiments document that red coloration declines following exposure to UV radiation and ingestion of excess copper. These studies indicate that red coloration is inherently condition dependent, potentially because C4-oxygenation is necessarily tied to vital cellular process.

1223 Karl Hill, Vikram Chandra, Mansi Srivastava

Simple growth rules could explain brain assembly in an acoel worm

Animal brain anatomy is generally stereotyped. Within species, each brain has roughly the same components and spatial organization. This is likely a derived feature of centralized nervous systems, and how it evolved is poorly understood. We have begun to study the 'brain' of the highly-regenerative acoel worm Hofstenia miamia, which appears intermediate between diffuse and truly-centralized nervous systems. Here, we study the largest structure in the Hofstenia brain: a single-layered, subepidermal network of interconnecting neurite bundles wrapping around the worm's head. Using semi-automated segmentation of confocal brain images, we quantified and compared the morphology of this neural structure across worms, through development, and through regeneration. We find that although Hofstenia brains display similar network connectivity, they vary enormously in their precise topology (i.e., in the exact arrangement of the neurite bundles, and in the number and relative organization of the spaces between them), even among worms matched in age and rearing. Nonetheless, brain shape follows a similar trajectory of growth through post-embryonic development and regeneration. Specifically, neurite bundles thicken through time (but only up to a point), spaces between bundles increase in number, and the uniformity of their spacing and geometry likely increases as well. In future experiments, we hope to study the wiring rules that individual neurons follow, and to better understand the dynamics of brain assembly in Hofstenia.

1350 Jessica Hill, Matt Grisnik, Ryan Hanscom, Jeet Sukumaran, Timothy Higham, Rulon Clark

Describing a Predator-Prey System using Ecological Niche Models: Rattlesnakes and Kangaroo Rats

Ecological niche models are a growing area within spatial ecology which identify critical environmental factors associated with a given species. This information can then be used to model the current distribution of the species, as well as past distributions and future range shifts under climate change conditions. These methods are increasingly being applied in community ecology, where joint species distribution modeling (JSDM) is used integrate data on factors such as species abundances and environmental covariates of more than one species in a community. Our study focuses on the predator-prey system of prairie rattlesnakes (Crotalus virdis) and Ord's kangaroo rats (Dipodomys ordii). We first created current and future range predictions using the package MAXENT for both species, allowing us to calculate overlap metrics. Because these two species cooccur throughout a wide latitudinal range from Northern Mexico to Southern Canada, the variables underpinning their joint distribution are particularly diverse. Additionally, in areas where both species are abundant, kangaroo rats compromise a large portion of rattlesnakes diets. These factors make this system an excellent candidate for exploring community dynamics in niche models, and we aim to use this model system as a demonstration of how JDSM ecological niche modeling can be integrated with traditional ecological and spatial data to establish a holistic understanding of the factors impacting population stability in near term climate scenarios.

1540 Katie Hinde

The Adaptively-Relevant Environment of the Primate Neonate: Mother's Milk in Developmental Context

Mother's milk has been shaped by hundreds of millions of years of natural selection. Although some reptiles, fish, birds, amphibians, and invertebrates produce milk to nourish their young, uniquely among all mammals is the synthesis of complex biofluid obligate for infants to survive and thrive. As a complexly structured food, medicine, and signal, milk nourishes, protects, and informs the developing neonate through nutrients, immunofactors, and hormones. The precise composition of milk varies across species, across populations within species, across individuals within populations, and across time within individual mothers. Analyses of 1000+ milk samples synthesized by hundreds of rhesus macaque mothers (Macaca mulatta) at the California National Primate Research Center have yielded important insights into the adaptively relevant environment of developing primate infants. Emerging results suggest that mothers with fewer somatic resources may program offspring phenotype in part through milk bioactives that orchestrate dynamic tradeoffs among behavioral activity, cognitive development, and somatic growth of the developing neonate. Moreover, variation in mother's milk is implicated in behavioral phenotype of offspring with effects persisting long after the period of maternal dependence. Better understanding of variation in milk composition, especially for milk constituents linked to infant cognition, neurodevelopment, behavior, and metabolism, enhances an evolutionary biological perspective of parent-offspring dynamics.

292 Hannah Hirsch, Yuichiro Suzuki

Why do insects grow faster at higher temperatures?: Hormonal responses to temperature changes.

As global temperatures rise due to climate change, a common trend across many different organisms is an increased growth rate with a smaller final body size, which is often associated with reduced fitness. The tobacco hornworm, Manduca sexta, exhibits such a response, but the cause of this trend is largely unknown. In this study, we tested the hypothesis that hormones may play an important role in mediating this effect. At higher temperatures, we observed elevated expression of Insulin receptor (InR) and genes coding for juvenile hormone (JH) degradation enzymes, such as juvenile hormone esterase (JHE). Higher temperature was also associated with a reduced expression of Krüppel homolog 1 (Kr-h1), a JH response gene. These findings suggest that hormones respond to temperature to impact growth rates and final body size.

1303 Natalee Hite, Diana Sarko

Contractile Properties of the Naked Mole-Rat Masseter: Impacts of Tooth Loss

The naked mole-rat (Heterocephalus glaber) is a subterranean rodent with robust evolutionary adaptations regarding dentition and mastication. With disproportionately strong bite force, large muscles of mastication, and high behavioral reliance on dentition, this animal model is ideal for investigating the impact of unilateral tooth loss on the contractile properties of the superficial masseter. For this study, adult naked mole-rats underwent unilateral mandibular incisor extraction or sham surgeries, followed two months later by the dissection of both the ipsilateral and contralateral superficial masseters. Each isolated masseter was stimulated at various frequencies and voltages to obtain the force-frequency relationship, contraction threshold, tetanic threshold, and maximum contractile force. A comparison of these variables between contralateral and ipsilateral masseters, with respect to the surgical site, within and between sham and extraction animals was performed using a MANOVA, with a Bonferroni correction and a post hoc pairwise comparison of significant effects. The results of this study reveal inherent contractile properties of the naked mole-rat masseter, while also aiding us in understanding part of the impact that tooth loss has on masticatory function.

1361 Jennifer Hodge, Danielle Adams, Laura Alencar, Benjamin Camper, Olivier Larouche, Mason Thurman, Keiffer Williams, Katerina Zapfe, Samantha Price

Effects of history on ecomorphological convergence across marine acanthomorph fishes

Organisms that acquire energy from the same resources often converge on similar strategies or morphological features. Across clades, the repeatability and predictability of ecomorphological convergence may be constrained by evolutionary history. Yet, few studies have been conducted at scales sufficient to assess the contribution of ancestral effects. In fishes, selective planktivory is a distinct type of foraging often associated with a suite of morphological specializations for visually detecting and capturing microscopic plankton.

However, inconsistencies in the trajectory and magnitude of morphological change following transitions to selective planktivory across clades studied to date allude to the potential importance of ancestral effects. Here, we describe morphological trends associated with selective planktivory across 1,995 marine acanthomorph fishes and comparatively assess effects of ancestral morphology and foraging condition on trajectories of morphological change. Mapping foraging mode on the phylogeny spanning $\sim$ 150 myr of evolution reveals independent transitions to selective planktivory in various lineages with disparate ancestral foraging modes, providing many replicates for testing morphological convergence. Our preliminary results indicate that ancestral foraging condition impacts both the direction and magnitude of morphological changes following transitions to selective planktivory for many morphological traits. Overall, our findings describe the extent to which the functional demands of selective planktivory have led to generalizable morphological features among Acanthomorpha and highlight the importance of ancestral effects in shaping patterns of morphological convergence.

153 Brett Hodinka, Tony Williams

Phenotypic plasticity in mass loss during breeding: annual and individual variation

It has long been recognized that mass loss during breeding could be adaptive (e.g., by ameliorating the costs of increased parental activity). However, many studies still commonly interpret mass loss as evidence of “stress” or a cost of reproduction (a negative effect of high workload during chick provisioning). Despite several studies reporting evidence in support of both hypotheses, the ecological and/or life-history context under which mass loss may be viewed as a cost of reproduction or an adaptive strategy are still unclear. Using a long-term dataset from a breeding population of European starlings, we aimed to investigate the natural annual and individual variation in body mass and mass loss to determine if regulation of body mass as a potential strategy to modulate costs of parental care is context dependent. We hypothesize that if mass loss is an adaptive strategy, it should (1) vary among years, or with pre-hatching patterns of reproductive investment, (2) be associated with parental workload, and (3) have positive consequences for subsequent parental fitness (future fecundity and/or survival). We found significant annual variation in incubation mass, chick-rearing mass, and mass change. Mass loss was weakly repeatable across years indicating that it may be a context-dependent strategy used to modulate costs. Future analyses will explore sources of individual variation in mass and mass loss in relation to breeding success within an ecological context.

1750 Alex Hoffman, Haruka Wada

Developmental thermal stress and its effects on wound healing in adulthood in zebra finches

Environmental conditions experienced during development can have persisting and irreversible effects on phenotype. Chronic stressors during this period can negatively impact fitness-related traits such as immune function and reproduction. However, depending on the magnitude of exposure, such stressors may induce adaptive phenotypic adjustments that promote tolerance to future stressful conditions. Although these adjustments may be costly if there is a mismatch between the early life and adult environment. Previously, we observed that when zebra finches (Taeniopygia guttata) were conditioned at 38°C as juveniles, they exhibited slower wound healing rates when not exposed to a thermal stressor in adulthood. Here we examined how a higher temperature thermal conditioning protocol influences immune function later in life when confronted with a thermal stressor of a higher magnitude. To do this, we subjected juvenile male and female zebra finches to a heat stress of 40.5°C or control (22°C) temperature every other day for 28 days. In adulthood, these finches were then exposed to either a high heat stressor (42°C) or control (22°C) temperature for 3 consecutive days. During this period, we measured the rate of wound healing as a proxy for overall immune function. We predict that finches exposed to the thermal conditioning as juveniles will have faster rates of healing when exposed to the 42°C stressor compared to their juvenile control counterparts.

1143 Casey Holliday, Alec Wilken, Kaleb Sellers, Ian Cost, Kevin Middleton, Lawrence Witmer

Avian cranial kinesis is the result of increased encephalization during the origin of birds.

The evolution of the avian skull from that of non-avian theropod dinosaurs involved dramatic increases in brain size but also significant biomechanical modifications in the feeding apparatus which resulted in the origin of powered prokinesis of neognath birds. Powered kinesis is considered in part responsible for the trophic diversity and success of birds, but how changes in neuroanatomy impacted the jaw muscles and cranial joints of the feeding apparatus remains unclear. Using an integrated approach of 3D reconstructions of skull morphology, jaw muscle modeling, and lever mechanics, we quantified the changes in muscle orientations and their influences on moments and reaction forces about articulations between of the palate and neurocranium necessary for cranial kinesis across the theropod transition to birds. Here we demonstrate that expanding braincases during non-avian theropod evolution reoriented the primitively mediolaterally diagonal orientations of jaw muscles into more rostrocaudally oriented positions in birds. These phenotypic transformations resulted in increased muscle lever arms about intracranial joint axes, enabling the propensity for cranial kinesis. These findings illustrate the coordinated evolution of the neurosensory and feeding systems during the origin of birds and provide a new approach to identifying cranial kinesis in extinct vertebrate species.

620 Bridget Hollowell, Elizabeth Borda, Jose Valdez

Aquatic Macroinvertebrates in relation to Climate Change in the San Antonio River

Aquatic macroinvertebrates serve as biotic indicators of environmental quality in aquatic systems. Each taxon has different sensitivity levels to pollutants or habitat disturbances, which directly affect their abundance and composition within the river community. Habitat disturbances and water pollution are evident in urban rivers impacted by anthropogenic activity and climate change, such as the upper San Antonio River. Climate change influences the frequency and intensity of rain events and air temperature, which directly influence the river hydrology. Current and future changes in river hydrology might present new or unknown scenarios for aquatic ecosystems. Anthropogenic activities alter river hydrology by increasing impervious surfaces, changing the type of vegetation cover, and therefore altering surface run off. With this in mind, we studied the aquatic moths of the genus Petrophila and Trichoptera species, which inhabit shallow rocky site along the river, and are more vulnerable to changes in river hydrology. We studied the changes in abundance and species composition of these two groups in response to river parameters influenced by extreme weather events over a 10-year period. Results from this study provide a list of indicator species that could help assess future impacts of extreme weather events and anthropogenic disturbance specific to urban rivers.

541 Roi Holzman, Christopher Martin, Peter Wainwright

The functional morphospace of fish skulls is constrained by evolutionarily rigid, ubiquitous bounds

As lineages enter ecologically available and competitor-free “adaptive zones”, they tend to undergo rapid morphological evolution which leads to their adaptation to these zones. It is thought that such lineages accumulate morphological disparity until they fill the functionally available morphospace; at which stage the rate of their morphological evolution decelerates. However, it is unclear which mechanisms set the bounds of the morphospace, and how evolutionarily stable these bounds are. Here, we characterized the tempo and mode of evolution of functional traits across 13 fish radiations, featuring age ranges of 0.1-50 Myrs. We used functional traits because variation in such traits can be mechanistically linked to variation in feeding performance. We found that the bounds (i.e. min and max value) and ranges for size-corrected functional traits were remarkably consistent across the 13 radiations, and did not expand with the age of the radiation. For most of the traits we quantified, a model of bounded Brownian motion was overwhelmingly favored over other models of trait evolution. Disparity through time analysis indicated that 50% of the disparity was reached within ∼10 Myrs, and then plateaued. Our analysis suggests that physical, rigid constraints on the design of bones and muscles bound the functional morphospace during adaptive evolution. While the functional morphospace initially fills rapidly, diversity is ultimately maintained through “recycling” previously utilized morphospace regions.

1294 Regan Honeycutt, Allison Welch

The effects of elevated salinity on oviposition site choice and mate choice in squirrel treefrogs

Anthropogenic change challenges organisms with novel conditions in which existing traits may prove maladaptive. Although evolution optimizes fitness, competing demands in rapidly changing environments can undermine previously adaptive behaviors. For many animals, two co-occurring factors are important determinants of offspring success: mate choice and oviposition site choice. Freshwater salinization is a threat to many freshwater systems globally and can impact habitats in which various amphibians breed and develop. We characterized the mating calls of male squirrel treefrogs (Hyla squirella) from a local population and investigated how reproductive female squirrel treefrogs responded to variation in oviposition site salinity and in male advertisement call frequency. Phonotaxis tests were conducted in which reproductive female frogs were presented with two speakers, each broadcasting a synthesized frog call and each associated with a pool of water. Females were presented with various combinations of salinity and call frequency in order to test whether mate choice would be altered by variation in oviposition site quality. Female frogs showed low responsiveness, particularly in trials with water pools. If females' ability to choose a high quality mate is compromised by the challenge of selecting a suitable oviposition site, reduced offspring quality may result. Thus, for species in which oviposition site choice and mate choice co-occur, anthropogenic habitat change could constrain mate choice, resulting in a previously unrecognized threat to offspring fitness and population persistence.

383 Richard Hoover, Olivia Hawkins, Jack Rosen, Conrad Wilson, Callie Crawford, Meghan Holst, Jonathan Huie, Adam Summers, Cassandra Donatelli, Karly Cohen

The hydrodynamic cost of armor and its tradeoff with adhesion across ontogeny in E. orbis

Armor is a multipurpose structure found in many fishes that can be used for flow manipulation, sexual selection, and/or protection. There are, however, costs to this shield: the potential increase in hydrodynamic drag as armor complexity or surface area increases. Pacific spiny lumpsuckers (Eumicrotremus orbis) are covered in rows of odontic, cone-shaped armor that mitigate the impacts of life in the rocky subtidal. These fish also have a suction cup, allowing them to adhere to their environment and remain stationary. Armor coverage and complexity increases with lumpsucker size; we hypothesize that drag will increase with the growing surface area and excrescences. There may also be a tradeoff between the growth of the suction cup and the armor as the demands for staying put and being protected from smashing into rocks changes. Using ?CT we compared armor volume to disc area over lumpsucker development. We then used these scans to build 3D models to measure changes in drag over ontogeny. We found that drag increases with armor coverage and complexity and that drag differs depending on orientation. Preliminary results show that suction disc size is negatively allometric. This may represent a trade-off, as the role of suction to protect from potential impacts is replaced by physical protection across development, with increasing hydrodynamic cost.

1485 Alexander Hoover

Modeling multiple pacemaker control in jellyfish swimming

Recent studies have found that there are important biomechanical constraints that arise from the timescales associated with neuromuscular activation and the elastic response of flexible appendages or bodies. In jellyfish, the neuromuscular response is governed by the interaction of pacemakers with the underlying motor nerve net that communicates with the musculature. This set of equally-spaced pacemakers, located at the bell rim, alter their firing frequency in response to environmental cues, allowing for different swimming modes to be activated when sets of pacemakers fire in concert. In this work, we explore the control of neuromuscular activation with a computational model of a jellyfish bell immersed in a viscous fluid and use numerical simulations to describe the interplay of multiple pacemakers. We will look at the role a single pacemaker can play, as well as when a pair of pacemakers fire in unision and the resulting fluid dynamics that can result from their interaction.

831 Sydney Horan, Elizabeth Cochrane, Gabrielle Solomon, Ashley Love, Alyssa McGurer, Kunzika Kunzika, Sarah Knutie

Beating the heat: Mechanisms mediating effects of temperature on host resistance to parasitism

Climate change, including temperature increases, can affect species interactions worldwide. For example, an increase in microclimate can positively affect host defense strategies against parasites. However, the specific mechanisms that influence host defense strategies (e.g. resistance) in response to temperature changes require further study. For our study, we conducted an experiment to determine the mechanism that mediates the effect of temperature on host resistance to parasites. Specifically, we experimentally increased the temperature in the nests of Eastern bluebirds (Sialia sialis), then characterized blood loss to parasitism (i.e. hemoglobin), first primary feather length, and targeted immune gene expression in the blood of nestlings. We also identified and quantified all parasitic taxa in the nest. We found that blood loss and feather length decreased in response to increased temperature, suggesting that hosts have higher resistance in response to higher temperatures, which might come as a cost to growth. The immunological mechanisms influencing these effects and the abundance and diversity of nest parasite taxa will be discussed.

65 Jennifer Houtz, Maren Vitousek, Monique Pipkin, David Chang-van-Oordt, Kelly Hallinger, Jennifer Uehling, Cédric Zimmer, Conor Taff

Experimental cold exposure increases glucocorticoid sensitivity to future stressors in a wild bird

As the global climate shifts, many species are negatively impacted by changing thermal regimes. Despite rising global temperatures, some populations must contend with more frequent or extreme cold. For these populations, the ability to cope with cold may be an important determinant of fitness; however, the mechanisms underlying these phenotypic shifts are not well understood. Prior work in our lab found that cold temperatures cause shifts in two potential mediators of thermally-induced plasticity including the hormonal stress response and gut microbiome in wild tree swallow nestlings (Tachycienta bicolor). In this study we aimed to determine how cold temperatures impact adult tree swallow phenotype including stress responsiveness and gut microbial diversity. We experimentally lowered the internal nest box temperature by 5ºC during days 4 to 6 of nestling provisioning and then simulated an acute cold snap on day 12. Experimental cold exposure impacted the hormonal stress response by upregulating the sensitivity to future challenges (increased stress-induced levels). Cold exposure also increased the initial speed and duration of the acute hormonal stress response but did not impact gut microbial diversity. These results suggest that thermally-induced increases in glucocorticoid sensitivity to future challenges may prime individuals to respond more strongly or rapidly to worsening conditions.

683 Stephen Howe, Kendall Steer, Maxwell Johnson, Khaled Adjerid, Chloe Edmonds, Rebecca German, Christopher Mayerl

Exploring the Interaction of Viscosity and Nipple Design on Feeding Performance in Infants

Infant feeding behaviors are modulated via sensorimotor feedback, such that sensory perturbations can significantly impact performance. The properties of the nipple-milk system (e.g., nipple hole size and viscosity) are one critical source of sensory information. However, the direct effects of varying milk and nipple properties on motor outputs and the subsequent changes in infant feeding performance are poorly understood. In this study, we use an infant pig model to explore the interaction between nipple hole size (using artificial silicone nipples) and milk viscosity. Using videofluoroscopy and electromyography, we measured key performance metrics including sucks per swallow and suck duration, then synchronized these data with the onset and offset of activity of jaw opening and closing muscles. Neither sucking activity nor muscle firing patterns differed among pigs feeding on thin milk with small-holed nipples and pigs feeding on thick milk with large-holed nipples. Pigs feeding on thick milk from small-holed nipples had more sucks per swallow and activated jaw opening muscles earlier in the suck cycle than the other three treatments. Pigs activated jaw closing muscles later in the cycle when feeding on thick milk from large-holed nipples compared to the other three treatments. Changes in suckling performance induced by changing viscosity can be offset by changing hole size, indicating that infants are more sensitive to changes in overall flow rate than any contributing parameter.

1730 Chi Huang, Ioana Murgulet, Wei Xu

Development of a novel human breast cancer xenograft model in zebrafish

Zebrafish have been used as carriers for various human cancer xenograft models. The human breast cancer zebrafish xenograft (BCZX) model has been widely applied to the mechanistic studies of breast cancer metastasis for a decade. Previous BCZX models only introduced breast tumor cells to zebrafish embryos, while an essential type of cell contributing to the microenvironment of breast cancer development, pre-adipocyte, was ignored. The present study aims to develop a new BCZX model by introducing both human pre-adipocytes and one of the human breast cancer cell lines (MCF-7 or MDA-MB-231) into zebrafish embryos. Migration of the cancer cells is tracked by fluorescent microscopy, and the cancer cell proliferation rates of fish recipients are estimated by quantitative PCR. The metastasis of the breast cancer cells in zebrafish is evaluated by the expression of the breast cancer metastasis-associated genetic markers. The results demonstrated significant differences between the two breast cancer cell lines' migration and proliferation levels. The implantations of two cancer cell lines showed rapid migration. However, the MDA-MB-231 shows decreasing proliferation, and its fish carrier has a shorter life. Compared to the previous BCZX models with one breast cancer cell line, the new model co-injected with two types of human cells showed more significant migration of cancer cells. This model can be used in the studies of cell interactions between pre-adipocytes and breast tumor cells.

1716 Christian Hubicki, Jacob Hackett, Craig McGowan, Monica Daley

Modeling adaptive locomotion behaviors using risk-aware optimal control

Locomotion in animals is plastic and adaptive to changing environments and physical capabilities. We present a computational framework for modeling locomotion behaviors that are both extemporaneous and shaped by prior experience. This modeling framework builds atop a trajectory optimization approach, which synthesizes behaviors for a math-modeled organism that minimizes a pre-defined cost. Traditionally, trajectory optimization is used to generate individual gaits for legged locomotors by minimizing energy costs. Our approach expands on existing methods by 1) continually re-optimizing behavior during simulation, 2) minimizing a probabilistic risk of failure (e.g. predation or energy loss), and 3) updating failure probability estimates from learned experiences. These extensions equip the framework with extemporaneous behavior, emergent prioritization, and acquired personality traits based on experience, respectively.As a primer, this presentation will introduce the foundations of continual trajectory optimization, called "model-predictive control" (MPC). Further, we will demonstrate how minimizing overall failure probability allows the framework to reprioritize behavior based on immediate need. For instance, a starving animal may put itself at greater risk of predation to forage for food. Lastly, we will show how varied experiences with stochastic risks (e.g. a chance injury) can create emergent "bold/shy" personalities in simulation. Example simulations range from simple double-integrator models to running bipeds. These proof-of-concept simulations are a steppingstone toward unifying behavior at the biomechanical level with larger environmental and ecological pressures.

721 Sonja Huč, Avery Hiley, Marina McCowin, Greg Rouse

The First Mitochondrial Genome Phylogeny of Pilargidae (Phyllodocida, Annelida)

Pilargidae is a family of phyllodocid annelid worms found all over the world, from shallow coastal habitats to deep-sea chemosynthetic environments. The family currently contains around 100 accepted species in 12 accepted genera, with six additional genera being subjective synonyms. Historically, pilargids have been genetically under sampled owing to their usually small body size and being relatively uncommon, especially in shallow waters. Using a diverse sampling of recently obtained specimens from the USA, Norway, Belize, and Costa Rica, this study presents the first complete mitochondrial genomes of pilargids, including several of the eleven genera. The resulting phylogenetic tree based on the mitogenomes and some nuclear DNA data gives insight into the intrafamilial relationships of Pilargidae and greatly increases the available genetic information for this intriguing group of annelids.

1182 Hannah Hughes, Mar Huertas

Effects of Chronic Nitrite Exposure on Gonad and Embryo Morphology in Xiphophorus couchianus

Xiphophorus couchianus (Monterrey platyfish), are a species of live-bearing fish with an average gestation period of 28 days. Thus, X. couchianus are a possible model to further our understanding of vertebrate pregnancies. More specifically, to model how exposure to ubiquitous nitrites can hinder embryo development. To do this, it is necessary to first understand how exposure to nitrite alters the morphology of reproductive organs and, consequently, embryos. We predict that exposure to nitrite in X. couchianus will accumulate in tissues and induce malformations in embryo and hypertrophy of cells in gonadal tissues. To assess the effects of chronic nitrite exposure on embryo and gonad morphology, 1 male and 2 female X. couchianus were exposed to 0.3 mM or 0 mM of nitrite (2 replicates per treatment) for 28 days. Water quality samples were taken each morning to monitor nitrite levels. Upon completion of the experiment, reproductive organs and embryos were sampled and fixed in bouin. Paraffin blocks were cut in 7 μm sections and stained following alcian blue staining procedures. We found that nitrite accumulated in both embryo and gonadal tissues, thus changing the morphology of gonads in X. couhianus and hindering typical development of embryos. The results show that chronic exposure to low concentrations of aquatic nitrite, a common waterway pollutant, can affect embryo development in vertebrates.

1677 April Hugi

Sailfish larvae in the Gulf of Mexico: Prey Selectivity, Prey Quality, and Larval Growth

The Gulf of Mexico is an important early life habitat for sailfish (Istiophorus platypterus), whose larvae experience high growth rates despite their highly specialized diets, limited foraging abilities, and oligotrophic offshore habitats. Variability in the recent growth of sailfish larvae was compared to environmental, spatial, diet, prey availability, and fatty acid metrics using data collected from near-surface waters in the northern Gulf of Mexico (2017 - 2019). Results support that early larvae have an extremely narrow feeding niche that expands with ontogeny. Sailfish larvae showed significant positive selection for Evadne spp. and female Farranula spp.. Fatty acid analyses indicated that the total fatty acid concentration of preferred prey was highest in habitats closest to shore, and that Evadne spp. had lower percentages of DHA and higher percentages of AA than did other preferred prey types. Percentages of DHA, EPA, and AA increased in the tissue of sailfish larvae with ontogeny while the concentration of total fatty acid remained consistent, indicating that these essential fatty acids may be significant in development. Recent growth of larval sailfish was higher when more prey were consumed, when dissolved oxygen concentrations were greater, and when larvae were found in anticyclonic boundary regions. This is the first study to examine and report sex-specific selection of zooplankton prey by sailfish larvae, and to examine the fatty acids of sailfish larvae and their preferred prey.

1213 Fredrik Hugosson, Brent Foster, Mark Martindale

Expansion of Notum genes in Nematostella vectensis: Implications for Wnt signaling in development

The canonical Wnt signaling pathway is required for the correct basic axial patterning in metazoan embryos. One key regulator of this pathway is a decarboxylase, Notum, that inactivates Wnt ligands via deacetylation. Most animals from acoels to humans have a single Notum gene, whereas cnidarians—the sister group to bilaterians—contain two Notum genes. Nematostella vectensis, an anthozoan sea-anemone, show an additional expansion to four Notum genes. Two of these genes are reported to be upregulated during oral regeneration (Schaffer et al., 2016) in addition to several other components of the Wnt pathway, suggesting that Notum plays a role in Nematostella regeneration. Here, we will characterize the developmental expression of the four Notum genes in Nematostella vectensis from early cleavage to the polyp stage. We have performed knockdown experiments using shRNAs targeting single and multiple Notums and analyzed their effect on patterning and development. To block Wnt signaling, we have also injected mRNA encoding each of the four Notums in zygotes and analyzed their effects on Wnt signaling. We will present the implications for a expanded Notum repertoire in Nematostella and discuss if Notum has evolved new functions or whether these genes share ancestral function. This work will shed light on the regulation of Wnt signaling during development in cnidarians.

93 Jonathan Huie, Callie Crawford, Emily Kane, Allyson Evans, Karly Cohen, Thaddaeus Buser, Matthew Kolmann

The enemy of your anemone: feeding kinematics and biomechanics of a narrow niche cnidarian nibbler

Of the 15,000 species of marine fishes, only 13 consume anemones as a major food source. The North Pacific intertidal is home to one of these anemone feeders, the mosshead sculpin (Clinocottus globiceps). Anemones are abundant in tropical and temperate regions, but their tough-to-tear tentacles and stinging cells (nematocysts) deter most predators. We hypothesized that specialized feeding behaviors and morphologies facilitate anemone feeding. We used high speed videography to document C. globiceps feeding on anemones and pieces of shrimp. To compare jaw biomechanics, we employed micro-CT scanning coupled with contrast staining to visualize bone and musculature. Using scanning electron microscopy and histological sectioning we examined the dentition and soft tissues of the buccopharyngeal cavity. To tear tentacles, C. globiceps launched stereotyped attacks that involved rapidly twisting and bending their bodies, which differed from their varied behaviors used to feed on shrimp. Compared to its close relatives, C. globiceps had more robust jaws, the capacity for higher bite forces, and rows of teeth pointed with flat blades – instead of the conical teeth found in other intertidal sculpins. The surface of C. globiceps' oral and pharyngeal jaws were also covered with mucous and fibrous tissue, not seen in other sculpin species, that may reduce sensitivity and protect against nematocysts. While C. globiceps exhibits specialized feeding traits, they may be best described as exaptations co-opted for anemone-feeding.

94 Jonathan Huie, Dylan Wainwright, Adam Summers, Karly Cohen

A sticky ichthy trinity: adhesive performance in clingfish, lumpsuckers, and snailfish

The coastal waters of the North Pacific are home to the northern clingfish (Gobiesox maeandricus), Pacific spiny lumpsucker (Eumicrotremus orbis), and marbled snailfish (Liparis dennyi) – three fishes that have ventral adhesive discs. Clingfish adhesive performance has been well characterized, and is impressive in both stress and acceptable surface roughness. We compared peak adhesive forces and work to detachment of clingfish, lumpsuckers, and snailfish on surfaces of varying roughness and over ontogeny. We also visualized adhesive disc morphology through micro-CT scanning, scanning electron microscopy, and fluorescence. Adhesive performance is tied to our understanding of the intensity and variability of flow regimes in the fishes' habitats. The northern clingfish generates the highest adhesive forces and lives in the rocky intertidal where it must resist high exposure to crashing waves. Lumpsuckers and snailfish both generate only a fraction of the clingfish's adhesive force, but live more subtidally where currents are slower and less variable. However, lumpsuckers generate more adhesive force relative to their body weight than snailfish, which we attribute to their more drag-inducing body shape and frequent bouts into the intertidal. Even so, the performance and morphology data suggest that snailfish adhesive discs are stiffer and more effective than lumpsucker discs. Lastly, we determined the papillae on the surface of each species' adhesive disc fluoresces under UV light.

1576 Tyler Hunt, Michael Hogan, Niall Whalen

Visual Field Analysis of Two Viperid Snakes

Visual fields delimit the area over which an organism can gather near instantaneous optical information about their environment. Knowledge of the inter- and intra-specific variability of these fields, their role in behavior, and the evolutionary mechanisms that determine their margins remain poorly understood. Here, we use the ophthalmoscopic reflex technique to measure the in vivo visual fields of two viperids of differing feeding ecologies—the terrestrial eastern diamondback (Crotalus adamanteus) and the semi-aquatic cottonmouth (Agkistrodon piscivorus). This procedure uses an ophthalmoscope mounted on a graduated perimeter arm to measure the extinction of the retinal reflex (red eye or eye shine), demarcating the maximal limit of the visual field subtended by the retina. The visual fields of these two taxa exhibit substantial variation particularly with regard to the location of the maximal widths of the binocular fields. The binocular field of C. adamanteus ($n = 5$) reaches its maximum of $45.6^\circ \pm 3.3^\circ$ at the horizontal (90°) and extends through 120° vertically, whereas A. piscivorus ($n = 2$) possess a maximal width of $34.5^\circ \pm 2.5^\circ$ that is ventrally shifted 20° relative to the horizontal and extends through 100° vertically. Remarkably, most of the binocular field of A. piscivorus is directed below the head, possibly enabling binocular vision when performing their characteristic predator deterring gape position.

1784 Eloise Hunt, Ryan Felice, Joseph Tobias, Anjali Goswami

Ecological and Life History Drivers of Avian Skull Evolution

One of the most famous examples of adaptive radiation is that of the Galapagos finches skull morphology correlating with feeding ecology. Yet, increasingly studies are questioning the strength of this correlation between feeding ecology and morphology in relation to the neornithine radiation. We aim to test the influence of habitat density, migration, and developmental mode in shaping avian skull evolution. We utilised a sample of high-density 3D geometric morphometric data for 354 extant species for flexible phylogenetic regressions in the mvMORPH R package and we estimated evolutionary rates. Our results showed that there is a significant relationship between shape and both habitat density and migration categories ($P < 0\ .001$), but not between shape and developmental mode ($P = 0.096$). Birds in open habitats evolve ~3 times more slowly than those in dense or semi-open habitats. Precocial birds evolve ~3 times faster than semi-precocial birds and ~4 times faster than altricial birds, with elevated rates in the vault module of the skull. Migratory birds evolve faster ($1.64\times10\text{-}7$) than sedentary or partially migratory birds ($7.07\times10\text{-}8$ and $1.06\times10\text{-}7$ respectively), with particularly rapid evolution in the vault and rostrum of migratory birds. These patterns demonstrate that habitat density and migration help shape the tempo and mode of avian phenotypic evolution, and that skull evolution in birds is not simply a reflection of feeding ecology.

1486 Ione Hunt-von-Herbing, Francis Pan

Multiple Stressors, Allostasis and Metabolic Scaling in Developing Zebrafish.

Deoxygenation and warming affect adult fish physiology in all aquatic ecosystems, but how these stressors impact the energetics of sensitive developing stages is largely unknown. Addressing this knowledge gap, we investigated chronic and acute effects of two stressors (high-temperature and hypoxia) in yolk-sac larval (48-168 hpf) zebrafish (Danio rerio) energy budgets measuring, oxygen consumption rate (MO2), growth rate (absolute (AGR) & specific (SGR)), % net conversion efficiency (KN), net cost of growth (Cr) and scaling relationships. Embryos and larvae were raised under four chronic treatments, 1) control (28°C & pO2 21kPa, T28O21), 2) high-temperature (31°C & pO2 21kPa, T31O21), 3) hypoxia (28°C & pO2 11kPa, T28TO11), and 4) high-temperature and hypoxia (31°C & pO2 11kPa, T31O11). From each chronic treatment, larvae were acutely exposed to the same combinations of stressors for 1h in a respirometer. At hatching, larvae from chronic high-temperature (T31O21 & T31O11) treatments were larger than controls (T28O21 & T28O11), but by the end of the yolk-sac stage, increased metabolic demands diverted energy away from growth increasing Cr and lowering % KN. Control metabolic scaling relationships were significant (metabolic exponent, combined b of 1.19 ± 0.25) and differed from 0.75, but metabolic levels (La) were lower in acute hypoxia and high-temperature/hypoxia. Thus, high-temperature dominated larval energetics and acted synergistically with hypoxia increasing cumulative energetic costs and making allostasis difficult to attain compared to older stages.

579 Laura Hunter, Anna Wisniewski

Tempo and mode in the evolution of primate dental morpholog

Primate dental morphology is highly correlated with diet across the over 400 species alive today, allowing-paleontologists to make inferences about the ecology of taxa for which little else is known. Armed with suchdata it becomes possible to test hypotheses about tempo and mode in ecomorphological evolution, such asearly burst adaptive radiation. To explore the evolutionary history of tooth morphology, and by extensiondiet, across the order Primates, we measured the occlusal surface complexity of the second mandibular molarsof 100 extinct and 140 extant species, representing all major taxonomic groups. Using a phylogenetic treeof living and extinct primates, we compared a series of evolutionary models to characterize the tempo andmode of primate dental evolution. When simple models of continuous trait evolution are considered, a singlestationary peak Ornstein-Uhlenbeck receives the most model support. However we also explore if relaxingmodel assumptions and allowing for multiple adaptive peaks suggests a more complex adaptive landscapefor primate dental morphology.

1719 Audrey Hurt, Rachel Pepper, Brett Klaassen-van-Oorschot, Isabella Gravante

The effect of peridiole shape on the kinematics of splash cup dispersal in bird's nest fungi.

Bird's nest fungi are organisms that help decompose wood on forest floors. They have a unique cup-like shape, which disperses its peridioles (packages for its spores) using a dispersal mechanism known as a splash cup. Splash cups in bird's nest fungi use the kinetic energy of raindrops to eject their peridioles large distances and heights relative to the size of the fungus' fruiting body. Understanding the biomechanics behind splash cup dispersal in these organisms can be used to compare with the biomechanics of splash cup plants and to better understand evolutionary pressures on these organisms. Previous work has examined the effect of cup shape and the species of bird's nest fungi; however, the role of peridiole shape in the biomechanics of splash cup dispersal hasn't been studied. In plant species, the seeds are typically an approximate spherical shape, but peridioles in bird's nest fungi have a more lenticular shape: two convex lenses put together. To test the role of peridiole shape on ballistic dispersal trajectory, we dropped water drops on plastic models of spherical and lenticular peridioles on 3-D printed biomimetic bird's nest fungus cups. We measured the kinematics of the model peridiole ejection. We found that on average the spherical peridioles had greater dispersal distances and height. These results suggest that there is no benefit for dispersal of peridioles to have a lenticular shape.

1538 Jerry Husak, Rachelle Belanger, Michele Johnson, Kristopher Karsten, Matthew LeFauve, Jason Macrander, Thomas Sanger, Kari Taylor-Burt, Lisa Whitenack

Integrative Biology at Primarily Undergraduate Institutions

Primarily undergraduate institutions (PUIs) are home to many SICB members, and their inclusion is important to the Mission of SICB. Despite their substantial involvement in the society, PUI faculty tend to have very different professional responsibilities and priorities compared to large research institutions. There is a common misconception that all PUI faculty exclusively teach, with primary research contributions related to teaching or pedagogy, but we show that PUIs are important places for high-impact integrative research, student mentoring, community service, and fulfilling collaborations. This interactive poster will describe the diversity of PUI institutions and their faculty, as well as allow interested individuals to ask questions about what it means to work at a PUI. We especially encourage graduate students and postdocs interested in working at a PUI to explore this poster and talk with the presenters. We will serve as a focus point to build community and advertise PUI presentations at the meeting.

128 Jacob Hutton

Environmental Thermal and Hydrological Variation: Examining Temporal Treefrog Population Dynamics

Globally, amphibians continue to decline more rapidly than any other vertebrate group. Habitat loss, disease, and climate change are often cited as the major drivers of their decline. Local climatic factors such as temperature, rainfall, and humidity are often seasonally or temporally dynamic, resulting in variable conditions that require amphibians to utilize behaviorally, morphologically, and or physiologically-selected traits. However, as shifts in historical thermal and hydrologic regimes continue to increase in both severity and frequency as a result of climate change, researchers must examine the real-world ability of amphibians to respond to these pressures. Here, we estimate the occupancy, detection, abundance, movement, survival, and body condition/growth of a treefrog community in response to temporal shifts in localized climatic and environmental conditions. We investigate the potential capacity of treefrogs to cope with temporal thermal, hydrologic, and environmental pressures along the aquatic-terrestrial ecotone of a bottomland hardwood wetland in Southern Illinois by conducting capture-mark-recapture surveys. Temporal environmental parameters and hourly measurements of localized temperatures will allow for the examination of shifts in conditions and their influence on treefrog population dynamics. We present our estimates within a robust Bayesian framework, incorporating multiple capture occasions to assume both open and closed population conditions. This study emphasizes the importance of attempting to understand how continued shifts in climatic pressures may further influence the decline of amphibian populations.

739 Tran Huynh, AJ Feldman, Christina Cota

Regulation of mitotic FGF receptor degradation during heart development in Ciona robusta

Cyclin-dependent kinase 1 (CDK1) is a highly conserved serine/threonine kinase that plays a critical role in controlling cell division1. In the tunicate, Ciona robusta, active CDK1 prevents degradation of Fibroblast Growth Factor Receptors (FGFRs) responsible for cardiac cell induction during asymmetric pre-cardiac founder cell division2. However, the precise mechanism by which CDK1 controls mitotic FGFR degradation remains unknown. During mitosis, CDK1 phosphorylates Rab4, a GTPase required for the fusion of endosomal membranes with the plasma membrane during membrane recycling2,3. Analysis of the amino acid sequences in other Rab-family GTPases revealed a putative CDK1 phosphorylation site in Rab7, a protein required for the fusion of late endosomes with lysosomes. We hypothesize that CDK1 inhibits mitotic FGFR degradation by phosphorylating Rab7. Using site-directed mutagenesis, we mutated the predicted CDK1-phosphorylation site in Rab7 and generated a non-phosphorylatable, phospho-deficient Rab7 transgene (Mesp>Rab7S197A, Mesp>Rab7S197Q). To determine whether CDK1-mediated phosphorylation of Rab7 is necessary and sufficient to prevent mitotic FGFR degradation, we generated Ciona embryos expressing each of these Rab7 transgenes (Mesp>Rab7S197A, Mesp>Rab7S197Q and Mesp>Rab7S197D). Our results will provide critical insight into the mechanism underlying CDK1-mediated protein degradation in dividing cells. Literature Cited1. Freeman, S. et al. Biological Science. (Pearson, 2017).2. Cota, C. D. et al. PLoS Biology 19(1), e3001029 (2021). 3. van der Sluijs, P. et al. Cell 70, 729-740 (1992).

1674 Joonha Hwang, Daniel Soto, Daniel Goldman

Robotic collective structure formation in geometrically entangled soft matters

Biological collectives like ants and termites manipulate environmental soft materials (soil, twigs, leaf litter) to create 3D structures that suit the swarm's needs, despite no individual having knowledge of the global design. To discover principles by which groups perform such tasks we develop a robophysical swarm whose agents can individually manipulate soft materials to create simple structures. We use a model geometrically cohesive material (staples) which can form complex 3D structures. Further, we develop a scalable mudskipper-inspired robophysical model (length = 24cm, width and height = 16cm) capable of traversing the heterogeneous terrain formed during environmental manipulation. The robots can traverse 5cm tall obstacles and move at 12cm/s via a combination of limb, wheel, and tail actuation. The robots operate within a dark arena (length = 1.8m, width = 1.2m) in which light cues dictate different behaviors based on color and intensity. A single agent can transport ∼10% of the overall staple mound over 4 hours and create multiple piles at the deposition site. We aim to task these robots to remove material from an excavation site and use the acquired material to construct a complex formation in a deposition site one meter away. The behaviors we discover during structure formations will provide insight on the methods of collective construction in soft matter environments and develop hypotheses for how complex habitats emerge in biological collectives.

1464 Apolo Ibanez-Rincon, Alberto Castro, Faroz Mirza, Theodore Garland, Natalie Holt

Muscle-tendon unit morphology in HR mice selected for high levels of voluntary wheel running

Tendons, elastic tissues that connect muscles to bones, can act as springs during running. In cursorial mammals, longer tendons and shorter muscles are thought to have evolved to reduce muscle work, volume and metabolic cost. Here, we compared mice from four replicate High Runner (HR) lines that have been selectively bred for high levels of voluntary wheel running for over 90 generations, to those from four non-selected Control (C) lines. Hindlimbs were dissected and fixed with knee and ankle joints at 90 degrees. The triceps surae complex was weighed, and the muscle complex and Achilles tendon length measured. Soleus, plantaris, gastrocnemius muscles were isolated, weighed, and lengths measured. The gastrocnemius muscles were sectioned and imaged, and fiber length and pennation angle determined. Preliminary data show that HR mice have a lighter triceps surae complex than C mice (LS Means of 0.073 g and 0.131 g respectively), largely due to the mini-muscle phenotype found in two HR lines. HR mice also have a shorter triceps surae muscle complex than C mice (LS Means of 13.98 mm and 18.80 mm, respectively), and longer tendons (LS Means of 5.98 mm and 3.23 mm respectively). These results suggest evidence of the increase in tendon length, and reduction in muscle length, seen in cursorial species in an experimental evolution system. Supported by NSF grant IOS-2038528 to TG and NH.

1820 Ziad Ibbini, John Spicer, Manuela Truebano, John Bishop, Oliver Tills

HeartCV: a tool for transferrable, automated measurement of heart rate and heart rate variability in

Heart function is a key component of whole-organismal physiology. Bioimaging is commonly, but not exclusively, used for quantifying heart function in transparent individuals, including early developmental stages of aquatic animals, many of which are transparent. However, central limitations of many imaging-related methods is a lack of transferability between species, life-history stages and experimental approaches. Furthermore, locating the heart in mobile individuals remains challenging. Here, we present HeartCV: an open source Python package for automated measurement of heart rate and heart rate variability, that integrates automated localization and is transferrable across a wide range of species. We demonstrate the efficacy of HeartCV by validating it against manual measures for species with radically different heart morphologies: the sea squirt Ciona intestinalis, the snail Radix balthica and the prawn Palaemon serratus. Lastly, we illustrate the applicability of HeartCV to experiments of varying design to demonstrate the use/utility of the software in different experimental approaches and for different dataset types, such as those corresponding to longitudinal data.

177 Ipeknaz Icten, Bradley Davidson, C. J. Pickett

Comparative genomics of D. gegenbauri: The evolution of heart development in a polymorphic chordate

Tunicates, a diverse group of marine invertebrates, deploy highly conserved cell fate specification patterns and underlying gene regulatory networks (GRNs) despite millions of years of divergent evolution. Thaliaceans, such as Dolioletta gegenbauri, are unique amongst tunicates in their ability to drastically change their morphology over a multi-stage life cycle. The taxonomic classification of thaliaceans is a subject for debate and their ability to produce multiple distinct morphs remains a mystery. Heart development amongst tunicates is highly conserved; therefore, comparison of the cardiopharyngeal GRN of D. gegenbauri with other tunicate species can provide important insights into how this GRN has been rewired in association with the emergence of divergent traits. We identified the orthologs of transcription factors that play an essential role in tunicate heart development within the D. gegenbauri genome and transcriptome. We found that ETS1/2, a kemodulator of growth factor dependent fate specification in tunicates, is completely absent from the genome. Other D. gegenbauri heart transcription factors showed highest similarity to the ascidian Ciona robusta. These results suggest that major modifications in growth factor dependent fate specification may have potentiated divergent evolution in the doliolids and that the current taxonomic classification of thaliaceans might need to be revised. Our work provides a starting point for multi-scale analysis of evolution encompassing both gene network rewiring and redeployment of embryonic lineages associated with trait acquisition.

238 Masaya Iijima, Jim Darlington, Kent Vliet, Richard Blob

Terrestrial locomotion of American alligators across body size ranging three orders of magnitude

Larger terrestrial tetrapods must accommodate elevated mechanical demands on their limbs through some combination of changes in limb kinematics, kinetics and bone and soft tissue geometries and properties. Mammals are known to change limb posture across size, but there has been little evidence for size-dependent changes in limb posture among tetrapods with non-parasagittal limbs. Although our recent work showed that small juvenile American alligators use more crouched limb posture than larger juveniles, the scaling of limb kinematics throughout their entire ontogeny remained uncertain. To fill this gap, we examined limb kinematics in three adult American alligators, as they walked in a zoo enclosure. Compared to juveniles, adult alligators showed similar (or slightly greater) values of humerus and femur adduction, as well as elbow and knee flexion, during mid stance. The most striking difference for large adults was in the long axis rotation (lar) of the humerus and femur, where the humerus lar was smaller, and the femur lar was larger than that of juveniles. The potential relationship of increased adduction and increased lar for the femur does not follow expectations from previous studies, perhaps reflecting the unique origin of non-parasagittal limb kinematics in crocodylians. These results reveal how the largest living tetrapods with non-parasagittal limbs move on land, which would help clarify the evolution of limb kinematics and body size in tetrapods.

942 Aissam Ikmi

Muscular hydraulics drives larva-polyp morphogenesis

During development, organisms often experience changes in both form and behavior, which are typically connected. However, little is known about how organismal-scale behaviors such as body contractility and motility impact morphogenesis. Here, we use the cnidarian Nematostella vectensis as a developmental model to uncover a mechanistic link between organismal size, shape and behavior. Using quantitative live imaging, combined with molecular and biophysical experiments, we demonstrate that the muscular hydraulic machinery that controls body movement also drives larva-polyp morphogenesis. We show that organismal size largely depends on cavity inflation through fluid uptake, while body shape is constrained by the organization of the muscular system. Generation of ethograms identifies different trajectories of size and shape development in sessile and motile animals, which display distinct patterns of body contractions. With a simple theoretical model, we conceptualize how pressures generated by muscular hydraulics can act as a global mechanical regulator that impacts tissue remodeling. Altogether, our findings illuminate how early-branching metazoans harnessed the physics of hydraulics to link animal behaviors and morphogenesis.

1074 Natalie Imirzian, Fabian Plum, David Labonte

Investigating the foraging feedback loop in leaf-cutter ant colonies

Maintaining an ant colony of millions of individuals requires efficient coordination between workers in resource acquisition. In leaf-cutter ant colonies (Atta spp.), there is an additional step to this process, as resources gathered are not directly consumed by the ants. Instead, the ants gather leaves in order to sustain a fungal crop grown within the colony. To investigate how ants communicate different resource states and foragers flexibly adapt to changes, we developed a system of automated video capture of ant foraging behavior using deep learning and computer vision methods. In contrast to many previous studies on leaf-cutter ants that only look at foraging for set time intervals, we collect data over continuous time periods, and show how the foraging traffic fluctuates over time. Using the ant species Atta vollenweideri, we investigate how traffic flow relates to resource availability, and how quickly changes in leaf availability are communicated to the colony. The foraging dynamics of leaf-cutter ants show us how a society can function without centralized control, providing insight into behavioral adaptations that have allowed leaf-cutter ants to become dominant herbivores in the Neotropics.

1465 Jared Ingram, Matthew Fuxjager, Nigel Anderson, Doris Preininger, Madeline Ketner

Measures of visual acuity in male and female Asian common toads

Jared Ingram 1, Madeline Ketner 2, Nigel K Anderson 3, Matthew J Fuxjager 3, Doris Preininger 4 1 Dillard University 2 Eckart College 3 Department of Ecology, Evolution, and Organismal Biology, Brown University, Providence, RI 4 Vienna Zoo, Vienna, AustriaVisual acuity describes the spatial resolution of the visual system, and the eye´s ability to discriminate static detail at a particular distance. Many species' visual acuity is poorly understood, leaving a major gap in our knowledge about an important component of the visual system and motion detection across the tree of life. In this study, our goal was to test the visual acuity of adult male and female Asian common toads (Duttaphrynus melanostictus). We therefore tested the toad's optomotor response, an innate orienting behavior, by exposing them to rotating black and white stripes of decreasing widths (20 – 2.5 mm) in an optomotor drum. If toads perceived the moving stripes, they oriented their head and/or body in the direction of movement. By contrast, if toads lacked the visual acuity to detect the moving stripes, then they moved indiscriminately in the optomotor drum. We found that the highest spatial frequency eliciting tracking behavior in toads was 0.3 cycles per degree (minimum separable angle: 1.67°; stripe size 5mm). There was little evidence of a difference between males and females. Compared to the very.

1577 Kyndal Irwin, Caitlin Gabor

Role of diversity and environmental complexity on cognitive performance and behavior in mosquitofish

Environmental complexity and Shannon Diversity characterize the dynamic of ecological interactions. Variations in diversity and physical structure of a habitat can influence biological processes by mediating predator-prey interactions, as increasing diversity and structural complexity reduces prey capture rates and predator efficiency. Therefore, diversity and complexity may have profound effects on life history traits, behavior, and the ability to problem solve in live-bearing female Western Mosquitofish, Gambusia affinis. We assessed the relationship between habitat structure, problem-solving, motivation, and exploratory behavior across 9 populations of female G. affinis from streams varying in physical and biological dimensions of complexity. We used videos to capture the physical structure of each microhabitat to quantify complexity. Additionally, we measured Shannon Diversity for aquatic plants and vertebrates in the water and percent development surrounding the stream. Stream-bank stability was assessed using Multiple Indicator Monitoring technique for each habitat. We tested cognitive performance of G. affinis using a detour test (with an adult female as the goal) and measured latency to exit the start alley as an indication of exploratory behavior. We subsequently measured individual brood size as a measure of reproductive investment. Preliminary results suggest that cognitive problem-solving improves as diversity increases. The link between biodiversity and motivation is unclear but varied across populations. We predict that further analysis of habitat complexity and percent development will elucidate these findings.

785 Kota Ishikawa, Heng Wu, Satoshi Mitarai, Amatzia Genin

Differential responses of swimming reef fish and anchored garden eels to turbulence

Zooplanktivorous fish play an important role in trophically connecting pelagic and reef ecosystems through predation on their drifting prey. Thus, understanding their feeding responses to flow environments is of interest. Most fish swim to capture prey, while some fish, such as garden eels, forage while being anchored in burrow in the sediment. Various responses of fish to mean flow speed but not to turbulence have been investigated. Using a flume, we studied the effects of turbulence (weak, medium, and strong) and flow speeds (slow and fast) on the foraging movements and feeding success of both “free” fish and anchored eels. Feeding rates of the free fish significantly dropped under the combination of slow flow and strong turbulence where they significantly decreased the swimming area by 16%. A similar decline of feeding rate was observed for garden eels under the combination of the fast flow and strong turbulence where they slightly decreased the successful strike rate. Neither free fish nor eels showed significant effects of turbulence on strike parameters, such as strike distance and time. The findings suggest that fish with different feeding styles and habitats have their own optimized feeding strategies in response to turbulence.

178 Catherine Ivy, Christopher Guglielmo

Seasonal flexibility in the oxygen cascade of migratory songbirds

Migratory flight is an intensive exercise that requires birds to maintain high aerobic capacities for many hours or days. Maintaining O2 supply to flight muscles is therefore important during migration. Recently, radar studies have shown that songbirds and shorebirds will ascend to altitudes of 6,000 m during migratory flight where O2 is less readily available (hypoxia). Whether there are adaptations or seasonal plasticity along the O2 cascade that allow birds to fly at such altitudes during the migratory season is unknown. Here, we investigated seasonal plasticity at various steps along the O2 cascade (breathing, haematology, pectoralis muscle histology) in 6 songbirds (3 families) during migrating and wintering conditions. During migration, songbirds were observed to have greater hypoxia tolerance, a more effective breathing pattern for O2 uptake, and reductions in muscle fiber size that would enhance O2 and fuel diffusion into the muscle. Some species also exhibited changes in haemoglobin-O2 binding affinity, but these findings were not consistent between species or within families. Our findings show that songbirds exhibit seasonal plasticity along the O2 cascade which enhance O2 transport to tissues during migration that would be beneficial during high-altitude migratory flight.

1023 David Izquierdo, Mahaut Sorlin, Carolina Vargas, Shauna Odum, Gerard Beaudoin, Simon Lailvaux, Michele Johnson

Exercise-Induced Plasticity in Gray Matter Composition of Green Anole Lizard Brains

Exercise changes the vertebrate brain. In mammals, research has shown that increased performance activities increase the overall volume of the brain and the proportion of the brain that is composed of gray matter, regions related to muscle control, sensory perception, and cognition. Histologically, these regions are marked by a high concentration of neuronal cell bodies. Yet the extent to which exercise influences brain morphology in non-mammalian species is not clear. In this study, we trained green anole (Anolis carolinensis) lizards to be sprinters or endurance runners, while others remained in a control, unexercised group. We cryosectioned each brain (total $n = 99$), and stained tissues with thionin, a Nissl stain. Preliminary analysis indicates that a portion of the exercised lizards had brains with higher mass, and

examination of a subset of brains suggest that exercised lizards may exhibit more variation in gray matter than control lizards, although we have not yet determined whether there is a difference in gray matter composition among the experimental and control groups. This work will contribute to our understanding of how animal behavior contributes to plasticity in the brain, and whether these effects are consistent across vertebrate taxa.

994 PIOTR JABLONSKI, Jinseok Park, Jong-Yeol Moon, Hongsup Shin, Changku Kang, Jeongeol Park, Gylhyun Cho, Minyoung Son, Nicholas Strausfeld, Ronald Mumme, Hyungpil Moon, Sang-im Lee, Yuong-Nam Lee

Simple neural circuits in prey and large scale phenomena in predators: flush-pursue foraging

Prey escape responses can either result from complex cognitive processes involving full evaluation of the situation including the recognition of predator type, size, its approach direction and speed, or they can be mediated by simple neural circuits that code the intensity of looming and translational stimuli from approaching/attacking predators. The latter are susceptible to exploitation by flush-pursuers: the predators who visually flush the prey to subsequently capture it in aerial or terrestrial pursuits. I will argue that basic properties of these simple escape circuits in arthropod prey are sufficient to explain the origin of multiple independent evolutionary lineages of brightly colored avian flush pursuers, and their biogeographic variability in plumage coloration. The relative simplicity of the escape circuits combined with the theory of "rare enemies", which posits that some unique and relatively rare predators may be able to exploit antipredatory responses that protect prey from the majority of the predators in an ecological guild, are sufficient to explain not only the behavioral and morphological evolution but also the relatively low proportions of flush-pursuers in ecological guilds of avian insectivores worldwide. Finally, I will present evidence suggesting that the origin of dinosaurian proto-wings, which led to the evolution of bird wings and avian adaptive radiation, might have also been shaped by the simple escape circuits in prey of the hypothetical dinosaurian flush-pursuers.

642 John Jacisin, Antonio Meza, Tianyi Xu, Melissa Kemp

Interspecific and ecomorphological variation in the mandibular elements of Greater Antillean anoles.

Greater Antillean Anolis lizards are a natural replicate system for evaluating the structure and temporal stability of morphological diversification through adaptive radiation. Although developing methodological frameworks to include fossil elements is key to understanding organismal-environmental interactions over time, few methods applicable to both living and fossil Greater Antillean anoles have been established. To build one such framework, we investigated shape variation in the mandibular elements of extant Greater Antillean Anolis species using geometric morphometric methods (GMM). We selected the mandible because it is not fully integrated into an ecomorphological framework for anoles, but is expected to exhibit ecomorphological variation, and is commonly preserved as fossils. We examined the dentary, coronoid, and surangular bones individually and as whole mandibles in lingual and lateral orientations for 42 individuals representing 16 species from the Greater Antilles. ANOVAs indicated statistically significant shape variation in individual and combined elements for ecomorphs both between and within islands. Discriminant function analyses indicated that, while all individual elements showed some success in predicting ecomorphology, whole mandibles performed best overall in both lingual and lateral orientations; however, individual elements performed better in lingual orientation. Future work including more complete taxonomic representation from each island, 3D GMM, and additional cranial elements will improve our understanding of the long-term patterns and effects of environmental change and adaptive radiations in anoles.

454 Emma Jackson, John Carlson

Feeding Habits of Carcharhinus plumbeus, Off of the Southeast U.S Coast From 2006-2022

Sandbar sharks, Carcharhinus plumbeus, are apex predators that may structure marine communities through predation. Despite historic studies, there is no current quantitative data on the diet of sandbar sharks off the Southeast U.S. *coast*. This study describes the diet, highlighting changes in feeding habits, determining ontogenetic changes within the diet, and comparing this contemporary study with previous studies. From North Carolina to the Gulf of Mexico (GOM), 705 shark stomachs were obtained through the NOAA Fisheries Observer Program using bottom long line methods between 2006 and 2022. Of the 705, 258 were used for diet analysis, excluding empty and those with only bait as contents. In the two regions, there were 173 females and 85 males caught with similar numbers of juvenile and mature adults but females being more prevalent in both. Diet was assessed by life-stage and quantified using five indices: percent by number, percent by

weight, frequency of occurrence, the index of relative importance (IRI), and IRI expressed as a percent (%IRI) for prey categories and lower taxonomic classifications. The largest consumed prey item between age class, sex, and region were teleost followed by cephalopods according to their indices of relative importance (IRI). The survey of prey items ranks cephalopods of higher importance than previous studies. Ontogenetic shifts were not likely due to large juveniles and a lack of neonates within the region.

1323 Molly Jacobs, Lora Babb

U360: Training College Students as Real-World Sustainability Superheroes

U360 is an innovative, effective, and free year-long program that connects college students with small business owners to solve complicated, real-world sustainability challenges. College students across disciplines are frequently passionate about environmental sustainability, but lack the skills and resources to influence sustainability decisions in their communities. Although their collective environmental impact is large, small businesses are often overlooked in the environmental sustainability space because they are so numerous, and so diverse in scope, scale, location, and operations. Part course and part internship, U360 is a replicable model that provides intensive professional skills training to college students and then connects them directly with small business owners to discuss business challenges and sustainability, and to design sustainability plans. U360 is remarkably effective - students report increased professional confidence, skills and knowledge, leading to improved job prospects and career paths. Business owners, who typically agree to participate because they are motivated to help college students learn, frequently report positive changes to their sustainability practices as a result of their participation. We will present lessons learned from five years of U360, and share resources and information.

741 Nima Jadali, Margaret Zhang, Marieke Gartner, Josh Meyerchick, Jodi Carrigan, Joseph Mendelson, David Hu, Andrew Schulz

Improving Foraging Behavior using a Low-Cost DIY ForageFeeder

Automated feeders have long been used for laboratory animals, livestock, and poultry. However, animals such as western lowland gorillas (gorilla gorilla gorilla) are fed manually since their food items, which are cut vegetables and fruits, cannot be dispensed by commercial automated feeders. Feeding at a set time and location decreases the ability for natural foraging behavior in gorillas and reduces the amount of exercise and enrichment that accompanies foraging. Thus, there is a need for an inexpensive device to help animals like gorilla's forage more naturally. We report the results of an experimental study in which we designed and built ForageFeeder, an automated gorilla feeder that spreads food at random locations and times throughout the day. The feeder introduces a different type of food distribution that can improve the foraging behaviors observed in captive gorillas. Using ethograms, we observed improvements in observed foraging behaviors which are correlated with more gradual energy intake throughout the day. The ForageFeeder is also an open-source and easy to manufacture and modify device, making the feeder more accessible and usable for zoos. All the components of the device are easily sourced or manufactured. The assembly instructions, design files, and source code are publicly available online. The design presented here reduces manual labor for zoo staff and may be a useful tool for studies of animal ethology.

286 Anna James, Andrea Brenner, Alexandra Bentz

Predicting maternal testosterone allocation using environmental context and life-history traits

Hormone-mediated maternal effects are an important source of non-genetic phenotypic variation in which the mother transfers hormones to her offspring during prenatal development. For example, female birds can transfer the steroid hormone testosterone to their egg yolks, and this prenatal exposure to testosterone can ultimately impact offspring development and fitness. Past work has demonstrated that numerous environmental contexts affect the amount of testosterone a female will deposit in her yolks, including mate quality, competition, and stress; yet there are inconsistencies between studies, with many showing non-significant results. We identified over 100 studies that measured whether yolk testosterone levels differed significantly by an environmental context, and roughly half were non-significant. This variation may be due to environmental factors, female condition, or species-specific life history traits. Here, we will apply machine learning to determine which traits predict whether a significant maternal effect will occur. We are specifically testing if environmental contexts (e.g., stressors, competition, etc.) elicit variable flexibility in testosterone allocation or if life-history traits (e.g., coloniality, developmental mode, etc.) have exerted selection pressures that have shaped a female's ability to allocate testosterone. These findings will ultimately help us predict how avian species will respond to environmental changes and will increase our understanding of phenotypic plasticity in the context of maternal effects.

1803 Emmy James, Bhart-Anjan Bhullar, Martha Munoz, Henry Camarillo

Lunging as a Possible Compensatory Mechanism for Muscle-Powered Feeders within Plethodontidae

Lungless salamanders (Family: Plethodontidae) are a group of terrestrial amphibians that largely rely on tongue prehension for feeding. Of the two known types of tongue prehension within Plethodontidae, muscle-powered feeding conveys much less force than its counterpart, spring-powered feeding. In the latter, more powerful form of prey capture, elastic energy is stored in the muscles and released as the tongue is projected via a spring-like mechanism. Therefore, plethodontids that rely on muscle-powered feeding expend greater energy for a less forceful projection of the tongue than their spring-powered counterparts. Often associated with tongue prehension is a forward lunge, which may deliver a greater force to captured prey. However, the extent to which tongue prehension and lunging interact is generally unknown. How does lunging capacity vary between feeding types, and is lunging a compensatory mechanism for less-powerful tongue prehension? Here, CT scans of plethodontid pectoral girdles are compared to determine individual species' degree of optimization for lunging. By comparing lunging capacity across Plethodontidae, we aim to uncover links between muscle-powered feeders and pectoral girdle morphology that is optimized for lunging.

1853 Tim James

Sex without sexes: understanding the evolution of mating systems in fungi

Fungi have evolved myriad ways of uniting gametes. Some of these patterns involve the fusion of larger gametes with smaller gametes (anisogamy), with the terms male and female applied to the gametes. Yet, in essentially all fungal systems there are no biological sexes because individuals either 1) produce both types (large and small) of gametes, or 2) produce gametes that are compatible but morphologically identical (isogamy). For this reason, the term mating types is preferred over sexes, and only individuals of differing mating type can mate (homoallelic incompatibility). In anisogamous fungal species, there is scant evidence that there are more than two mating types, and this appears to be because mating types often play a role in determining the inheritance of cytoplasmic genomes. However, when cytoplasm is not mixed during mating, but instead, the nuclei are exchanged reciprocally between partners, as in mushroom fungi, species may evolve a large number of mating types which will lead to individuals being able to successfully mate with the majority of other individuals within the population. Moreover, after mating in most filamentous fungi, the nuclei of the two mating types exist separately but not fused, a dikaryotic cell type that facilitates both future separation of remated partners as well as the formation of unstable mosaic genotypes comprised of three or more individuals. The evolution of extreme mating type diversity comes with the price that selfish behavior may evolve through the rise of mating types that display false signals of fitness or that fail to participate equally in growth and cellular functions. In summary, contrast between fungi and organisms with sexes provides critical insights into the relationship between individualism, sexual identity, and the process of finding a mate.

512 Jerrica Jamison, Kenneth Welch

Sugar Transporter Evolution in Bats Specializing in High Sugar Diets

For most mammals, consuming large quantities of sugar leads to cardiovascular and metabolic diseases. However, there are species of mammal that ingest immense amounts of sugar as a part of a specialized frugivorous or nectivorous diet. Particularly, bats evolved both frugivory and nectivory multiple times independently, which makes them an excellent system to study the challenges associated with high sugar diets. One such struggle for a mammalian system is the ability to rapidly transport vast quantities of sugar into tissues quickly for catabolism. Sugar movement into and out of mammalian cells is handled by the highly conserved and diverse GLUT family of transporters. We used molecular evolution analyses to examine the evolution of several of the most biologically important GLUT sugar transporters across the independent evolutions of high sugar diets in bats. We can associate specific types of dietary transitions with evolution in individual transporters and identified positive selection acting on amino acids known to be key in the movement of sugar across cell membranes in frugivorous and nectivorous bat species. Evolution in the GLUT transporters, therefore, represent a critical adaptation that facilitates the specialization of frugivorous and nectivorous bats.

566 Madison Janakis, Daniel Speiser

Comparative visual ecology of two sympatric crabs from tidal creeks

Visual signaling is particularly challenging in some environments due to dynamic light conditions. Tidal creeks, for example, frequently experience high turbidity due to shifting tides and local weather conditions. Light scattering increases as turbidity increases, reducing sighting distance. Furthermore, these waters are often spectrally narrow, decreasing contrast of color signals. How have animals in tidal creeks adapted to the demands of their dynamic visual environments? Both green porcelain crabs, Petrolisthes armatus, and black-fingered mud crabs, Panopeus herbstii, inhabit the same tidal creeks. Their similar body plans reflect convergent evolution as their lineages diverged over 200 mya. To study their visual systems, we employed two methods: electroretinography (ERG) and optomotor behavioral experiments. Using achromatic optomotor stimuli (black and white stripes), we found porcelain crabs exhibit a spatial resolution between 4 and 10°. Additionally, we used polarized optomotor (perpendicularly arranged linear polarized filter) to test polarization sensitivity. We found porcelain crabs do not reliably follow polarized stimuli, but mud crabs appear to. Using ERG, we found the compound eyes of P. armatus demonstrate broad spectral responses consistent with at least two spectral classes of photoreceptors. Present results suggest porcelain crabs and mud crabs have distinct adaptations to tidal creek environments. We anticipate porcelain crabs may forgo polarization sensitivity in favor of color perception while mud crabs do the opposite.

676 Aubrey Jane, Doug Rasher, Eric Annis, Jesica Waller, Markus Frederich

Ontogenetic shifts in thermal tolerance of the American lobster (Homarus americanus)

The American lobster is an ecologically and economically important species in the Gulf of Maine. Climate change is reshaping its biogeography; therefore, understanding the physiology of this species is required to predict future range shifts. While the thermal tolerance of adult lobsters is well studied, thermal tolerances of the earliest developmental stages remain understudied, and previous research has used only lab-reared larvae. We reared lobsters up to stage IV and exposed them to acute (4°C-32°C) or chronic (8°C-26°C) temperature treatments in each stage. Post-larvae were also caught in the wild to allow for comparisons between lab-reared larvae and natural populations. Critical temperatures, defined by a complete lack of scope for activity after acute (20-minute) exposure, were reached at 4 and 32°C in stages I and II; 8 and 32°C in stage III, and 8 and 26°C in stage IV. Wild stage IV lobsters reached critical temperatures at 4°C and 32°C. These ontogenetic shifts in thermal tolerance, as well as the discrepancy between lab and wild lobsters, were corroborated by chronic exposure assays and molecular data. The reduced thermal tolerance of lab-reared larvae suggests an important limitation in our current knowledge of the thermal tolerance of larval stages. Such results have important implications for understanding the drivers of settlement patterns, and therefore species distribution in a changing climate.

1082 Judith Janisch, Jesse Young, Nicole Schapker, Noah Dunham, Allison McNamara, Lydia Myers, Liza Shapiro, Taylor Phelps

Substrate-related variation in limb joint kinematics in wild primates

Arboreal locomotion is precarious and places multiple challenges upon stability when moving over narrow, compliant, angled, and disparate supports. Previous research has shown that captive primates often respond to narrower and steeper supports by flexing limb joints (thereby lowering the center of mass) and adopting a compliant gait, marked by increased proximal joint excursions and increased yield at distal joints (thereby flattening the center of mass trajectory). We tested if these strategies are also adopted by wild primates – including platyrrhines, catarrhines and strepsirrhines – freely ranging over a variety of supports in their natural habitats. We used ImageJ to measure the angular kinematics of forelimb and hindlimb joints from high-speed videos of quadrupedal locomotion on a variety of arboreal supports. Spearman rank order correlations were used to test for associations between joint posture and support diameter/inclination (measured using a forestry-grade rangefinder). Preliminary results partially confirm previous kinematic studies of captive primates and suggest that variation in support orientation, rather than diameter per se, may exert a stronger influence on quadrupedal gait kinematics in primates moving in natural environments.

1160 Judith Janisch, Leonida Fusani, Cliodhna Quigley, Elisa Perinot

Variability in courtship movements influences mating success in golden-collared manakins

Differences between individuals can have a great impact on mate choice or male-male competition and are often selected for. In this study, we investigated individual variability in courtship movements of the lekking male golden-collared manakins when displaying in their courtship arenas to attract females and to

understand if these traits are subject to female choice. We recorded male manakins with a 3D motion capture system in their natural habitat and used an automated tracking software to derive new courtship parameters such as take-off height, take-off velocity, and take-off angles from fitted parabolas of their jumps. When looked at independently, take-off height and take-off velocity seem to be important factors for mating success. Correlation analysis showed that successful males generally displayed higher on the saplings within their court and jumped more in their displays. This suggests that males with higher courtship success, and therefore often joined by females in their courtship arena, might adapt their jumping routine to females for better alignment with them during a duo-dance. Finally, the higher number of jumps performed during a display routine is in line with female choice for male vigour and endurance.

451 Mark Jankauski, Avery Russell, Stephen Buchmann

Buzzing Bees and Bending Flowers: Investigating the Mechanics of Buzz Pollination

Approximately 10% of flowering plants house their pollen within specialized tube-like structures called poricidal anthers. Bees extract pollen from poricidal anthers through buzz pollination (also floral buzzing), a behavior where the bee vibrates the anther by rapidly contracting its flight muscles. The efficacy pollen extraction relies on the vibratory forces produced by the bee as well as the structural mechanics of the anther. To better understand the mechanics of buzz pollination, we devised an experiment to measure the directional, time-resolved forces produced by defensively buzzing carpenter bees. The largest forces occurred within a plane formed by the bee's indirect flight muscles and exceeded the bee's weight by 80 times. Force magnitude was positively correlated with the vibration velocity of the deforming thorax. Then, to determine how these forces would influence anther vibration, we developed a finite element model of a Solanum elaeagnifolium stamen. The model accurately predicted experimentally measured natural frequencies and vibration mode shapes. The model also showed that, when the mass of insect was considered, stamen natural frequencies fell within the reported range of floral buzzing frequencies. To excite these natural frequencies, bees should force the anther in the axial-normal direction, which is consistent forcing directions measured in carpenter bees. Together, these studies suggest that bees leverage vibration amplification to enhance anther deformation, and consequently pollen expulsion.

1528 Kaushik Jayaram, William McDonnell, Walter Gililland, Heiko Kabutz, Hari Krishna Hari-Prasad

Integrated and Distributed Mechanosensing for Robust Locomotion

In order to achieve animal like performance in natural environments, robots must overcome their lack of robustness, i.e., the ability for persistent behaviors in the presence of disturbances. Towards achieving this goal, our group's research aims to translate the sensorimotor convergence principle related to the design, encoding and feedback of distributed mechanosensors, ubiquitous across animals, into robotic systems in order to increase their agility and robustness of locomotion in natural environments and thereby, accelerate the integration of autonomous robots into real-world tasks and operations. As a first step in this direction, we discuss our work on design, fabrication and integration of biologically inspired mechanosensors (campaniform and slit sensillae) into insect-scale robots.

1651 Jen Jelincic, Danielle Dillon, C. Loren Buck, Kathleen Hunt

Multi-year patterns of DHEA and glucocorticoids in >50-year-old bowhead whale baleen

Baleen powder has been previously shown as a viable technique to study stress and reproduction in large, Mysticeti whales. Steroid hormones are deposited into the baleen's keratin matrix in such a way that allows for multi-year study of single individuals. Several steroid hormones have been validated in bowhead whales (Balaena mysticetus), and here for the first time in baleen an additional adrenal hormone, dehydroepiandrosterone (DHEA), that will complement other baleen hormone data. An enzyme immunoassay (EIA; Arbor Assays) from pooled baleen powder indicated 79 pg/mg of DHEA. The extracted hormone was parallel to the standard curve ($p = 0.8533$). Following the validation of the DHEA EIA, we evaluated adrenal hormones (corticosterone, cortisol, DHEA) in five juvenile bowhead whales, and plotted the resulting data. Each whale was sampled 15-43 times along the length of the baleen plate, which may represent hormone concentrations from the entire life of the whale, up to 20 years of data. The function of DHEA has been debated since its isolation in the 1930's, from anti-aging, performance enhancing, metabolism, immune function, reproduction, allostasis, and chronic stress. Ultimately, DHEA is a multifunctional hormone that, when evaluated in conjunction with other hormones, may be used to evaluate developmental, environmental, biological, and social changes as well as serve as an

index marker for allostatic load in whales and other mammals.

629 Caitlyn Jencarelli, John Hranitz, Thomas Klinger

Paracentrotus lividus in the Gulf of Kalloni may represent a thermotolerant ecotype

As oceans warm, the ability to tolerate elevated sea surface temperatures is crucial to survival. The purple sea urchin, Paracentrotus lividus, in the Gulf of Kalloni, Lesvos, Greece may be an ecotype already functioning at the higher sea surface temperatures expected for the Northern Aegean Sea. There were no significant differences (ANOVA, $p>0.05$) in mean activity coefficients, nor in mean gonad and gut indices, between individuals collected in the Gulf and the adjacent open Aegean sea, indicating that P. lividus is functioning well in both the warmer and the cooler environments, respectively. However, the horizontal diameters (37.6 + 2.0 mm vs. 55.0 + 2.1 mm; all values represent mean + 1 SEM, for individuals from the Gulf of Kalloni, $n = 15$, vs. the adjacent Aegean Sea, $n = 20$, respectively), whole animal weights (49.5 + 1.4 g vs. 57.6 + 1.2 g) and relative height of the test (55.1 + 1.1% vs. 60.0 + 1.0%), as well as the relative length of the spines (45.8 + 2.0% vs. 33.9 + 1.0%), and relative weights of the Aristotle's lantern (3.1 + 0.2% vs. 4.7 + 0.2%), test (4.7 + 0.2% vs. 3.1 + 0.2%), and coelomic fluid (43.4 + 1.6% vs. 52.4 + 1.1%) were significantly different for P. lividus collected from the two locations. Ossicles from sea urchins in the Gulf.

1244 Kelsey Jennings

LGBTQ+ People in the Outdoors: Insights and Gaps

LGBTQ+ (hereby: queer) identities in the United States have risen dramatically over the past decade but research with queer communities has not followed. We examined current literature on queer people in outdoor and nature-based recreation and careers and found recurring themes of negative experiences like exclusivity, or the outdoors feeling unwelcoming, and behavior modification, or queer folks changing their behavior to not be recognized as queer. However, we also found a considerable theme of nature as healing, where queer participants felt they could be their full selves in nature. We also identified some apparent gaps. There needs to be more research on how queer people are engaging in outdoor and nature-based recreation and careers. All of the examined papers were based on qualitative interviews, so it is also necessary to implement mixed-method studies that gather more generalizable quantitative data. Research must also examine specific limitations and motivations for queer recreationists and professionals to help develop effective programs, policies, and procedures to ensure full inclusion. Future research needs to examine LGBTQ+ people both intentionally and through a community lens. Queer recreationists and professionals are frequently mentioned as an afterthought or emerging community group as opposed to the diverse and long-lasting group that they are. With further understanding, we can begin to address barriers and support motivations that make the outdoors safe and inclusive for LGBTQ+ people.

108 Paul Jerem, Michaela Hau, L. Michael Romero

Body surface temperature as a biomarker of sympathetic nervous system activation during acute stress

Characteristics of body surface temperature (BST) dynamics during acute physiological stress are thought to reflect hypothalamic-pituitary-adrenal (HPA) axis activity. Consequently, measurement of BST using infrared thermal imaging is increasingly promoted as a novel method for inferring acute stress. However, the rapid BST fluctuations during acute stress suggests they likely also track 'fight-or-flight' sympathetic-medullary-adrenal system activation, potentially offering valuable opportunities to non-invasively assess the autonomic stress response. To explore this possibility, we compared BST measured using thermal imaging with heart-rate variability – a measure of sympathetic/parasympathetic dominance – in captive house sparrows during acute stress. We then made multiple additional comparisons within the same individual, each time pharmacologically blocking or stimulating a different stress system component, to investigate the specific mechanisms driving acute stress-related BST changes. We examined autonomic pathways by selectively blocking alpha and beta adrenergic reception, and we evaluated HPA axis involvement by stimulating maximal glucocorticoid secretion with exogenous ACTH and blocking glucocorticoid receptors with RU486. We predicted BST variation during acute stress would correspond to changes in heart-rate variability, and that autonomic mechanisms would have a greater influence over short term BST variation than those relating to the HPA axis. Our results will provide critical information for the reliable physiological interpretation of BST measurements made during acute stress, and the development of thermal imaging as a technique for assessing sympathetic activation.

1776 Paul Jerem, Judith Smit, Andrew Cronin, Peter Moran, Wouter Halfwerk

Interactive phenotypes as a novel tool to study signal evolution under field conditions

Documenting signal evolution over many generations is central in understanding if and how species can adapt to, for example, human modified environments, but in practice often takes a long time for most vertebrate systems. We therefore developed a fully interactive playback setup, which combined with quantitative genetics of behavioral traits, allowed us to carry out experimental evolution with artificial phenotypes.We focus on the model species the túngara frog, in which the reproductive success is determined by both attracted female frogs as well as by predatory bats. Our set-up broadcasts artificial calls created to match variation in urban and forest populations, and using AI object recognition, detects attracted frogs and bats, allowing us to assign fitness values to different acoustic phenotypes. Our phenotypes are able to respond in real time to the detected frogs by increasing signaling effort or, in case of a bat, by ceasing to call, thus realistic mimicking real field conditions. Combining fitness scores with heritability estimates of different behavioral traits to determine its contribution to the next generation finally provides us phenotypes for the next generation(s).We show that, when employed under different environmental conditions, our tool can document how signals respond within and across generations to divergent natural and sexual selection pressures, and thus provides novel experimental options to study both proximate and ultimate processes related to signal evolution.

870 Yordano Jimenez, Janne Pfeiffenberger, Gina Kim, Erik Anderson, Eric Tytell

Linking body mechanics and swimming kinematics of scup, Stenotomus chrysops

Fish swim using deceptively simple undulations that emerge from complex interactions between internal body forces and external fluid forces. The same swimming muscles that generate bending torques for locomotion simultaneously change body stiffness, altering fluid-body interactions that could impact the acceleration, speed, and stability of swimming. Therefore, quantifying how fish change body stiffness is key to understanding their locomotor performance. Using scup (Stenotomus chrysops), we measured swimming kinematics at different swimming speeds in a flow tank and then measured passive and active body stiffness on the same individuals. Euthanized fish were mounted in an oscillatory bending apparatus in which tail flexion was controlled with a servomotor on one end and bending forces were measured with a force transducer on the other end. We stimulated red muscle and bent the body to match in vivo kinematic and muscle activation patterns. Our kinematic data show that scup, like most fishes, increase tailbeat frequency but not tailbeat amplitude as swimming speed increases. Our bender data show that, when tailbeat frequency is increased and bending amplitude is held constant, active body stiffness generally changes with a U- or bell-shaped curve, depending on the amplitude. These results suggest body stiffness changes non-linearly with swimming speed and demonstrate how muscle can contribute to locomotor performance by both producing movement and modulating body stiffness.

533 Anna Jirik, Katrina White, Makenzie Reed, Anthony Hinders, Shanna Barber, Calvin Dirickson, Devaleena Pradhan

Evaluating the spectrum of protandrous sex change in the hermaphroditic fish Lythrypnus dalli

Sexually plastic teleost fish respond to changes in their social environment to increase reproductive success. Lythrypnus dalli exhibit bidirectional sex change in adulthood based on status within their social group. A stable hierarchy consists of one dominant male and subordinate females. The male maintains a nesting territory and provides parental care while females solicit invitations into the nest for spawning. To date, there are few studies that give an in-depth analysis of protandrous (male first) sex change in L. dalli. To study this phenomenon, we assembled groups of two males and one female. We hypothesized that the second-largest, second most dominant fish would transition from a male into a female. We tracked hierarchy formation, and within one week, social statuses of all fish were established. We examined behavioral, hormonal, and morphological changes throughout the next four weeks. In the transitioning fish, female-associated behaviors increased with concurrent submission to the male and dominance over the female. Thus, this fish emerged as the alpha female by the end of the experiment. During transition, the genital papilla underwent morphogenesis from being long and pointy for the release of sperm to rounded/flattened for the release of eggs. Currently, we are examining whether changes in systemic sex steroids can explain emergence of these external phenotypes. These findings will provide us insight into the process of feminization at an organismal level.

902 Elizabeth Jockusch, Christopher Evelyn

Evolutionary correlates of elongation in plethodontid salamanders

Evolution of an elongate body form has occurred frequently in tetrapods. For example, among squamate reptiles, elongation is inferred to have evolved >70 times. This major change in body shape has organism-wide consequences, with morphological, physiological, behavioral, reproductive, ecological, and other traits also evolving convergently. Among amphibians, elongation is ancestral for caecilians and evolved repeatedly in salamanders. The most species-rich family of salamanders, the Plethodontidae, shows a high degree of variation in body shape. Here we evaluate organism-wide consequences of elongation in this clade. There are at least five independently-evolved lineages of elongate, limb-reduced, fossorial salamanders in the family Plethodontidae, three of which have undergone subsequent diversification. We identify several traits, including reproductive output and limb morphology, with evolutionary patterns that appear to differ from those in other elongate taxa. Elongate Batrachoseps achieve proportionately larger clutch volumes than their less elongate relatives, which is opposite the pattern observed in elongate lizards. Perhaps the most common morphological correlate of body elongation is limb reduction. At the extreme, this has resulted in the complete loss of external limbs in caecilians and squamates. However, all elongate plethodontids retain their limbs. We consider both internalist and externalist explanations for these differences in organism-level consequences of elongation. We conclude with a novel, testable hypothesis for why limbless plethodontids are a 'missing form' in the tree of life.

240 Sönke Johnsen, Eleanor Caves, Tracey Sutton

Grandma, what big pixels you have: optimal visual acuity in marine fish and sharks

All eyes have to balance spatial resolution and sensitivity. An eye with large pixels will be sensitive but provide coarse vision; an eye with small pixels will render fine detail but may not be sensitive enough. This balance is particularly critical in animals that operate in light-limited environments such as the deep ocean. Depending on the size and contrast of what is being looked at, and the ambient light level and turbidity, there is an optimal visual acuity that maximizes information transfer. We developed a theory that predicts this optimal acuity for looking at patterned objects in the ocean, and then compared it to a newly collated database on visual acuity in fish and sharks found at different depths in different water types. This analysis showed that epipelagic and upper mesopelagic species fit the model well, but lower mesopelagic fish (>500 m depth) had significantly higher acuity than predicted. This latter result is consistent with the theory that animals founder deeper than 500 meters operate in a visual world of point sources of bioluminescence, where high visual acuity is advantageous. Overall, the results suggest that the eyes of fish and sharks at all depths are maximizing information transfer.

367 Soren Johnson, Kyle Piller

Clarifying the taxonomy of the Blacktail Shiner (Leuciscidae: Cyprinella venusta) using genomic data

Early designations of subspecies were often based on differences in morphological features without considering evolutionary history. However, these designations can often be incongruent with phylogenetic studies based on molecular data. One species with incongruence between subspecies and molecular phylogenies is the Blacktail Shiner (Cyprinella venusta). This species of fish is abundant in riverine environments throughout the southeastern United States. Currently there are three recognized subspecies based on morphology: C. v. venusta, C. v. cercostigma, and C. v. stigmatura. The validity of these subspecies has been challenged by phylogenetic studies using mitochondrial DNA. To help clarify these taxonomic issues, we used high-throughput sequencing, specifically double digest restriction-site associated DNA sequencing (ddRADseq), to produce single nucleotide polymorphism data (SNP). These data were then used to infer a phylogeny and analyze the genetic population structure across the range for C. venusta. The inferred clades and identified genetic clusters from the population analysis generally aligned with one another and were not congruent with the subspecies designations. Based on our data there appear to be multiple distinct lineages in what is currently recognized as C. venusta, none of which align with the subspecies. This study further displays the usefulness of genomic data to help address taxonomic issues.

413 Erik Johnson

Asymmetrical Genitalia in Livebearing Fishes

The evolution of a bilaterally symmetrical body plan is considered a key breakthrough in the evolutionary history of many extant species. Bilateral symmetry comes with many advantages related to locomotion, foraging and sensory traits. However, in many instances, bilateral symmetry is often accompanied by morphological traits that exhibit asymmetries. Although these asymmetries are prevalent in nearly all bilaterally symmetric groups, little is known about these traits. Our work aims to explore asymmetric traits, the reasons they evolve, and their relationship to other traits such as behavior. We use livebearing fish (or fish that exhibit internal fertilization and give birth to live young) to address these questions. This system contains species with asymmetric genitalia as well as those with symmetric genitalia. These genitalia serve as an ideal system for exploring our questions and provide us insight into why asymmetries evolve and how they connect to behavior or other traits.

426 Erynn Johnson, Nimran Shergill, Madhusudhan Venkadesan, Derek Briggs

Specialized shell-peeling morphologies are advantageous to durophagous crabs

Most fossil evidence of durophagous predation on mollusks comes from repair scars. Therefore, the evolution of durophagy is largely understood through evidence of predator failure rather than success. This bias affects the understanding of hundreds of millions of years of evolutionary interactions between predators and their prey. One group of durophages with highly specialized predatory morphologies are shell-peeling crabs, whose peeling morphology dates back to the Cretaceous. We seek to understand how the biomechanics of shell peeling influenced the evolution of mollusk shell morphologies and elucidate the underlying ecological circumstances. To mitigate limitations of the fossil record, we conducted live feeding experiments and compared the capabilities of the peeling crab, Calappa flammea, with the whole-body crushing crab, Menippe mercenaria. We found differences between the two taxa in prey manipulation techniques, handling times, and prey-size limitations. C. flammea initiated shell breakage in gastropods faster than M. mercenaria and relied on peeling almost exclusively, whereas M. mercenaria was slow to break shells and exhibited multiple predation strategies. C. flammea could also peel many different sized gastropod shells. When successful, mean handling time for bivalves was similar for both crab taxa; however, C. flammea was unsuccessful in about 40% of attempts of bivalve predation. Our results demonstrate potential predatory benefits such as greater speed and fewer prey size limitations when peeling gastropod shells rather than crushing them whole.

682 Lauren Johnson, Donald Miles

Revisiting the Ecological Consequences of Foraging Mode: A Cerebral Perspective

A central goal of evolutionary biology is to identify and understand processes that generate diversity. The vertebrate brain is highly conserved functionally but displays incredible variety in size and shape across taxa and even among closely related species. As a master regulator, the brain controls all aspects of animal behavior and ecology. Therefore, any change in brain structure is likely associated with new behaviors and ecologies, which could facilitate niche expansion and speciation. Lizards are morphologically and ecologically diverse, making them an ideal system for exploring these questions. Foraging mode is of particular interest because of its apparent impact on several aspects of lizard ecology and evolution, including body shape, endurance, and metabolic capacity. Different foraging modes have also evolved multiple times across taxa. In this study, we extracted brain shape and size information from 3-dimensional coordinate data of 29 lizard species from across the globe. We investigated whether differences in foraging modes explain variation in brain morphology. Active foragers primarily use their olfactory system when foraging, while ambush foragers rely mainly on vision. Indeed, we found that active forages have thick and relatively short olfactory bulbs, while ambush forages have incredibly narrow and elongated olfactory bulbs. These results suggest that similar brain shapes have evolved repeatedly in species with similar foraging behaviors.

1723 Meredith Johnson, Jon Harrison

Which abiotic factor limits the flight activity of the Sonoran Desert digger bee?

Desert animals balance both heat and dehydration; evaporative heat loss helps avoid overheating but exacerbates water stress. Smaller animals appear particularly vulnerable to water stress, but it is unclear whether dehydration is a more serious challenge for small animals than heat for desert-adapted animals. Males of the Sonoran Desert digger bee, Centris caesalpiniae, are small and near-continuously fly during some of the hottest and driest weeks of year. Activity continues from sunrise to midday when air temperatures reach 40°C with 10% relative humidity. Using a heat budget model, we showed that whole-body convective conductances increased several-fold through the morning, and that the abdominal variable-convector is the primary mechanism of thoracic thermoregulation. Critical thermal maxima for these bees are at least 5°C higher than body temperatures measured in the field and did not differ from other measured bees. Water loss rates weakly increased with air and body temperature, indicating that active evaporative heat loss is not a major mechanism of thermoregulation. This is likely because water loss rates are so high that approximately 17% of body water is lost per hour. Adding to the water stress, male C. caesalpiniae did not drink or forage on nectar before or during mating activity. We conclude that water, not heat stress, is the major abiotic factor challenging activity for this desert bee, and likely many small animals.

404 Rocky Johnston, Timothy Judd

Effect of photoperiodic temperature changes on the initiation of diapause in bivoltine trap-nesting

Trap-nesting wasps are solitary and provision their young by creating a series of chambers in holes in wood. Each chamber holds a single offspring and the food it will need to survive until it reaches adult-hood. Trap-nesting wasps in Missouri are bivoltine, the summer generation does not go through diapause while the fall generation does. The cues that are used by developing individuals to determine if they will enter diapause or not have yet to be determined. One possible cue is the fluctuation in ambient temperature that corresponds to photoperiod. Individuals collected as eggs from the fall generation of Euodynerus foraminatus and E. schwarzi were subjected to one of three conditions: daily temperature changes that correspond to either fall or summer photoperiods or no daily temperature change. Based on the results, there is no effect of temperature on the eclosion of individuals.

351 Aubree Jones, Matthew O'Donnell, Amy Regish, Jacqueline Webb

Rearing Temperature Affects the Development of the Lateral Line System in Brook Trout

Larval period duration varies with temperature in salmonids. This is likely to have implications for sensory system development. The neuromast receptor organs of the mechanosensory lateral line system (LL) detect local water flows that mediate critical behaviors (e.g., predator avoidance, prey detection). In larval fishes, neuromasts increase in number throughout ontogeny and then either enclose in bony canals (canal neuromasts) or remain on the skin (superficial neuromasts). In this study, we compared the rate of development of the canals and neuromasts of the cranial LL in brook trout (Salvelinus fontinalis) raised at three temperatures: the temperature regime of a long-term study stream (+0oC), and fish reared at +2oC and +4oC. The number of canal and superficial neuromasts were not significantly affected by temperature. Similarly, superficial neuromast size was not affected, but canal neuromasts were larger in trout reared at higher temperatures. In addition, trout reared at +4oC reached life history events (e.g., "swim up") and advanced stages of canal morphogenesis at an earlier age than +2 or +0 trout. These changes in developmental timing may have consequences for feeding (e.g., mismatch of onset of LL-mediated exogenous feeding and emergence of prey) in addition to increased energetic demands to sustain faster growth and development at higher temperatures. These effects could have serious implications for the behavior, ecology, and survival of this iconic cold-water species.

353 Aubree Jones, Kevin Conway, Jacqueline Webb

Silverjaw Minnow Lateral Line Development: Regional Specialization for Benthic Prey Detection?

The neuromast receptor organs of the mechanosensory lateral line system (LL) of fishes detect local water flows (e.g., for prey detection). In larval fishes, neuromasts increase in number and then either become enclosed in bony canals (CNs, canal neuromasts) or remain on the skin (SNs, superficial neuromasts). One of five LL cranial canal phenotypes is typically found in a species, but the silverjaw minnow (Notropis buccatus) has dorsal narrow canals and ventral widened canals on the head. We examined the development of this unusual LL morphology, which is thought to facilitate nocturnal benthic foraging, in an ontogenetic series (3-21.5 mm SL; hatch - juveniles) using multiple methods. The ventral widened canals enclose in smaller larvae ($\sim$10 mm SL) than the narrow dorsal canals (>20 mm SL). Prior to canal enclosure, the CNs in widened canals change in morphology, but do not diverge in size from those in narrow dorsal canals. Following canal enclosure, CNs in widened canals elongate across the canal floor. In addition, SNs below the eye and on the ventral side of the head, as well as taste buds on the lips and between SNs located over the widened canals, increase in number. This suggests that input from both CNs and SNs and perhaps multimodal input from the gustatory system mediate nocturnal benthic prey detection in this unusual North American minnow.

1255 Korin Jones, Myra Hughey, Lisa Belden

Bacterial colonization order on treefrog embryos impacts tadpole microbiome structure in tadpoles.

Priority effects, or impacts of colonization order, may have lasting influence on ecological community composition. The embryonic microbiome is subject to stochasticity in colonization order of bacteria. Stochasticity may be especially impactful for embryos developing in bacteria-rich environments, such as the embryos of many amphibians. To determine if priority effects experienced as embryos impacted bacterial community composition in newly hatched tadpoles, we selectively inoculated the embryos of lab-raised hourglass treefrogs, Dendropsophus ebraccatus, with bacteria initially isolated from the skin of wild, Panamanian D. ebraccatus adults over two days. First, embryos were inoculated with two bacteria in alternating sequences. Next, we evaluated the outcomes of priority effects in an in vitro co-culture assay absent of host factors. We then performed a second embryo experiment, inoculating embryos with one of three bacteria on the first day and a community of five focal bacteria on the second. Using 16S rRNA amplicon sequencing, we observed relative abundance shifts in tadpole bacteria communities due to priority effects. Our results suggest that the initial bacterial source pools of embryos shape bacterial communities at later life stages, however the magnitude of those changes is dependent on the host environment and the identity of bacterial colonists.

1702 Linden Jones, Thaddeus Gunther, Oliver Todreas, Andrew Mountcastle

Aerodynamic benefits of wing flexibility diminish with body size in Bombus impatiens bumblebees

As insect wings flap through the air tens to hundreds of times per second, they bend and twist in both the spanwise and chordwise directions. In some groups, including bumblebees, wing flexibility is enhanced by the presence of a highly elastic protein (resilin) embedded in flexible vein joints. Several years ago we developed an experimental technique to reversibly increase wing stiffness in live bees by splinting a single flexible vein joint, and we used this technique to discover that bees could generate greater vertical aerodynamic force with naturally flexible vs. artificially stiffened wings. However, it remained unknown whether and how the aerodynamic benefits of wing flexibility varied with body size. In this study we used an incremental load-lifting assay to investigate the effect of body size on vertical aerodynamic force capacity in Bombus impatiens bumblebees with both naturally flexible and artificially stiffened wings. We found that larger bees could lift a relatively smaller proportion of their body mass than smaller bees, and that the reduction in vertical force capacity, as a proportion of body mass, caused by splinting the wings was negatively correlated with body size. In short, larger bees benefit relatively less from wing flexibility than smaller bees. We also used high-speed videography to investigate and quantify the effect of the micro-splint on flapping wing kinematics.

1790 Julia Joos, Donald Miles

Thermal ecology and activity patterns of desert-living tortoises

Almost 50% of modern tortoise species are endangered or already extinct. The compact body plan of tortoises favors heat conservation compared to other terrestrial ectotherm vertebrates, potentially increasing risk of overheating. Desert-dwelling tortoises dig burrows or seek refuge in rock crevices to avoid the heat. However, tortoise habitat in arid environments is increasing in temperature and prolonged drought reducing available habitat due to climate change. There are six tortoise species in North America and Mexico (genus Gopherus) and they differ in genetics, distribution, morphology, body size, diet, habitat, and shelter site selection. Most Gopherus species have been assumed to have a similar physiology as G. agassizii despite differences in genetics and ecology and more recent evidence suggesting varying thermoregulatory strategies for different species. Therefore, understanding each species' specific habitat requirements and physiological properties are important to allow inferences about tortoises' potential to cope with temperature shifts and habitat alterations. Niche modeling predicts extensive range contractions for many chelonian species, but there is a lack of sufficient physiological data at an appropriate resolution of microhabitats to refine these models and improve predictions to guide conservation action for specific populations and species. Our study measures core physiological data, operative environmental temperatures, and movement and activity patterns of species occupying differing habitats: G. flavomarginatus, G. morafkai, and G. evgoodei in the Southwestern US and Mexico.

1035 Justin Jorge, Sheila Patek

Comparative biomechanics of energy storage and release across seed-shooting witch hazels

The seed-shooting fruits of three confamilial species shoot their seeds at similar speeds despite their seeds spanning an order of magnitude in mass. The fruits of Fortunearia sinensis, Hamamelis virginiana, and Loropetalum chinense use the same pinch-based mechanism: a spring-like structure surrounding each seed pinches on the seed to eject it. As a spring-actuated system, fruits shooting more massive seeds are expected to have significantly lower seed ejection speeds if the other seed-shooting components are held constant. Given that this is not the case, we investigate how the fruits of these species adjust to launch larger seeds. We collected measurements of seed mass, spring mass, energy storage, and energy release. We found remarkable variance in the strategies used to shoot larger seeds across species that use seemingly similar seed-shooting components. The spring of F. sinensis was the most massive of the three species and stored the most elastic energy. Meanwhile, the spring of L. chinense was the least massive, stored the least amount of energy, yet stored the most mass-specific elastic energy. From these findings, we concluded that across the three species, larger springs stored more energy but this increase in energy storage did not scale isometrically. Additionally, we compared the ratio of energy stored to energy released and found that as fruit size increased, the conversion efficiency of elastic energy to kinetic energy decreased.

22 Benjamin Jorgensen, Kit Yu Karen Chan

Diet modulates upper thermal limit of larval sand dollars

Ocean warming has negatively affected marine organisms, especially those with narrower thermal safety margins. For marine organisms with complex life history, the early planktonic stage is thought to be more vulnerable and have lower upper thermal limit than adults. Nutrient provision, both diet quantity and quality, affect the rate of larval development and stress tolerance in adults. It is therefore reasonable to assume that an elevated diet ration and/or quality could elevate larval thermal stress tolerance in a mechanism similar to that for adults. Here, we investigated how food concentration (starved vs ad. libitum) and diet quality (three types of algal food varying in fatty acid content) affect the upper thermal limit of larval sand dollar, Dendraster excentricus. Larvae were exposed to temperature gradients for 2 hours at three different time points: prism, 4-arm, and 8-arm stages. As expected, the upper thermal limit (LT50) increased with larval age, and presence of food significantly elevated larval LT50. However, the difference in larval LT50 between diets of different quality, at high food concentration, was small ($< 1^{\circ}$C). Our study highlights the importance of considering the effect of diet and other physiological conditions when making estimates of upper thermal limits and applying them to predict future distribution of marine organisms in the face of climate change.

1724 Marcus Jorgensen, Diana Hews

Hair and plasma cortisol in the big big brown bat, Eptesicus fuscus

Plasma glucocorticoid (GC) levels typically elevate to mobilize glucose and coordinate other adaptive responses to short-term stressors. Hair glucocorticoid levels provide longer-term measures of circulating glucocorticoid levels, from weeks to months, and fur of juvenile mammals captures glucocorticoid exposure both in utero and post-birth. There is little research exploring the relationship between plasma cortisol (CORTp) and hair cortisol (CORTh) from the same individuals, especially for bats. Here we present measures for adult and juvenile big brown bats (Eptesicus fuscus) from two summer field seasons in northeast Missouri. Not all bats had both GC measures, and for a much smaller subsample, we also evaluated neutrophil:lymphocyte (N:L) ratio, an indicator of infection. We hypothesize that CORTp We used one-way or two-way ANOVAs to evaluate hypotheses. Neither CORTh nor CORTp explained variation in N:L ratio. Year, but not handling time, was a significant main effect for CORTp, which was significantly higher in 2019 versus 2021. Interestingly, a two-way ANOVA evaluating sex and year on CORTh was significant in 2021.CORTh was higher in 2021 than in 2019. CORTp tended to be negatively but not significantly correlated with CORTh for adults. We hypothesize that bats with higher hair CORT are hypo-reactive, producing lower plasma CORT in response to an acute stressor (capture & handling). Currently, we are improving our procedures to further evaluate this effect from an acute stressor.

231 Cas Jorissen, Sam Van-Wassenbergh

Force-frequency trade-offs in muscle-powered lever systems

The body of animals includes a variety of lever systems operated by antagonistic muscle pairs. Some of these lever systems are responsible for different tasks with conflicting mechanical demands. The force-velocity trade-off for rotation in one direction has been the topic of several studies. However, sequential rotations in two directions at high frequency are often needed. How the mechanical demands of such high-frequency movement is in conflict with adaptations for static torque increase in one direction, leading to a torque imbalance between the antagonists, remains unknown. An example of such a system are songbird beaks exerting high forces to bite and move up-and-down at high frequency during vocalisation and food handling. Here, we used the songbird mandible system as a case study to gain understanding of the factors involved in force-frequency trade-offs. By forward dynamic simulation using Hill-type muscle models with optimisation of muscle activation patterns, we evaluated the effects of parameters such as muscle fibre type, cross-sectional area, moment arm, and beak mass. The force-frequency trade-off is moderately manifested in a combined increase in beak mass and moment arm of the biter muscle (frequencies up to -20%), and antagonist force imbalance (frequencies -10%). Much stronger effects on frequency are caused by the proportion of fast muscle fibres, indicating that both force and frequency are in strong conflict with endurance.

1231 Chloe Josefson, Emma Sells, Amy Skibiel

Maternal effects of chronic stress during lactation

Developmental stress has been well-documented as having the potential to alter offspring phenotype in many different taxa. Milk production is particularly susceptible to the effects of chronic stress given the high energetic and nutritive demand that the process of lactation imposes on multiple physiological systems. Additionally, milk synthesis allows for considerable maternal regulation of offspring development beyond gestation, as information about the maternal environment can be communicated to young via biochemical signals contained within milk. Here, we present work that explores the impact of chronic stress during lactation on maternal physiology, milk composition, and offspring physiology using a Sprague-Dawley rat model. Daily exposure to a novel male intruder significantly increased fecal corticosterone metabolites and hepatic gene expression of mineralocorticoid receptor (MR), and significantly decreased hepatic gene expression of glucocorticoid receptor (GR). In addition, exposure to chronic stress decreased milk yield and crude fat. Chronically-stressed mothers also had a significant increase in milk corticosterone. Although there were no differences in offspring mass at weaning between control and chronically-stressed mothers, offspring of the stressed mothers had lower hepatic gene expression of both MR and GR. Together, our results demonstrate that exposure to a chronic stressor during lactation impacts maternal physiology and milk synthesis, which in turn has the potential to impact offspring development via nutrition and direct hormone effects.

416 Luberson Joseph, Emily New, Jordyn Sisovksy, Adam Ramirez, Woodley Tamarra, Vanessa Franco, Liz McCullagh

Species Differences in Binaural Hearing Ability of Small Mammals in Oklahoma, USA.

Sound localization in a bionetwork is a critical behavior that promotes foraging, social behavior engagement, avoiding predators, and other tasks vital for reproduction and subsistence. Body size differences, sex, ear morphology, and environmental stresses are important factors in influencing mammals sound detection and hearing sensitivity in the wild. However, few studies have explored whether social structure influences mammals hearing ability and sound localization. We report that there are many factors that potentially influence binaural hearing ability of wild mammals across different social groups. Auditory brainstem recordings (ABRs) and anatomical markers of brainstem nuclei were used to explore small mammal binaural hearing ability across species with variability in genetics, size, habitats, and social structure (solitary, monogamous, highly social). Among the features investigated, social structure seems to have the greatest impact on binaural hearing capability across species affecting amplitude of ABRs. Promiscuous Peromyscus spp. and Neotoma floridana have a decreased amplitude of wave IV of the monaural ABR compared to other social groups. There is substantial variability in size of brain regions important for sound detection across species. Finally, morphological features (pinna size, body size and mass) vary substantially within and between species and likely contribute to rodent's binaural hearing. Our study validates the potential role of social structure, and other factors, on small mammal's binaural hearing ability.

154 Scott Juntti

Insights into female reproductive behaviors from CRISPR-edited and transgenic cichlids

The >2000 species of cichlid fish exhibit a wide variety of phenotypes in morphology, physiology, and behavior. However, how the genome encodes the information for distinct developmental and functional programs is still unclear. To address this question, we use Astatotilapia burtoni cichlids as a study species to develop and improve the tools to modify gene sequences, enabling researchers to understand how specific genes control the form and function of the body. We developed experimental pipelines that improved the injection and editing efficiency and transgenesis. By utilizing Tyrosinase gene targeting, we also developed a fast (as early as 2–3 days post-fertilization) and reliable approach tool to quickly validate CRISPR/Cas activity in vivo, and to troubleshoot problematic reagents and protocols. As a result, we utilize mutants for Tyrosinase and other genes to interfere with hormone signaling, pheromonal communication, plus transgenics to enable functional imaging.

114 Ana Jurcak-Detter

Power of the People! Utilizing Citizen Science in Course Curriculum

In an effort to engage students, faculty try to connect biological concepts from class to real world examples, while trying to display the importance of the course matter. With an increasingly diverse array of citizen science projects, these projects can be incorporated into course curriculum, allowing students to get involved in actual scientific studies going on across the globe. Different citizen science projects were incorporated into various ecological and behavioral courses in a variety of assignments. These assignments ranged from one time laboratory activities, to week long projects, to extra credit assignments. Citizen science projects assimilated into class curriculum involved going outside into the field, as well as using computers to collect and analyze data. In some cases, students within the same course could pick one from a variety of projects, finding one that matched their particular interests. Students also had the opportunity to present to the class about their particular citizen science project. Integrating the citizen science into the curriculum involved no monetary cost, and in some cases, free resources to educators were available. Students were able to be a part of ongoing scientific research, connect classroom concepts to the projects, and feel as if they were making a difference with their learning.

1493 Heiko Kabutz, Kendall Webster, Kimberly Fung, Kaushik Jayaram

Spatial gait analysis of araneae locomotion through confined terrain

The advantage of legged animals to maneuver across complex terrain has inspired development in robotic design and control. Araneae demonstrate excellent walking and climbing abilities over, around and through different obstacles with eight legs. Better understanding of leg placement and gait choices of araneae in confined spaces, specifically with lateral constraints, can provide inspiration for enhanced mobility of millimeter scale robotic platforms. Here, the gaits of araneae were analyzed while passing through an obstacle course with lateral constraints, limiting lateral leg expansion. Three different types of Lycosidae (Tigrosa georgicola, Hogna carolinensis, Hogna lenta) were used. Using high-speed videography, we analyzed the locomotion kinematics (gait pattern, speed, stride frequency and length) and quantified their variation with respect to the lateral constraints. We found that all spiders were able to easily navigate up to 70% confined with limited changes in kinematics and found systematic adaptation with increasing lateral confinement gap thereafter.

576 Elska Kaczmarek, Elizabeth Brainerd

Royal knifefish, Chitala blanci, breathe air using two functionally distinct breath types

Among the dozens of ray-finned fishes that use their gas bladder to breathe air, nearly all use the same movement pattern to expire and inspire air. This expiration-inspiration breath is considered the ancestral breath type of ray-finned fishes. Interestingly, one such species, Amia calva, is known to perform two distinct breath types. Amia use the expiration-inspiration breath when the fish has depleted its oxygen levels, and they also perform an inspiration-only breath to restore buoyancy. We present the first description of inspiration-only breaths in royal knifefish, Chitala blanci, a ray-finned fish that was already known to use expiration-inspiration breaths. To test whether the two breath types are performed for the same functions in royal knifefish as they are in Amia, we recorded the frequency of each breath type under different conditions of oxygen availability. We found that decreased aerial oxygen content caused knifefish to perform more expiration-inspiration breaths than inspiration-only breaths, while very high aerial oxygen content caused knifefish to perform primarily inspiration-only breaths. This suggests that, as in Amia, royal knifefish perform expiration-inspiration breaths in response to low oxygen levels and likely perform inspiration-only breaths to maintain buoyancy. Inspiration-only breaths may be more common among fishes than we are aware. Investigating the prevalence of inspiration-only breaths among extant fishes could provide new insights into the functional drivers, evolutionary history, and origin of air-breathing.

1503 Shirel Kahane-Rapport, Julia Teeple, James Strother, Misty Paig-Tran

Using biologically accurate models of manta ray filters to determine flow patterns

Mobula rays (manta and devil rays) are marine filter feeders that forage on small zooplankton using a unique foraging mechanism known as ricochet separation. Their specialized, cartilaginous filters are arranged in parallel rows of leaf-like lobes, the filter lobes, along the gill arches. Previous work using a simplified model of the Manta birostris filter found that as water passes over the filter lobes, a train of captive vortices is produced in the pores between filter lobes. These vortices force particles to contact and bounce away from the filter lobes toward the esophagus; this filtration method is called ricochet separation. While this method of filtration has been described using a simplified model of M. birostris filters, this has not yet been tested in other species of mobulas that have distinctive morphologies. We microCT-scanned and 3D-printed biologically accurate filters to determine the flow patterns in 6 species of Mobulids. Using digital particle image velocimetry (DPIV), we visualized the differences in vortex shape

and size and flow pattern among the species. Maintaining specific tangential to transverse ratios and specific angles of attack were critical to vortex formation. We noted the presence of double vortices within the same pore under slower freestream conditions. While all Mobulid filters can form vortices under laboratory conditions, future work is needed to determine if these conditions are present during natural foraging.

1648 Leah Kahn, Seth Finnegan, Z. Jack Tseng

Mechanics and defensive functions of gastropod shell ornamentation

Many mollusk shells exhibit prominent external ornaments which are hypothesized to function as a defense against shell-crushing predators. Ornamentation may provide protection by inhibiting attack or by influencing shell mechanical properties, but only a handful of studies have quantified the latter effects. We use compression tests of 3D-printed gastropod shell models to investigate how ornamental spines affect a shell's resistance to crushing forces. The relationship between morphology and mechanical strength in real shells is complicated by factors such as shell microstructure and taphonomic history. 3D-printed models provide greater experimental control by isolating the role of morphology via standardized constructional material. We generated a digital 3D model from microCT data of the early Eocene volutid gastropod Athleta tuomeyi. Two other models representing alternate degrees of ornamentation were created by digitally lengthening and removing the spines on the original model, respectively. Models were printed using a resin 3D printer, then subjected to compression testing between two flat steel plates to simulate the jaws of a vertebrate predator. Results suggest that spine length does not significantly affect either the maximum force or the amount of work required to break a shell. Ornamental spines do not appear to increase the ultimate strength of a shell; instead, their defensive role may result from increasing the shell's effective size and/or making it more difficult for predators to manipulate.

1320 Hussain Kalavadwala, Jacob Daane

Evolutionary Loss of Glomeruli Across Teleost Fish Kidneys – A Comparative Genomics Approach

Organisms face the challenge of maintaining internal homeostasis in the face of fluctuating environmental conditions. In vertebrates, the kidney plays an integral role in maintaining homeostasis by regulating fluid osmolality and removing waste. Within the kidney, the glomerulus is a highly-specialized filtration unit composed of a tuft of fenestrated capillaries lined by podocytes, which directs fluid into Bowman's capsule for excretion and selective reabsorption within the kidney tubule. Despite the importance of the glomerulus in kidney function, the glomerulus has been lost up to eight times independently in teleost fishes, typically as an adaptation for the conservation of water or specialized proteins such as antifreeze. We are using comparative genomics to identify conserved genetic mechanisms underlying glomerulus development and function. We have assembled whole-genome sequencing data representing all eight glomerulus losses in teleosts, with a specific focus on the loss and re-evolution of the glomerulus in Antarctic notothenioid fishes. We predict that genes and gene-regulatory regions regulating glomerulus function will be under relaxed selection following glomerulus loss and can be identified through this signature. We will model identified genes through gene editing tools in transgenic zebrafish models. These data will aid in our understanding of adaptation to environmental change and in providing insights into human kidney diseases that arise due to the loss of glomerular function in humans, such as Diabetic nephropathy, glomerulonephritis, and glomerulosclerosis.

500 Maryam Kamran, Kelsey Jennings, Ashley Dayer

Fieldwork and LGBTQ+ identities: Queering the outdoors

Fieldwork is considered an integral component of research within conservation biology and ecology. Oftentimes, institutions and researchers share resources on general safety when collecting data in field settings. Despite an increasing awareness, there has been a lack of transparency and communication in terms of the hazards associated with fieldwork. These include but are not limited to an increased risk of sexual harrasment and assault. These risks are compounded particularly for those from marginalized racial and gender identities, who experience increased risk. In addition to this lack of acknowledgement, the added risks to those that identify as lesbian, gay, bisexual, transgender and queer (LGBTQ+) are often overlooked. We have found that there is not only a lack of data on sexual orientation and gender identities and the barriers they may face as field based scientists, but also a lack of awareness of how we can support those from these marginalized groups within our disciplines. Creating a SAFE and INCLUSIVE community for those with marginalized identities is key to sustaining the diversity within our discipline. Here we outline a series of recommendations that can be utilized to address the harassment, homophobia and transphobia that our LGBTQ+ colleagues face. These recommendations range from what can be applied at the local level (within a lab group), at the department level, at the institutional level as well as field sites.

35 Suzanne Kane, Sophie Frem, S. Tonia Hsieh

Characterizing the adhesive forces of insect sticky traps

Although sticky traps are widely used to monitor and control insect populations, information is lacking on the adhesive forces they exert on insects. This study explored adhesive characterization methods useful for comparing traps with different glues, colors, chemoattractants, etc. Adhesive forces were measured for 3rd and 4th instar nymphs of the invasive spotted lanternfly (SLF, Lycorma delicatula) and cockroach exoskeleton control samples. SLFs were released onto Web-Cote SLF traps such that 4-6 body parts adhered, frozen until dormant, and tested using methods developed for insect tarsal adhesion, yielding measures of force-extension curves during peel-off, adhesive strength (maximum force), and (for controls) tenacity (maximum adhesive stress). Mean trap adhesive strengths for 3rd and 4th SLF instars did not differ significantly, consistent with field study findings that larger, presumably stronger nymphs are less effectively trapped. SLF specimens were observed to debond in stages with detached body parts remaining connected by glue fingers that stretched before fracturing, requiring additional energy compared to brittle fracture. The exoskeleton control data indicated that the different temperature treatments used did not significantly affect adhesive properties and that Web-Cote SLF sticky traps have significantly greater (2.5X) tenacity than a brand intended for controlling smaller insects. These findings provide new insights into how insects interact with adhesive traps, and provide a testbed for comparing trap properties.

1650 Caroline Kane, Austin Garner, Michael Russell, Alyssa Stark

Adhesion and locomotion of the green sea urchin in response to elevated temperature

Green sea urchins (Strongylocentrotus droebachiensis) employ a duo-gland adhesive system to attach firmly to rocky substrata of intertidal and shallow reefs. Global climate change poses a significant threat to this heat-intolerant species, where high adult mortality occurs at ∼22?. Changes in temperature negatively affect development, but little is known about how it affects adhesion and locomotion of adults. We hypothesize that adhesive and locomotor performance decline during exposure to above average temperatures, increasing the potential for adhesive failure. To evaluate adhesive and locomotor performance across various temperatures, we measured disc tenacity (i.e., adhesive force/disc surface area) and maximum locomotor speed of sea urchins exposed to 10°, 14°, and 18°C seawater. Our results provide valuable insight into how current and future temperature fluctuations from global change will impact the performance and survival of adult sea urchins.

1832 Eva Kanso

Cilia-powered pumps

Ciliated organs that drive luminal fluids are ubiquitous in animal biology. While the structure of individual cilia is remarkably conserved across the animal kingdom, the morphology of ciliated organs vary drastically and so does their physiological function. Examples range from cilia-powered transport and clearance of fluids in the mammalian respiratory, reproductive, and cerebrospinal systems to cilia-powered filtration and waste excretion in small invertebrates. Despite progress in analyzing specific systems, the relationship between the structure of ciliated organs and their fluid pumping function remains opaque. Here, using mathematical modeling, experimental studies in animal models, and a survey of ciliated organs across all animal phyla, I will discuss two aspects of cilia structure-function relationship. I will show that cilia can spontaneously organize into traveling wave patterns that break symmetry and pump fluids. Then, I will explain how the morphology of ciliated organs directly predicts whether they are optimized for fluid transport or filtration. Our work suggests that the convergence of ciliated organ design in the animal kingdom is based on functional constraints rather than phylogenetic distance, and establishes design rules for bio-inspired and tissue engineered cilia powered pumps.

1392 Katherine Karkosiak, Hunter King, Ravi Schwartz, Todd Blackledge

Do spider egg sacs prevent water vapor loss?

Female spiders produce silk egg sacs to encase and protect their developing young until it is time to hatch. Although there are many hypotheses about the function of spider egg sacs, in this study we focus on the ability to protect against extreme water losses that can lead to egg desiccation. Data on whether silk egg sacs prevent water loss is contradictory with some studies showing that they can variably limit water vapor loss and provide an environment of higher humidity, while others show that the removal of egg sacs either does or does not affect survival and water loss depending on the species and developmental stage. The high variation in egg sac morphology, varying from a few pieces of silk to thick multi-layered meshes, could contribute to variation in this function. I hypothesize that egg sacs of greater fiber density and thickness are better at preventing water vapor loss. We test this hypothesis by measuring rates of water loss through spider egg sac material. We also develop a predictive model for diffusive flux through porous materials to better understand the potential for natural selection to shape the water resistance properties of egg sacs produced by spiders in diverse habitats.

827 Julie Karlsson, Aubrey Jane, Markus Frederich, Doug Rasher, Jesica Waller, Eric Annis

Cardiac performance as a function of temperature in larval American lobsters (Homarus americanus)

Larvae of the American lobster (Homarus americanus) are being affected by the increasing water temperature in the Gulf of Maine due to climate change. Rising temperatures are shifting where lobster larvae settle with cascading effects on adult lobster population dynamics and the lobster fishery over time. Significant gaps remain in our understanding of the physiological response of lobster larvae to changing temperatures and the limits of their thermal tolerance are not well defined. Metabolic processes are an important part of the lobster larvae physiological response to temperature, and cardiac performance is one metric for assessing their response to thermal stress. We examined larval cardiac performance in laboratory reared stage I, II, III and IV larvae, and in wild-caught stage IV larvae. Heart rate of larvae was measured at 4, 8, 18, 26 and 30°C to assess how temperature affects physiological performance and provide information for determining upper and lower critical temperatures. There was a linear relationship between temperature and heart rate for all stages. There were no statistically significant differences in heart rate between the developmental stages of laboratory reared larvae, nor between lab reared and wild-caught stage IV larvae. We will report stroke volume, estimates of cardiac output and pleopod beats across all stages and rearing conditions. The combination of these metrics will be used to identify the range of larval thermal tolerance.

692 Jessica Karr, Jamie Cornelius

Metabolic and acute stress responses to abrupt cold acclimation in a nomadic songbird

Physiological adjustments promote the usage of energy stores for thermoregulation during abrupt temperature change. Songbirds can adjust metabolic capacity (i.e., summit metabolic rate - or the ability to increase metabolic rate to produce heat) and must also supply energy to support this capacity. Long-term cold exposure induces the development of higher metabolic capacity in several species; however, how quickly metabolic capacity changes and responds to temperature may vary among species. Further, hormonal responses that manage energy availability (e.g., circulating glucocorticoids) are largely undescribed in the context of changes in metabolic capacity during cold exposure. We present the metabolic and corticosterone responses of two ecotypes of red crossbill (Loxia curvirostra) of variable body size during abrupt cold acclimation. Loxia curvirostra are nomadic songbirds commonly found in northern latitudes that experience highly variable weather conditions year to year. The smaller-bodied Type 3 and lager-bodied Type 5 red crossbills were randomly assigned into treatment groups and housed in warm conditions (22°C) for two months before placement into the cold treatment (6°C). Basal and summit metabolic measurements were measured via □open circuit respirometry and baseline corticosterone samples were taken prior to and during cold acclimation over a ten day measurement period. Using this comparative approach, we attempt to better understand the associated metabolic and hormonal responses during cold acclimation in small-bodied endotherms.

718 Hilary Katz

Rohon-Beard neurons and perspectives on sensorimotor integration after spinal cord regeneration

Recent studies have highlighted the role of mechanosensory neurons in supporting robust locomotor control. This work has emphasized the need to examine the recovery of sensorimotor integration in spinal cord regeneration, which has received less attention than the recovery of motor output. Here, I discuss our work characterizing Rohon-Beard (RB) neurons, the primary mechanosensory neurons in larval fish and amphibians. Additionally, I discuss our recent work in the larval sea lamprey, Petromyzon marinus, examining functional recovery after a complete spinal transection, with particular attention to behavioral findings that highlight the need for more in-depth study of the regeneration of spinal sensory networks. We previously demonstrated that RB neurons vary in their sensitivity and receptive ranges along the rostrocaudal axis in larval zebrafish. This complexity coupled with their accessibility make RBs a valuable population for studying sensorimotor integration within the spinal cord. RBs are thought to be homologous with Dorsal cells found in lampreys, jawless vertebrates. We have found that larval lampreys are able to recover their ability to burrow, but not to the same degree as they recover swimming. One hypothesis is that this may be caused by deficits in sensory feedback in the regenerated spinal cord. Ultimately, we propose that future work is needed to better understand sensorimotor integration, particularly with respect to Dorsal cells, in the regenerated spinal cord.

1086 Emily Kaufman, Harry Tuazon, Darshan Chudasama, Saad Bhamla

Thigmotactic Clumping of Substrate by Aquatic Worms

It has been shown that annelids can change the environment around them, a process known as bioturbation. In this talk, we introduce a novel substrate clumping behavior amongst non-hierarchical annelids in California blackworms (L. Variegatus). Blackworms measure around 2-4 cm and feed on detritus in shallow, marshy waters. We discover that worms can collect both inorganic and organic matter at the individual and collective level. Blackworms can clump together a variety of materials, including algae, fish food pellets, porous materials, and even nylon mesh or microplastics. Individual blackworms show the ability to collect material along their body and aggregate discrete particles into a large clump. For both algae and microplastics, we use machine learning and image analysis to show that individual worms can collect 75-80% of well-mixed material into a clump. In smooth substrates, blackworms physically entangle with one another to form a collective "blob." Worm blobs can collect material into smaller clumps by pulling it into themselves. On average, a worm blob can reduce the surface area of well-mixed algae by half. We hypothesize that worms use their chetae and externally secreted mucus to collect material along their bodies, using their eversible pharynx to gather larger objects together. We discuss the potential implications of this novel clumping behavior by worms because of thigmotactic responses, which may be another mechanism of altering their habitat.

1020 David Kay, Haley O'Brien, Paul Gignac

Crocodylian differential alveolar completion suggests trade-offs in socket formation and crown shape

Some crocodylian species have categorically heterodont dentitions while others are homodont. The role of alveoli in shaping this dental disparity is unknown. Heterodont alligatorids, like Alligator mississippiensis, hatch with up to five complete alveoli in the dentary, whereas more homodont crocodylids, like Crocodylus acutus, hatch with up to eight. During crocodylian odontogenesis, additional sockets form iteratively within a distal trough by growth of alveolar bone, expanding with each tooth cycle and potentially constraining root and crown shapes. Previously, we have shown a significant relationship between alveolar and dental crown morphologies in A. mississippiensis: slow growing distal sockets are elliptical and associated with ovoid tooth shapes, contributing to heterodont crowns within the same jaw. Here, we evaluate interspecific differences in tooth disparity by hypothesizing that if alveolar bone shapes tooth crowns in crocodylians, heterodont taxa will show slower alveolar completion during ontogeny than more homodont taxa. We test this hypothesis using μCT data, reconstructing an ontogenetic series of jaws from A. mississippiensis and C. acutus. We use ANCOVAs to compare the degree of alveolar completion to skull width and life-stage between species. Results were significantly different ($p < 0\ .05$). We found that more homodont C. acutus completes more alveoli earlier in ontogeny relative to heterodont A. mississippiensis. These results suggest a previously unidentified trade-off between tooth-socket completion and tooth-shape variation in Crocodylia.

1806 Pushpalata Kayastha, MAGDALENA GAWLAK, MONIKA MIODUCHOWSKA, ?UKASZ S?UGOCKI, DANIEL STEC, ?UKASZ KACZMAREK

Integrative description of Paramacrobiotus gadabouti sp. nov.–a next widely distributed Pam.

Integrative description of Paramacrobiotus gadabouti sp. nov. – a next widely distributed ParamacrobiotusUsing integrative taxonomy, we describe Paramacrobiotus gadabouti sp. nov. from Madeira. Description is based on morphological and morphometric data from both phase contrast light microscopy (PCM), as well as, from scanning electron microscopy (SEM). The DNA markers, three nuclear (18S rRNA, 28S rRNA, ITS-2) and one mitochondrial (COI) were used to provide genetic characterisation of new species and their phylogenetic position. Based on genetic data from GenBank we found that Pam. gadabouti sp. nov. has a quite wide distribution. The wide distribution of new species once again confirms that for some tardigrade species (especially parthenogenetic like e.g. Pam. Fairbanksi Schill, Förster, Dandekar & Wolf, 2010) 'Everything is Everywhere (EiE)' hypothesis is trueKeywords: Madeira Island, taxonomy, water bears, cosmopolitism, dispersal, zoogeography, "everything is everywhere hypothesis".

1429 Ellen Keaveny, Mitch Helling, Franco Basile, James Strange, Jeffrey Lozier, Michael Dillon

Common garden reared bumble bees (Bombus vosensenskii) maintain constitutive differences in cellular

Cold tolerance of ectotherms can vary strikingly among species and populations. Variation in cold tolerance can reflect differences in genomes and transcriptomes that confer cellular-level protection from cold; however, shifts in protein function and expression can be altered by other cellular constituents as cold-exposed insects from the same population often have shifts in their metabolomes. Even without a cold challenge, insects from different populations may vary in cellular composition that could alter cold tolerance, but investigations of baseline metabolomes across populations remain rare. To address this gap, we reared Bombus vosensenskii queens collected from OR and CA that differ in cold tolerance (CTmin = -6°C and 0°C, respectively) in common garden conditions, and measured offspring metabolomes using nontargeted LC-MS/MS. We found similar metabolites across all body segments (head, thorax, and abdomen) as hemolymph bathes all tissues throughout the bee, with abdominal tissue being most distinct likely due to the diverse tissue including fat body, and digestive and reproductive organs. As predicted, metabolites associated with cold tolerance, including maltitol, turanose, and ornithine, were upregulated in OR bees although relative abundances varied across body segments. Overall, our results reveal constitutive differences in metabolomes across bumble bee populations that likely alter cold tolerance.

1084 Chloe Keck, Carol Boggs, Daniel Speiser

Investigating color preference in male butterflies during mating

Investigating resource allocation strategies of lepidopterans can open the door to understanding the evolutionary trade-offs involved in preserving specific morphological traits and reproductive strategies. Resource allocation in holometabolous insects, such as butterflies, occurs at several developmental stages. Thus, larval dietary stress can impact adult morphology and behavior. For instance, butterflies subjected to larval dietary stress tend to exhibit lower adult wing pigmentation than butterflies not experiencing larval dietary stress. Here, I examine adult Speyeria mormonia male color preference during mating from a resource allocation framework. Using spectral reflectance values of several adult female butterfly wings varying in color, I selected three color chips that closely resembled the reflectance curve of the adult wings. I constructed several decoy butterflies using the color chips to mimic adult females. The color chips represented low-pigment individuals and high-pigment individuals. Additionally, I constructed a super-stimulus decoy by doubling the high-pigment reflectance curve and matching the result to a color chip. I conducted three decoy comparisons (high pigment versus low-pigment, high-pigment versus super-stimulus, and low-pigment versus super-stimulus) in which I recorded the number of adult male approaches to each decoy. Preliminary results suggest that 1) adult males distinguish potential mates based on color, 2) adult males prefer females that appear more saturated (i.e., more pigmented), and 3) adult males may use color as a proxy for reproductive fitness in females.

1076 Rachel Keeffe, Dylan Maag, Brandon Hedrick, Rulon Clark, Patricia Brennan

Shape differences in the hemipenes of rattlesnakes in a hybrid zone

The oldest hypothesis to explain the evolution of diverse genitalia is the “lock and key” hypothesis, where male intromittent organs are proposed to act as “keys” that fit into specific female “locks”, thereby reinforcing speciation by preventing mating between incipient species. However, when put to the test, the “lock and key” hypothesis has received little support, even though it has been assumed to be the most likely explanation for morphological diversity in snake hemipenes. Here we examine hemipene shape in a rattlesnake hybrid zone between Mojave rattlesnakes and their hybrids with Prairie rattlesnakes using 3D morphometrics and automated landmarking. We used Auto3dgm with 2000 semilandmarks to compare 27 specimens, 20 Mojave rattlesnakes and 7 hybrids. The main axis of shape variation along PC1 explained 51% of the variance, with negative values showing widely bifurcated hemipenes and positive values showing less bifurcation between hemipene lobes. Five of the seven hybrids fell out in the positive PC1 region, though an ANOVA between hemipene shape and species was not significant ($p = 0.054$). Future work will examine Prairie rattlesnakes, as well as female genitalia in all species and hybrids, to test if assumptions of the lock and key hypothesis can explain genital diversity in this system.

155 Greta Keller, Marta Marchini, Naaz Khan, GiHo Jeong, Thomas Sanger, Rushabh Shah

The role of Hedgehog signaling during craniofacial development of the lizard Anolis sagrei

Great variation exists in the skeletal composition of amniote face and skull. For example, bird faces are primarily composed of the premaxilla since their maxilla is highly reduced. In many other species, the maxilla makes up a larger proportion of the face and the premaxilla is a relatively small bone at the anterior of the skull. Although facial patterning is thought to be conserved among amniotes, the developmental bases of this skeletal variation remains unexplored. The goal of this project is to understand the role Hedgehog signaling plays in squamate facial development in the lizard Anolis sagrei. We hypothesized that Hedgehog signaling disproportionately regulates the development of the midline facial skeleton compared to lateral maxillary derivatives. Sonic hedgehog is expressed in a dynamic pattern during craniofacial morphogenesis, beginning in the neural tissue, then in the oral epithelium, and finally along the margins of the growing facial prominences. Knockdown of Hedgehog signaling during facial patterning results in embryos with a range of variability from a shortened face to severely ablated midline structures. Skeletal analysis of mature experimental embryos reveals disproportionately affected midline structures like the premaxilla and anterior nasal cartilage. The maxillae do not appear to be as grossly affected as the midline skeletal elements, supporting our experimental hypothesis. Our research highlights that modifications in early craniofacial patterning may lead to diversity in the amniotes skull.

210 Riley Kellermeyer, Rachel Moran, Luis Espinasa, Nicolas Rohner

A natural hybridization experiment: eyed and eyeless Astyanax mexicanus reveal origins of eye loss

Loss of eyes is a common adaptation for animals that live in constant darkness. Independent evolution of eye loss has occurred in the Mexican tetra, Astyanax mexicanus, a two-morph species with an eyed surface-dwelling morph (surface fish) and eyeless cave-dwelling morphs (cavefish). The Caballo Moro (CM) cave in northeastern Mexico is a karst window that exposes cave morph A. mexicanus to sunlight and houses both eyed and eyeless cavefish, despite no obvious opportunities for surface fish intrusion. We found that the eyed morph had remarkably cave-like skull and body composition despite the presence of eyes. Phylogenetic analyses of 42 CM individuals and nearby surface fish indicated that eyed CM fish were the result of cave-surface hybridization that occurred approximately at the time of the karst window collapse. We used this hybridization event to identify a novel eye loss gene for troglomorphic organisms - a lens gap junction protein, Connexin 50 (Cx50), the human homolog of which is linked to heritable cataracts and small eyes. Cx50 SNPs are found in other independently evolved A. mexicanus cave populations as well as other cave-adapted organisms. We generated the Cx50 SNP from eyeless CM fish in mice, which resulted in cataracts, smaller eyes, and smaller lenses. This hybridization event allowed us to identify a novel allele that contributes to eye loss adaptations in potentially multiple cave species.

550 Audrey Kellogg, Christin Murphy, Sarah Kienle, Marilyn Marx, Joy Lapseritis, Michael Moore

Post-process Imaging Techniques to Create Photorealistic 3D Models

Photogrammetry is a quick, low- cost data collection technique we utilized to develop three-dimensional models of large entities. Data collection of large marine mammals is not only limited due to size, but also the unpredictability of the stranding or tagging event location which restricts image collection by time, location, weather, and non-uniform conditions. 360° photo sequences of two North Atlantic right whales (Eubalaena glacialis) and four leopard seals (Hydrurga leptonyx) were collected at stranding and tagging events, respectively. While we are unable to move these large marine mammals to ideal imaging locations, we can process the field collected photos to modify any variables that may prevent the reconstruction of an accurate 3-D model. We were able to preserve the accuracy of the specimens in the 3-D model regardless of background, glare, shadows, or haze which allows for a more accurate computational analysis of the stranded specimens. Testing different post- processing techniques on varied backgrounds, textures, lighting, and angles, we have created methodology that conserves the biological accuracy of the imaged species as compared to models developed without post-process editing. The developed methodology for each image defect was constructed into an open-source macro available on our GitHub Repository. Here we share the image processing methodology used on each photo series collected that produced a morphologically accurate 3-D model for computational analysis.

1083 Audrey Kellogg, Joseph Legris, David Beal, Christin Murphy, Brooke Flammang

2D PIV of Bioinspired Oscillating Mola mola Fin Derived from Morphology and Kinematics

The Giant Ocean Sunfish, Mola mola (Order: Tetraodontiformes; Family: Molidae), propel their two-ton bodies to extensive depths using only their lobate dorsal and anal fins. Due to the sheer size of an adult Mola mola, measuring the swimming mechanics in a controlled environment has not been possible. To overcome this issue and gain a better understanding behind their extreme locomotive performance, we applied a combination of morphology, kinematics, and robotics to develop the bioinspired flapping fin. MicroCT scans of the fin rays were resin printed at high resolution and molded into a morphologically accurate fin cast. Swimming mechanics of Mola mola were analyzed using DeepLabCut which provides cartesian coordinates of the landmarked fin through time. The coordinates were developed into a general shape of motion using custom Matlab script. The bioinspired fin was attached to a two degree of freedom flapping actuator coded to Mola mola swimming parameters calculated from the kinematics. The amalgamation of these approaches produced a bioinspired fin capable of oscillating exactly like a live Mola mola. Two-Dimensional Particle Image Velocimetry (PIV) analysis was performed on the flapping bioinspired fin to measure the velocity field produced during locomotion. A mounted load cell was used to measure force production of the bioinspired fins during PIV analysis. Collectively, these results will shed light on the swimming biomechanics of these otherwise impossible to study fish.

818 Tosha Kelly, Keegan Stansberry, Melanie Kimball, Kenedi Lynch, Christine Lattin

A transient reduction in circulating corticosterone reduces object neophobia in male house sparrows

Aversive reactions to novelty ("neophobia") can affect an individual's ability to exploit new resources and avoid potential dangers. However, despite its ecological importance, the proximate causes of neophobia are poorly understood. We tested the role of glucocorticoid hormones in neophobia in wild-caught house sparrows (Passer domesticus, $n = 11$ males) by giving an injection of the drug mitotane to reduce endogenous corticosterone for several days or a vehicle control, and then examined the latency to feed when the food dish was presented with or without a novel object in, on, or near the dish. Each sparrow experienced multiple novel object and control trials, and received both vehicle control and mitotane treatments, with a week between treatments to allow the mitotane to wash out. All novel objects significantly increased sparrows' latency to feed compared to no object present. Reducing corticosterone using mitotane significantly reduced the latency to feed in the presence of novel objects. In control trials without objects, mitotane had no significant effects on feeding time. Future studies using specific receptor agonists and antagonists will clarify the neurobiological mechanisms involved and determine whether baseline or stress-induced corticosterone is driving this effect. These results suggest that increased glucocorticoid secretion (e.g., due to human-induced stressors) could increase neophobia, affect the ability of individuals to exploit novel resources, and, ultimately, affect wildlife's ability to persist in human-altered environments.

Defaunation and species introductions alter long-term functional trait diversity in insular reptiles

Like many taxonomic groups, reptiles underwent significant biodiversity decline during the Quaternary, with many extinction events tied to anthropogenic impacts. Because reptiles provide a diverse array of ecosystem services, changes in reptile functional diversity due to extinction and colonization processes are important to quantify. This study uses Caribbean reptiles to explore functional diversity change over the Quaternary. Using ancient and present-day distribution data alongside trait data including body size, diet, and habitat affinity, functional diversity is quantified for seventeen islands with unique histories of human habitation and exploitation. During the Quaternary, several key functional entities (FEs)–groupings of species with similar traits that are expected to provide similar ecosystem services–have been lost completely due to extinction, but functional redundancy on large islands served as a buffer to major functional diversity loss. Small islands, on the other hand, lose up to 67% of their native FEs. While functional redundancy has shielded ecosystems from significant functional diversity loss in the past, it is being eroded and not replenished by species introductions, leaving many native FEs and the communities that they support vulnerable. This research provides critical data on long-term functional diversity loss for a taxonomic group whose contributions to ecosystem function are understudied and often undervalued.

597 Julia Kendrick, Frances Bonier

Beetlejuice: Anal secretions as a competitive strategy in the burying beetle, Nicrophorus orbicollis

An organism's ability to survive and reproduce is often related to its ability to compete for resources. Competition can be intense for organisms that rely on temporally or spatially limited or unpredictable resources. Carrion, often both a limited and unpredictable resource, is particularly valuable because it is nutrient rich. Animals that use carrion face intense competition from microbes, which can make the carcass unpalatable or inhospitable. I investigated adaptations to competition with microbes in the burying beetle, Nicrophorus orbicollis. Burying beetles require vertebrate carcasses to reproduce and use secretions containing antimicrobial components and beneficial microbes to reduce the growth of competitor microbes on carcasses. Nicrophorus parents provision their larvae with secretion-covered, regurgitated food. Ingesting secretions seems to aid in populating the larval gut microbiome, but the fitness consequences of preventing this vertical transmission have never been tested. I determined the fitness consequences of an experimentally altered gut microbiome for adult N. orbicollis and their offspring. Results demonstrate the importance of the gut microbiome for antimicrobial competition, but also indicate potential behavioural and immune responses that can at least partially compensate for disruption of the microbiome. Our findings increase our understanding of the strategies organisms use when facing intense microbial competition for scarce resources.

1638 Carly Kenkel, Rachel Wright

Can gene expression studies inform coral reef conservation and restoration?

Quantitative gene expression analyses have contributed to resolving the genomic basis of key physiological traits and increased understanding of coral adaptive capacity. In addition, a large and growing number of studies also reference potential conservation and restoration applications. Applied work has primarily focused on the development of methods to rapidly query stress responses and evaluate coral condition in situ, but several recent studies demonstrate the value of transcriptomics for assessing biodiversity across multiple scales of biological organization, from the structure and function of a single coral holobiont to adaptive variation among individuals and species. A review of the primary literature reveals that in addition to a lack of downstream development of promising discoveries, taxonomic and functional biases are a major barrier hindering the development of conservation-ready applications. Nevertheless, the ability to rapidly and accurately assess both functional and genetic biodiversity using a single method renders transcriptomics a powerful approach. Renewed focus on developing partnerships between researchers, managers, and practitioners, synthesizing the large body of existing transcriptomic datasets, and funding downstream development of promising tools will accelerate the integration of gene expression into conservation and restoration practice.

1131 Duncan Kennedy, Cassandra Donatelli, Kayla Hall, Kelsey Lucas

When fish fly: modelling the flapping flight of spotted ratfish (Hydrolagus colliei) pectoral fins

Chimaeras are an ancient group of cartilaginous fishes that swim by flapping their pectoral fins in a manner resembling bird flight. This unique swimming mode, termed flapping flight, induces a wave that travels from the leading to the trailing edge of the pectoral fin. The degree to which this waveform relies on fin flexibility versus fin ray structure is unknown. To determine how fin rays contribute to fin kinematics, we built a robot inspired by the spotted ratfish (Hydrolagus colliei). Using outlines of H. colliei pectoral fins, we designed multiple models with varying stiffness and internal structure and compared the kinematics of these models to the kinematics of live H. collei swimming in a flume. We find that embedding fishing line to mimic fin rays within models is necessary to reproduce the movement of ratfish pectoral fins. Understanding the role structure plays in swimming kinematics is essential for designing biologically faithful models and autonomous vehicles that perform as intended. Future work will compare morphological and swimming dynamic diversity across several chimaera species to provide insight into why this swimming mode evolved and reveal the functional tradeoffs that chimaeras may face.

1599 Deniz Kerimoglu, Nicholas Naclerio, Aradhya Rajanala, Alexa Mathis, Elliot Hawkes, Daniel Goldman

Cooperative effects of model root protrusions on extrusion and anchoring forces in granular media

Diverse living systems that interact with soft substrates can take advantage of complex structures (like those found in lizard toes) to modify local stresses and flows to improve intrusion (penetration) resistance. Less is known about how extrusion resistance is modified by complex structures. This is particularly relevant in plants as studies have shown that networks of hairs lining roots can increase anchoring force and enhance soil stability [Bengough et al.,J Exp Bot 2016]. To begin to develop principles for biological and engineering anchoring (extrusion) resistance, we study forces experienced by a rigid cylinder (8.3mm diameter) incorporating rigid protrusions (3mm by 5mm) as it is pulled from a model noncohesive soft substrate, dry granular media (1mm diameter particles). In laboratory experiments and validated Discrete Element Method simulations, we submerged the roots during fluidization and then performed extrusion experiments under constant displacement. We measured peak pullout force as a function of the distance between hairs. We observed that roots exhibited limited anchoring force for both too sparse or too dense hairs and peaked by approximately 3x in force at an intermediate spacing of 1-2cm between hairs. Our results are in accord with tests of a novel burrowing soft robot which generates hair-like structures during intrusion. Investigating the plant-inspired complex interactions with GM could inform future robot designs and control strategies, yielding effective robotic burrowing, maneuvering, and anchoring.

294 Kaitlyn Kern, Misty Paig-Tran

What's That on Your Head: A Morphological Investigation of the Cephalic Tenaculum in Chimaera

Chimaeras are chondrichthyan fishes that use internal fertilization as a mode of reproduction. Chimaeras have two accessory copulatory structures primarily found in males, the cephalic and pre-pelvic tenacula. These structures aid in grasping the female's pectoral or dorsal fins and ventral body during mating events. This study investigated the morphological variation of the tenacular denticles across taxa using scanning electron microscopy, CT imaging, and macro photography. With ImageJ and Photoshop software, we measured the density of denticles on the bulb, length, and width of the denticles on the cephalic tenaculum across the three families: the long nose chimaera (Rhinochimaeridae), the short nose chimaera (Chimaeridae), and the plow nose chimaera (Callorhincidae). We opportunistically documented the pre-pelvic tenaculum of Callorhinchus callorhynchus, a plow nose chimaera using macro photography. Stereopair images were created to understand the anatomy of the cup-like pouch that holds the denticulated cephalic tenaculum bulb. We found that the denticles of the cephalic tenaculum vary in their density, shape, and length among species. We found that the denticles of the pre-pelvic tenaculum in C. callorhynchus are flattened and more similar to the axial denticles in sharks while cephalic denticles are curved and pointed more similar to oral teeth. These data are critical for understanding the functional performance of the cephalic tenaculum during mating events in all families of Chimaera.

401 Abiageal Ketchersid, Sophi Brice, Jason Macrander

What happens when you take the sting out of venom?

The sea anemone Nematostella vectensis is an emerging model system to study the ecology and evolution of venom. Previous investigations into its venom repertoire have identified the sodium channel neurotoxin (Nv1) as a key venom component, highly expressed in adults throughout their distribution. A series of tandem duplication events within the Nv1 region of the N. vectensis genome have been attributed to this upregulation, with as many as 13 copies retained with high sequence similarity following a pattern of concerted evolution. Despite the ecological benefits of upregulating a key venom component, one population in Florida has experienced an extensive chromosomal reshuffling resulting in a near loss of the Nv1 toxin gene region and a dramatic reduction in Nv1 gene expression. To determine how this population may be affected by this reduced expression we examined their ability to defend against a typical grass shrimp predator (Palaemonetes sp.), an atypical nudibranch predator (Berghia sp.), and the commonly used brine shrimp (Artemia sp.) prey. We observed and recorded interactions between anemone and target organism for individuals from Florida and compared these to an established lab population with upregulated Nv1 toxins. Our results indicated that although the Florida population's ability to subdue prey quickly and defend against unfamiliar predators may be reduced, there were no notable differences observed when grass shrimp encountered both the established lab and Florida populations.

1654 Rehma Khan, Pete Hurd

Effects of Flutamide on Aggression and Courtship Behaviours in Kribensis Cichlids

Androgens are known to mediate male courtship behaviours such as aggression and courtship in teleost species. Short-term exposure to biologically active concentrations of flutamide can affect the fish at multiple levels and disrupt reproductive functions. This experiment will observe pre-mating behaviours, aggression, and courtship in Kribensis male and female cichlids, Pelvicachromis Pulcher. Male and female cichlids are treated with either androgen receptor antagonist flutamide or will be given a blank control. Following exposure to flutamide, fish are exposed to mirror aggression tests to observe aggressive behaviours. In this experiment, we test the hypothesis that flutamide inhibits androgen receptors and affects aggression and courtship behaviours in both male and female Kribensis Cichlids. Following this, we conduct an open field test to measure activity levels. Here we expose adult and juvenile cichlids to testosterone antagonist flutamide to assess the effects of this testosterone agonist on behavioural, morphological, and neurological traits and their development. The differences in courtship and aggressive behaviours associated with flutamide treatment are discussed as we hypothesize that males treated with flutamide will exhibit fewer courtship behaviours than males that are given blank controls.

910 Mia Kholy, Grace Anderson, Taylor Black, Jeremy Blackburn, Akshaya Ranjit, Michele Johnson

The Role of the Third Eye in Lizard Reproductive Physiology and Behavior

Almost all animals detect light through two lateral eyes. Yet, lizards (and many other ectotherms) also have a third eye, referred to as the parietal eye. This third eye is a translucent scale on the head that supplies light to the pineal gland in the brain, which regulates daily behavioral and physiological cycles. While known to be involved in melatonin production and thermoregulation, the role of the parietal eye in reproduction is largely unknown. Here, we altered light exposure to the parietal eye of Anolis sagrei (brown anole) lizards, a species that uses photoperiod as a reproductive cue. We captured 40 brown anoles (20 male, 20 female) and conducted male-female arena trials to identify a behavioral baseline. Then, “scale caps” (blackened bee marking tags) were glued onto the translucent scale of 20 lizards to block light from entering the parietal eye while scale caps were glued behind the translucent scale of 20 control lizards. After five weeks, we again conducted behavioral trials and then collected brains, testes, and liver tissues. Testes mass was marginally smaller in the experimental group, suggesting that these testes had begun to recrudesce, but preliminary analyses showed no difference in social display behavior between treatment groups. Overall, this study will further our understanding of the incredible parietal eye and the role it plays in seasonal cycles driven by light exposure.

954 Hesper Khong-Truong, Yuichiro Suzuki

Is Chinmo an essential regulator of the imaginal cells in Tribolium castaneum

Metamorphosis is the transformation of an organism’s form as it transitions from a juvenile to an adult stage. Recent studies have found that BTB domain transcription factor Chinmo is an essential regulator of the larval stage in Drosophila. Here, we utilized RNA interference (RNAi) to study the role of chinmo in the flour beetle, Tribolium castaneum. We found that chinmo inhibits the expression of the pupal specifier broad to prevent precocious development of pupal appendages. Moreover, Chinmo knockdown leads to precocious metamorphosis even in the presence of juvenile hormone (JH), indicating that it acts downstream of JH to maintain larval status of imaginal cells. Our research confirms that chinmo is an important contributor to the maintenance of the larval phenotype.

1060 Neil Khosla, Lauren O’Connell, Julie Butler

Evolution of microRNAs and social behavior in poison frog tadpoles

How new behaviors evolve in response to challenges and opportunities in their environment is a fundamental question in animal behavior. Neuroepigenetics affords us a framework through which we can study environmentally induced molecular changes in the brain that give rise to behavioral innovations. One group of epigenetic modifiers are microRNAs, small non-coding RNA molecules drawn to target sites on transcripts, where they can inhibit translation and reshape critical junctions of neural circuits. Research in many species has established that miRNAs can function as context-dependent social switches by inducing behavioral response to changing social environments. However, the role of miRNAs in juvenile aggression is unknown. Poison frog tadpoles show tremendous diversity in aggression, with some species being socially gregarious, others being violent cannibals, and others showing plasticity based on the social environment. Here, I quantify the miRNAomes in tadpoles of five species to test alternative hypotheses about miRNA-guided behavioral evolution. For one species of poison frog tadpole, I also quantify brain miRNA expression across varying social environments, revealing social environment-specific expression. To determine how this environment-specific miRNA expression influences behavior, I describe functional validation studies involving manipulation of miRNA expression in vivo. The goal of this work is to describe the role of microRNA in behavioral adaptation, underscoring the unique environment-sensing and circuit-reshaping capabilities of these small, non-coding epigenetic modifiers.

81 Kwanho Ki, Elizabeth Wu, Erin Lewis, Susannah French, Dale DeNardo

Effects of a high sugar diet on immune response in the green iguana

The immune system is critical to fitness with its primary purpose of defending against disease. Diet is especially important in supporting immunity, where abnormal dietary conditions may alter immunity. Given current concerns with obesity and the western diet, much attention has been focused on the health effects of a high sugar diet. Here, we investigated the effects of a high sugar diet on immune function in green iguanas (Iguana iguana). This study allowed us to test the downstream effects and interactions of a high sugar diet on the immune system and demonstrated the in vivo effects over multiple immunological challenges that are biologically and functionally relevant. We used a 2×2 design manipulating immunity (lipopolysaccharides or vehicle control) and sugar (dextrose or vehicle). We found the sugar groups had a reduced ability to kill bacteria 24 hours after a secondary immune challenge, when compared to the controls. The sugar group also had greater agglutination for several weeks following the lipopolysaccharide challenge relative to the control groups, suggesting potential immune stimulation.

These results corroborate mixed findings in the literature as to the inflammatory and inhibitory effects of sugar on the immune system. Regardless, there are significant health effects of sugar on immunity and future work should focus on long-term consequences of a high sugar diet as well as testing the effects of sugar on other physiological systems.

1280 Sarah Kienle, Renato Borras-Chavez, Carolina Bonin-Lewallen, Stephen Trumble, Emily Sperou, Dan Crocker, Michael Goebel, Shane Kanatous, Erin LaBrecque, Krista van-der-Linde, Dan Costa

Phenotypic plasticity across the species range of a Southern Ocean apex predator, the leopard seal

Leopard seals (Hydrurga leptonyx) are apex predators in the rapidly changing Southern Ocean. However, the scarcity of data on their biology makes it difficult to assess how these animals operate throughout the Southern Ocean and how they may be coping with environmental changes. Here, we assessed phenotypic plasticity in leopard seal morphometrics, spatial ecology, and diet/trophic position across their species range. We analyzed data from leopard seals sampled in Antarctica, subantarctic islands, South America, and New Zealand. Across their range, leopard seals show female-biased sexual dimorphism, where adult females are 1.5 times larger than males. Leopard seals also exhibit geographic differences in body condition, where subantarctic seals are in better body condition than seals from other areas. Leopard seals are flexible in their movement patterns and habitat use. Some seals show site fidelity and travel short-distances (1,000 km). Across their range, leopard seals have a diverse diet that varies as a function of sex, body size, and geography. Large adult females, for example, feed at higher trophic levels than males and smaller females. Together, our results showcase a high level of phenotypic plasticity in this apex predator across their range. This high degree of plasticity is likely advantageous, allowing leopard seals to adapt and respond to dynamic changes in their polar habitat.

186 Daniela Kim, Wing Ko, Kit Yu Karen Chan, Kaja Arusha, Sabrina Ellah, Krystle Boadi, Carolyn Bauer

Interplay between the endocrine stress response and cognitive assessments of anxiety-like behaviors

The goal of this study was to examine the relationship between the endocrine stress response and anxiety-like behaviors of the degu (Octodon degus), a caviomorph rodent endemic to Chile. We hypothesized that endocrine stress reactivity is positively related with anxiety-like behaviors in degus. To increase variation of the endocrine stress response, we cross-fostered some of our degus during the middle of postnatal development. At weaning, anxiety-like behaviors were measured through two cognitive assessments: the open field test and the light-dark box test. To assess the reactivity of the endocrine stress response, we collected blood samples to assess baseline, stress-induced, and post-dexamethasone (post-DEX) cortisol levels. We predicted that degus with more reactive stress responses (typified by higher stress-induced and post-DEX cortisol levels) would display higher rates of anxiety-like behaviors, such as more time along the perimeter of the open field test and more time in the dark portion of the light-dark box. We developed a user-friendly, open-source video tracking program to compute the total distance traveled, velocity, and percent time spent in the center of an open field test. Investigating relationships between the stress response and anxiety of degus will give further insight into the relationship between psychological states and physiological reactions in humans.

479 Melanie Kimball, Courtney Harding, Kaitlin Couvillion, Keegan Stansberry, Tosha Kelly, Christine Lattin

Estradiol and predator cues affect behavior and brain responses of captive female house sparrows

The presence of predators can cause major changes in animal behavior, but how this interacts with hormonal state and underlying brain activity is poorly understood. We gave female house sparrows (Passer domesticus) an estradiol ($n = 17$) or empty implant ($n = 16$) for one week. Four weeks after implant removal, we exposed birds to either 30 min of conspecific song or predator calls, and recorded behavior. Brains were then examined for neuronal activity using the expression of immediate early gene (IEG) ZENK. We predicted if female birds with estradiol implants “tune out” predator calls, they would show less fear behavior and decreased ZENK expression in brain regions involved in auditory (e.g., NCM) and threat perception (e.g., AMV) compared to controls. Female sparrows were less active during predator playback independent of hormone treatment and spent more time feeding during conspecific playback when previously exposed to estradiol. We observed an effect of hormone treatment, but no effect of sound treatment on ZENK expression. Our results suggest that songbirds maintain vigilance towards predators even during breeding condition and change their behavior accordingly.

1400 Melanie Kimball, Christine Lattin

The "seven deadly sins" of neophobia experimental design

Neophobia, an aversive response to novelty, is a behavior with critical ecological and evolutionary relevance for wild populations because it directly influences animals' ability to adapt to new environments and exploit novel resources. Neophobia has been described in a wide variety of different animal species from arachnids to zebra finches. Because of this widespread prevalence and ecological importance, the number of neophobia studies has continued to increase over time. However, many neophobia studies suffer from one or more of what we have deemed the "seven deadly sins" of neophobia experimental design. These "sins" include: 1) pseudoreplication, 2) lack of sufficient controls, 3) fixed treatment order, 4) non standardized motivation, 5) problems with novel object selection, 6) animals that are not habituated to the testing environment, and 7) using arbitrary thresholds for data analysis. We discuss each of these potential issues in turn and make recommendations for how to avoid them in future research. More consistency in how neophobia studies are designed would facilitate comparisons across different populations and species, and allow researchers to better understand whether neophobia can help explain animals' responses to human-altered landscapes and the ability to survive in the Anthropocene.

1505 Zoe King, Sydney Haywood, Giovanni Morris, Jeffery Anderson-Jr, Joshua Pulliam, Jerry Wong, Beckett Socha, Ulmar Grafe, Salwa Khalid, Jake Socha

Tongue-sticking in arboreal colubrids during gap crossing

Tongue-flicking in snakes is characterized by a rapid, high-frequency oscillation of the tongue, but other behaviors are known to be used. In tongue-sticking, the tongue is protruded statically without oscillation, a behavior previously noted in flying snakes (Chrysopelea) in the context of locomotion, specifically gap crossing and jumping prior to gliding. Is this behavior unique to flying snakes, or do other snakes also employ this form of tongue movement? And if so, how does the arboreal context influence the behavior? To investigate these questions, we recorded tongue behavior in sister taxa to Chrysopelea (Ahaetulla prasina, Dendrelaphis pictus, caudolineatus, and formosus) as well as outgroup species (Dryocalamus subannulatus, Boiga cynodon, drapiezii, and nigriceps, Lycodon capucinus) as snakes traversed a gap between two horizontally oriented perches. Snakes were first allowed to cross the perches in abutted position (a control, with no gap), and then were presented with gaps of 15%, 30%, and 45% SVL (snout-vent length) in random order. Among the species tested, only the close relatives of flying snakes (Ahaetulla and Dendrelaphis spp.) exhibited tongue sticking, present both in the control and gap trials. Furthermore, tongue sticking was more likely at the largest gap sizes, suggesting that tongue sticking plays a mechanosensory role associated with gap-crossing locomotion. This research was supported in part by the National Science Foundation under grant numbers 1922516 and 2027523.

506 Alexandra Kingston, Sarah Woodin, David Wethey, Rebekah Hansen, Daniel Speiser

Helmet-like orbital hoods protect snapping shrimp from shock waves

Shock waves are supersonic high-amplitude pressure waves that cause blast-induced neurotrauma in humans and other animals. Snapping shrimp (Alpheidae) produce shock waves with their snapping claws but do not seem to be harmed by them. We used behavioral trials to ask if snapping shrimp are protected from shock waves by a helmet-like extension of their exoskeleton termed the orbital hood. Then, we used pressure recordings and microCT to ask how orbital hoods may provide this protection. We found shock wave exposure slowed shelter-seeking and caused a loss of motor control in Alpheus heterochaelis from which we had removed orbital hoods but did not affect behavior in shrimp with unaltered orbital hoods. Shock waves thus have the potential to harm snapping shrimp but may not do so under natural conditions because of protection provided by their orbital hoods. We also discovered the orbital hoods of A. heterochaelis dampen shock waves. Sealing the anterior openings of orbital hoods diminished how much they dampened shock waves, which suggests these structures trap and expel water so kinetic energy is released away from the heads of shrimp. Finally, we found that orbital hoods are less dense than the surrounding exoskeleton which may contribute to shock wave dampening. Our results indicate that orbital hoods act as a helmet-like biological armor that dampens shock waves and protects snapping shrimp against blast-induced neurotrauma.

1198 Chase Kinsey, Richard Blob, Danielle Adams, Caleb Ratz

Bone density and mechanical properties across development in generalist and aquatic frogs

Limb bones of vertebrates have a critical role in transmitting forces that power locomotion. The loads that limb bones experience can vary in association with a range of factors, including locomotor environment or developmental stage. Neonatal vertebrates that are habitually found in environments with low locomotor loads might be predicted to also exhibit limb bones with less elevated mechanical properties. Frogs provide a distinctive case in which these ideas can be tested as they experience changes in both locomotor style and habitat as they develop. However, while many frog taxa shift from aquatic to terrestrial habitats as they metamorphose, some lineages, such as pipids, maintain an aquatic lifestyle even after metamorphosis. This study compares the mechanical properties and composition of the femur between generalist and aquatic frogs as they transition from metamorphic tadpoles to fully grown adults. MicroCT scanning was used to determine changes in bone density related to developmental stage and hindlimb use during swimming. Microindentation was then used to collect hardness values from the cortical bone of each femur, which were used to evaluate bone material properties. Changes in bone density and material properties across development may help to explain some of the differences in locomotor performance found between aquatic and terrestrial metamorphic frogs, providing insight into how environmental factors might correlate with bone ossification. Supported by Clemson University Creative Inquiry Project #479.

1272 Bonnie Kircher, Megan Meany, Douglas Menke, Richard Behringer

Female Reproductive Organ Anatomy and CRISPR Gene Editing of the AMH Locus in the Brown Anole

Reproduction modes across vertebrates are extremely diverse. Despite this, the reproductive organs of vertebrates have a similar architecture overall. In mammals, the reproductive organs develop from paired epithelial tubes called the Wolffian and Müllerian ducts. The Wolffian ducts contribute to the male reproductive organs whereas the Müllerian ducts contribute to the female reproductive organs. During embryonic development, the Wolffian and Müllerian ducts form in both sexes; however, Anti-Müllerian Hormone (AMH) secreted by the fetal testis induces the regression of the Müllerian Ducts and testosterone causes the differentiation of the Wolffian Ducts. The absence of AMH in female fetuses leads to retention of the Müllerian ducts and subsequent development of the female reproductive tract. Knowledge of these processes in other vertebrate lineages is limited. However, development of CRISPR genome editing techniques in non-mammalian systems has facilitated study of developmental mechanisms in a comparative context. Here, we present data from the brown anole (Anolis sagrei) exploring the development and adult architecture of the female reproductive system. We show that the adult female oviduct is divided into three regions that have unique transcriptome signatures. We have mutated the amh gene in A. sagrei and we present data on the role of amh in female A. sageri reproductive tract development. Our data complement histological studies of reproductive organ morphology and advance our understanding of reptilian reproductive tract development.

492 Jasmine Kirchner, Jacob Lasala

Ambient lighting effects on sea turtle nesting behavior in Sarasota County, Florida

Lighting can affect many nocturnal animals' behaviors by disorienting them and disrupting natural cues necessary for survival. Sea turtle behavior can be affected by artificial lights and repel nesting females from nesting beaches. To determine if ambient light affects normal nesting behavior, ambient light readings were taken at loggerhead (Caretta caretta) and green (Chelonia mydas) sea turtle nests or false crawls after the turtle had left the beach. Data were collected from 3 beaches in Sarasota County, Florida, and cloud coverage, moon phase, and moon presence were documented. We found that ambient light was significantly affected by the Julian date and the corresponding visible moon phases, as well as cloud coverage. There was no significant difference in ambient light averages between nests and false crawls, and ambient light increase did not significantly affect nesting success. Understanding how sea turtles are affected by lighting is essential to determine the best conservation methods for these threatened marine animals.

156 William Kirkpatrick, Sarah DuRant

Thermal Variation and Averages Oppositely Affect Breeding Behavior of Two Cavity Nesting Birds

Mean temperature is widely used to assess organismal responses to thermal change and little attention is given to the effects of thermal variation despite its equally important influence. Anthropogenic climate change will affect many aspects of cavity-nesting avian life, including shifts in parental behavior. We predicted that natural thermal variation would significantly alter breeding behavior in adult birds during critical stages of nesting. Using 208 nest-boxes across 5 thermally variable field sites, we examined how natural thermal variation impacts nesting behavior in Eastern Bluebirds and Tree Swallows. Using thermal probes in and outside of the nest, we quantified adult breeding behavior using NestIQ, a machine learning software which recognizes time spent off the nest by comparing internal and external nesting temperatures. Using linear mixed-effects models, we found that as thermal variation increased, individual and daily measurements of off-bout duration decreased during the egg incubation and early nestling stage when offspring rely heavily on parents for thermoregulation. Alternatively, individual and daily measurements of off-bout duration increased as average temperatures increased. We conclude that thermal variation and average temperature have alternate and equally important impacts on breeding behavior in each species. Incorporation of high frequency thermal variation is critical to understanding outcomes of climate change on the behavior of thermally sensitive organisms.

657 Danielle Kirsch, Barney Luttbeg

Does the timing of predation risk affect reproductive success across the lifetimes of snails?

Previous experiments in our lab have demonstrated that predator cue exposure early in life impacts survival and reproductive output in Physa acuta snails. Predator cue exposure also decreases the hatching success of a snail's egg masses, and hatching success worsens with age particularly strongly for snails with prior predator cue exposure (Auld & Houser 2015; pers. obs.). In this study, we seek to compare how predation risk exposure at three key points in a snail's life affects their reproductive output and the development of their offspring. These three key periods are 1) when a snail's egg mass is first oviposited, 2) immediately after a snail hatches from its egg, and 3) just prior to the onset of sexual maturity. I collected egg masses from wild-caught snails and randomly assigned them to one of four treatments: control, embryonic exposure, juvenile exposure, and adult exposure. All snails were randomly paired with three non-experimental control snails for 24 hours once per week for mating. I recorded the number of egg masses laid by each focal snail per day and randomly sampled two egg masses per snail per week. I recorded the hatch date of each sampled egg mass as well as its hatching success after two weeks. We compared individual and interactive effects of treatment and age on these metrics of reproductive output and success.

68 Kelly Kissane

The Effects of High Impact Practies on Student Success in Undergraduate Biology Courses.

Nearly 30% of STEM students switch from STEM majors to a non-STEM major according to the National Science Foundation. The reasons for switching to non-STEM majors include: uninviting atmosphere, difficult weed-out classes, and STEM courses that do not show their relevancy. High Impact Practices (HIPS), including independent research, writing intensive courses and diversity/global learning can not only increase student retention and engagement, but also help in improving equity. This talk will discuss the impacts of undergraduate research on student retention and student success in undergraduate biology courses.

1516 Sheila Kitchen, Robert Hall, Julian Wagner, Thomas Naragon, David Miller, Caltech Bi160 Class, Joseph Parker

Is Genetic Differentiation of Symbiotic Beetles Tied to Their Host Ant?

Rove beetles (Staphylinidae) comprise Metazoa's largest family: 64,000 mostly solitary, predatory species. From this ancestral state, many lineages have convergently evolved into highly social symbionts of ants. One symbiotic beetle, Sceptobius lativentris, integrates with their host ant, Liometopum occidentale, through behavioral adaptations in which they procure ant cuticular hydrocarbons (CHCs) during intense grooming. The beetles not only use the ant CHCs for entry into the ant nest, but also to prevent desiccation because synthesis of their own CHCs is highly reduced. In this study, we asked how does being an obligate symbiont impact S. lativentris population structure? Because S. lativentris are flightless, we predicted their dispersal range was limited to the ant foraging trails, and thus would experience reduced gene flow with increased inbreeding. Resequencing genomes of both species, we identified single nucleotide polymorphisms from 96 S. lativentris and 47 L. occidentale collected from 16 nests covering Southern California. Preliminary results revealed two distinct populations of symbionts and ants with evidence of local adaptation. Moreover, contrary to our prediction, the beetles exhibit high gene flow despite being wingless. This study highlights the dispersal patterns of a social symbiont and suggests high symbiont mobility between ant nests.

950 Brett Klaassen-van-Oorschot, Gerline van-Beusekom, Guillermo Amador

Improving biomimetic suction cups: What is the function of "sucker rings" in cuttlefish suckers?

Reversible adhesion presents a unique and ongoing engineering challenge that, once resolved, could reshape industry, medicine, and agriculture. Biomimetic engineering approaches have made significant improvements towards replicating the suction forces and reversibility of suction cups found in nature, but we still have much work to do. In an effort to further improve the function of biomimetic suction cups, we examine the role of a hardened proteinaceous ring (i.e. "sucker ring") found in decapodiform cephalopod suckers. While these rings are serrated and/or hooked in squid, presumably for anchoring into tissue, they are smooth in the common cuttlefish (Sepia officinalis). We hypothesize that in common cuttlefish this ring provides structural support to resist collapse under the low pressures achieved during suction. Additionally, the ring may provide a sealing surface in concert with hardened papillae that grow from the ring's edge. Here, we test the role of this ring by measuring adhesion force during suction before and after excising the ring in suction cups ex vivo. We then design biomimetic polymeric suction cups that incorporate a hard plastic ring and compare them to suction cups without rings.

1340 Luke Klein, Drew Stenesen, Jacob Moldenhauer, Arthur Sweeney, Sunny Scobell

Spectral sensitivity of the retina of the sex-limited color polymorphic damselfly, Ischnura ramburi

Intersexual conflict acts as a driving force for rapid shifts in morph density across subsequent generations of sex-limited color polymorphic damselfly populations. Mate preference trends demonstrate that males display a clear predilection for specific female morphs, even in the absence of female behavior; this suggests that visual recognition of specific color morphologies mediates mate-preference. However, comprehensive evidence is scarce regarding the underlying electrophysiology mediating the damselfly visual system. We investigated the relationship between morph/sex and spectral sensitivity of the compound eye in the Rambur's forktail damselfly, Ischnura ramburi, which has conspicuous female-limited color polymorphism: male-like andromorphs sport bright blue andor green coloration, and gynomorphs display more muted olive grey/green colors. Here we measured graded responses to light stimuli ranging from UV to red for males and each female morph to gain a better understanding of the I. ramburi visual system.

796 Andrew Knapp, Gizeh Rangel-de-Lázaro, Anjali Goswami, Matt Friedman, Sam Giles, Kory Evans, Zerina Johanson

How to tuna fish: Mosaic evolution in the skulls of pelagiarian fishes

Teleost fishes comprise roughly half of all extant vertebrates, numbering some 30,000 species, and have adapted to a side range of freshwater and marine habitats. The skulls of teleost fishes are composed of a large number of kinetic elements, involved in sensory housing and structural support (neurocranium), and feeding and respiration (jaws, suspensorium and operculum). Understanding morphological integration and disparity between the various elements of the teleost skull is therefore a vital step in understanding the evolution of this complex structure. This high morphological diversity and fairly small size of the clade Pelagiaria, including mackerel and tuna, makes it a good candidate for such a study. Using three-dimensional geometric morphometrics, we analysed whole-skull morphology of over 130 pelagiarian species, encompassing 14 of the 16 families and over 90% of genera. Around 40% of total shape disparity is correlated with elongation of the skull, reflecting body elongation and therefore swimming performance. Despite the clear separation of families at extreme morphologies, phylogenetic signal is low ($Rsq = 0.27$, $p = 0.001$). The kinetic elements of the skull are weakly integrated with the rest of the skull and are correlated with feeding ecologies. Our results show that the evolution of skull shape in pelagiaria is driven by a combination of factors, principally streamlining and feeding mechanics, allowing for the evolution of extreme morphologies in the open ocean.

432 Hungtang Ko, Yangfan Zhang, George Lauder, Radhika Nagpal

Tracking transient formations of fish schools

Schooling allows fish to reduce metabolic expenditure as they traverse the water. It is thought that they yield the energetic benefit by adopting a fixed formation that is hydrodynamically favorable, such as a diamond shape. But in practice, fish often rearrange their positions. In this project, we quantify the dynamic formation of giant danios (Devario aequipinnatus) in flows of different speeds and regimes (laminar vs. turbulent). We develop semi-automated algorithms that track individual fish within the school and reconstruct their 3D trajectories from multiple angles. Time series of multiple metrics, such as the school's centroid, density, and shape, are extracted. We discovered that fish schools exhibit a denser formation as the flow speed increases. Fish schools are located more downstream in turbulent flows than in laminar flows of the same speed. The new analytic approaches and findings promise new insights into the locomotive strategies of fish in schools and fish schools as a whole.

848 Hungtang Ko, Mathias Hagdu, Keyana Komilian, Ting-ying Yu, David Hu

Collective behaviors of fire ants on the water surface

To survive flooding seasons common in their natural habitat, the Pantanal wetland, imported fire ants (Solenopsis invicta) have evolved to build floating rafts consisting of hundreds of thousands of individuals. How do they interact with the fluid environment? In this study, we examine the collective behaviors of fire ants over both a short (5 minutes) and a long (10 hours) timescale. Surprisingly, we discover that ants prioritize separation and exploration: within minutes after being placed on the water surface, they flail their legs and bounce off neighbors when they collide. As a result, rafts consisting of fewer than ten ants disintegrate. The cohesion among floating ants is facilitated by the Cheerios effect, a capillary force that attracts small floating objects such as breakfast cereal. Over a longer period of time, fire ants start to exhibit adaptive behaviors. Large rafts stabilize and contract slowly after an initial expansion. When situated in a slow current of 6 cm/s, ants lowered their building activities at the leading edge of the raft. Consequently, the raft morphs into an elongated shape that reduces fluid drag. We complement the experimental results with theoretical models and numerical simulations. Together, we conclude that the success of fire ant rafts owes to both their physical properties and their behavioral strategies.

350 Orhun Koc, Ismail Uyanik

A Novel Experimental Setup to Study Multisensory Integration of Zebrafish During Rheotaxis

Animals perceive their environment through signals captured by different senses. The CNS constructs a representation of the environment by continuously integrating these signals. Our goal is to build a novel experimental setup to identify the dynamics of multisensory integration of freely-swimming zebrafish during rheotaxis. To achieve this, we built a swim tunnel for adult Danio rerio to perform rheotaxis against water flow. During rheotaxis, zebrafish orient their bodies toward the flow for station keeping. The key feature of the proposed setup is that we place a transparent D-shaped tube within the test area to obscure the flow in its surroundings. The obstacle forms a low-gradient regime, motivating the zebrafish to swim behind it. This tube is attached to a linear actuator, moving horizontally to change the location of the low-gradient regime. Besides, we placed a model zebrafish inside the transparent tube —attached to a different linear actuator— to generate visual stimulation. This allows us to separately generate visual and mechanosensory cues for the zebrafish. This is crucial to identify the dynamics of multisensory integration during free behavior. We tested $N = 5$ adult zebrafish using synchronous and conflicting stimuli. We estimated the frequency response functions for the closed-loop tracking behavior of the fish. Our results showed that zebrafish need mechanosensory stimulation to initiate the tracking response but utilize the visual cues to reduce behavioral variability.

285 Rebecca Koch, Geoffrey Hill, Yufeng Zhang, Matthew Toomey

House finches use an alternate pathway for red carotenoid pigmentation

The red, orange, and yellow carotenoid-based colors of birds have prompted research into the proximate mechanisms underlying expression and the ultimate forces shaping their form. A common North American songbird, the house finch (Haemorhous mexicanus), has become a textbook example of carotenoid-based color signaling where male coloration appears to be a quality-dependent signal used in mate choice. A wide range of studies have explored how male house finch plumage redness varies with physiological traits and challenges, yet questions remain as to the molecular pathways underlying color expression. Recently, a two-step enzymatic mechanism, which includes cytochrome P450 2J19 (CYP2J19), was described for the biosynthesis of red carotenoids in the avian retina and plumage of some bird species. To determine if house finches use this same mechanism, we assayed the house finch homologs of these enzymes in cell culture. Interestingly, we found that expression of CYP2J19 and its partner enzyme were not sufficient to produce the primary house finch ornamental pigment, 3-hydroxy-echinenone, though they do produce other red carotenoids. Moreover, RNA sequencing data revealed essentially no expression of CYP2J19 in the livers or growing feather follicles of house finches. We propose that house finches use an alternative enzymatic pathway to produce their characteristic red carotenoid-based coloration, which may explain the exceptionally large color variation observed in male house finches.

1696 Kristen Koenig, Christina Daly

Gene Regulation and Lens Evolution in the Squid Doryteuthis pealeii

The lens is a requisite innovation for high resolution vision. Coleoid cephalopods, including squid, cuttlefish and octopus, have a single chambered eye, similar to the vertebrate visual system, and have evolved a refractive lens in the anterior of the organ convergently. The developmental mechanisms underlying lens evolution across species remain largely unknown. Our interest is to better understand ontogeny and gene regulation of the lens in the squid Doryteuthis pealeii with the goal of revealing regulatory mechanisms involved in elaborating simple visual systems into more complicated morphologies. We have performed an in depth time course description of lentigenic cell differentiation and lens formation, performed scRNA-seq and large scale in situ hybridization experiments to better define the anatomy of the tissue as well as distinguish cell type identity and differentiation of the anterior segment and lens tissue. In addition, we have performed scATAC-seq to better evaluate key regulators of crystallin expression and lens development. This comparative dataset not only provides an unparalleled resource to the community but also gives greater insight into how the cephalopod has gained this novel trait and visual system complexity evolves.

1066 Abbigale Koenigsmark, Robyn Crook

Injury-induced nociceptive sensitization affects male contests in the cuttlefish Sepia bandensis

Nociceptive sensitization has been shown to reduce predation risk after injury, however, the protective behaviors that are upregulated during subsequent predation encounters cannot enhance fitness and cannot be selected if the animal fails to reproduce. Whether injury-induced nociceptive sensitization can alter reproductive behavior, compensating for potential losses to reproductive success, has never been studied. With their complex mating behaviors, cuttlefish (S. bandensis) are interesting and novel models for understanding the potentially adaptive function of nociceptive sensitization on reproductive success. Our goal is to assess the effects of injury on male agonistic contests, a behavior integral to reproduction in cuttlefish, and determine whether the presence of nociceptive sensitization changes male behavior during contests. We studied stumpy-spined cuttlefish (Sepia bandensis) contest behavior by analyzing interactions between males with different injury-like skin manipulations and controls. We are currently characterizing behaviors, contest outcomes, and other variables in control/control and control/sham-injury dyads. Ongoing work will examine the effects of minor abrasion injury on contest behavior. We hypothesize that males experiencing nociceptive sensitization after minor injury will be more successful than injured males with sensitization blocked by pharmacological manipulations. This study will be the first to assess how nociceptive sensitization may serve as a mechanism selected to compensate for the reproductive costs of injury.

900 Jack Koger, Sarah Foltz, Jamie Lau

Biodiversity of Insects in Southern Appalachian Burial Grounds Along an Urbanization Continuu

Urbanization is one of the many threats to biodiversity; however, urban areas can also contain remnants of previously existing ecosystems and provide alternative homes for native species that are able to tolerate the challenges within them. Although not disturbance-free, North American burial areas are commonly associated with large areas of vegetation and low levels of human activity. Our study focused on cemeteries in Appalachia, a region notable for high levels of biodiversity and endemic species. Focal cemeteries varied in age, urbanization level (rural, small town, small city), and size. We compared insect abundance, richness, and diversity across these variables. We collected insects from ground-level substrates using a hand-held sweep net. We conducted two 25m sweep-net transects at four randomly selected sites in each cemetery. Our analyses are on-going. We predict that: 1) older cemeteries will have higher biodiversity, 2) cemeteries in highly urbanized areas will have higher species richness but potentially lower diversity, than less urbanized areas, and 3) larger cemeteries will have higher diversity than smaller cemeteries. This study has the potential to help us better understand the role these burial areas may play in protecting and supporting wildlife communities, especially because these preserved green spaces are common across all levels of urbanization.

1587 Velin Kojouharov, Tianyu Wang, Christopher Pierce, Kelimar Diaz, Baxi Zhong, Daniel Soto, Valerie Zborovsky, Daniel Goldman

Bilateral actuation mechanism for complex terrain navigation in limbless robots

Limbless animals excel at locomotion in complex aquatic and terrestrial environments such as oceans, forest floors, and deserts. For years, limbless robots have been developed to study the mechanisms underlying the capabilities of their biological counterparts. We posit that the bilateral actuation mechanism of muscles and passive body mechanics in animals facilitates effective limbless locomotion; such mechanisms have rarely been applied to limbless robots. Building on previous work (Schiebel and Maisonneuve, et al., Living Machines., 2020), we developed a limbless robot featuring a bilateral actuation strategy (L = 86cm, 7 joints), inspired by the morphology of limbless animals (e.g., snakes, nematode worms). The robot also features an elastic mesh skin for smooth robot-environment contact, detachable modular wheels for variable drag anisotropy, and strings for actuation. Servo motor pairs in each joint wind/unwind these strings (i.e, muscles) on either side of the body, bending each body segment. This bilateral actuation scheme via independent control of muscle pairs enables scalable passivity, allowing for unprecedented open-loop capabilities in lab model terrains like lattices, channels, and granular media. Lattice and channel experiments revealed that by using scalable passivity, the mechanical cost of transport is reduced by nearly 50% compared to robots with strictly rigid bodies. Moreover, we have designed vertically bending modules using the same bilateral actuation approach which we hypothesize can extend the robot's capabilities into 3D spaces.

100 Matthew Kolmann, Richard Harrington, Matt Friedman

In a rush to catch their breath? Body shape diversification in the labyrinth fishes and their allies

Key innovations, like powered flight, are traits or character suites that fundamentally alter the manner in which these animals interact with their biotic and abiotic environment. Changes in the nature of these interactions are so radical, that the ecological diversification of the lineage as a whole should be markedly different from sister taxa lacking such an innovation. We explored whether the myriad means by which labyrinth fishes and their allies breathe air can be considered a key innovation, using body shape diversity as a phenotypic proxy for ecological function. The anabantarian or synbranchiform fishes exhibit a suite of different air-breathing structures, from vascularized pharyngeal sacs to complex air-breathing organs called labyrinth organs. Some of these fishes will actually drown if prevented from breathing at the water's surface. We radiographed 155 species and 402 individuals in total from all major clades and used 2D geometric morphometrics to characterize changes in their body shape. We tested whether air-breathing lineages exhibited higher rates of lineage diversification using Bayesian methods for estimating rate shifts and tip rates. We also tested whether morphospace occupation was inherently different among air-breathing and non air-breathing lineages. We also assessed whether any shifts in lineage or ecological diversification were better explained by continental invasion, i.e., that Southeast Asian or African continental fish assemblages exhibited different diversification regimes. Anabantarians/synbranchiforms show some indications of an early.

137 Gayathri Kondakath, Annushka Veliko-Shapko, Barry Trimmer

Nociception in Manduca sexta

Defensive behaviors are ubiquitous in animals, often activated by nociceptors. In the tobacco hornworm (Manduca sexta) caterpillar this consists of sudden movements in response to strong thermal or mechanical stimuli. Manduca has two distinct defensive behaviors: movement of the anterior body away from the stimulus ('withdrawal') or a rapid turn of the head and thorax towards the stimulated site ('strike'). The likelihood of withdrawal is strongly associated with stimuli towards the head or thorax, whereas strike results from stimuli on posterior abdomen segments. Stimulation of the anterior abdominal segments can initiate either behavior, even in a single individual, suggesting that the two motor programs are similarly connected to noxious stimuli. We are studying the factors that control program selection and the role of sensory context and behavioral state. For example, if Manduca is disturbed prior to a stimulus it can "freeze" in a sphinx position, with a drastically reduced tendency to strike or withdraw. Since nociception is the first step of conserved pain perception pathways across the animal kingdom, Manduca offers a tractable and ethical model system for studying pain processing and its alleviation in animals. We plan to follow up our results with electrophysiology readings from muscles that evoke nocifensive behaviors, as well as in vitro preps to demonstrate the underlying nociceptive circuit.

805 Emma Kordek, Amaya Yip, Alicia Horton, John Hatle

Effects of dietary protein quality on fecundity and longevity in grasshoppers

Dietary protein quantity increases animal reproduction but decreases lifespan. This reproduction vs. longevity trade-off may be broken by editing dietary protein quality, thus providing sufficient levels of all essential amino acids but not excessive levels of any amino acid. A diet with amino acid composition similar to yolk protein enhances growth and reproductive output without compromising lifespan in Drosophila. Similarly, in lubber grasshoppers, dietary amino acids can be matched to the composition of the precursor to egg yolk protein (vitellogenin; Vg). Adult females force-fed a liquid diet matched to Vg had increased reproduction and storage. This project uses agar-based diets with specific amino acid compositions, fed ad libitum. We test fecundity and longevity of grasshoppers using four diet treatments: high-quality protein (Vg-matched), an isonitrogenous low-quality diet, lettuce (positive control), and a negative control. Here we present direct comparisons of reproduction by the high- and low-quality diet groups. At least two clutches were laid by a greater percentage of grasshoppers on high-quality diet than those on low-quality diet (chi-square; $P = 0.04$). Of those that laid, these two groups showed no differences in clutch timing or size (MANOVA; all $P > 0.05$). During the second clutch, grasshoppers on high-quality diets weighed more, but did not eat statistically more, than those on low-quality diets, suggesting greater somatic storage. Protein quality may increase laying frequency and somatic storage in early adulthood.

86 Anne Kort

Testing the function of interlocking zygapophyses in lumbar vertebrae of early placental mammals

The lumbar column, a region of the spine unique to mammals, facilitates sagittal bending during locomotion. However, unusual lumbar morphology in extinct mammals suggests that this function has changed since the radiation of placental mammals 66 million years ago (mya). Many extinct placental mammals, including hyaenodonts, mesonycids, and arctocyonids, had interlocking zygapophyseal articulations, hypothesized to restrict axial torsion in the spine. I tested this hypothesis with the hyaenodont Limnocyon potens, a raccoon sized omnivore from the early Eocene (50-55 mya). I compared the range of motion (ROM) of the actual, interlocking joint morphology with an edited version of the vertebrae with artificially flattened zygapophyses. I microCT scanned the intact vertebral column from AMNH FM 13138 and segmented the vertebrae in 3D Slicer. I used Geomagic Design to clean and smooth the vertebrae and create a second set with flattened zygapophyses. I exported the vertebrae to Maya and used the Python package AutoBend to measure the ROM. This package systematically rotates the vertebrae around the joint until a bony intersection or joint strain is detected. After repeated trials with varied parameters, I found no difference in ROM between the unedited and edited zygapophyses. This shows that while intact, the interlocking joints have little effect on ROM. Instead, this morphology may buttress the joint against disarticulation, particularly shear forces that would sever the spinal cord.

316 Andrew Kovac, Henry Astley, Colleen Unsworth, Matthew Tarchick, Sarah McInerney

The Effects of Crocodilian Tail Serrations on Water Surface Disturbance

Semi-aquatic animals often have morphological features affecting locomotion hydrodynamics, such as increased surface area on propulsive structures for imparting momentum to larger volumes of water. Crocodilians use broad, laterally compressed tails to propel themselves through water, however, their dorsal scale serrations leave gaps, sacrificing tail area. Most crocodilians ambush terrestrial prey from shallow shorelines, requiring camouflage and stealthy movements near the surface. We hypothesize that serrations disrupt large-scale flow structures from tail movements and reduce visible surface disturbance. To test this hypothesis, we used a linear actuator to translate several serration patterns just beneath the water surface while recording the reflection of a fan-beam laser aimed at the water surface to visualize the resulting waves. From this video, we used Continuous Wavelet Transform (CWT) to quantify non-stationary spatial disturbances at a continuous range of frequencies via a global power spectra in which the magnitude of power represented the size of visible surface disturbances. These spectra demonstrated variance between the average intensities of each serration type across frequencies, suggesting that morphology has a significant impact on the amount and frequency distribution of water surface disturbances generated by serrations moving at the air-water interface. Understanding the effect of different serration types could uncover insights into bio-inspired noise or turbulence reduction and demonstrate the utility of CWT for measuring surface disturbance and three-phase interfaces.

924 Johanna Kowalko

Genetic underpinnings of behavioral evolution in the blind Mexican cavefish

Animals exhibit a vast array of different behaviors. Identifying the genes underlying behavioral diversity is challenging. We are investigating the genetic basis of behavioral evolution in the blind Mexican cavefish, Astyanax mexicanus. A. mexicanus exist in two forms, a river-dwelling surface form and a blind cave form. Cavefish from multiple, independently-evolved populations have repeatedly evolved a suite of traits including regression of eyes and reduced pigmentation, reduced sleep and alterations to social and foraging behaviors. We have established the use of CRISPR-Cas9 gene editing in A. mexicanus to investigate the genes underlying behavioral evolution in this species. We have evaluated the role of multiple genes implicated in the evolution of behavior in cavefish. For example, the oculocutaneous albinism 2 (oca2) gene is responsible for albinism in multiple cave populations. Utilizing surface fish with engineered mutations in oca2, we found that mutations in oca2 also cause changes to sleep and feeding behaviors. We are currently investigating additional genes implicated in the evolution of behavior in this species, as well as the neuronal bases of these changes. Together, these studies provide insight into the genetic basis of behavioral diversity in natural populations, and demonstrate that there is a link between morphological and behavioral traits.

1686 Mihika Kozma, Jorge Pérez-Moreno, Neha Gandhi, Luisanna Hernandez-Jeppesen, Tomer Ventura, Donald Mykles

The hunt for MIH Receptor: a quest to find missing pieces of the crustacean molt inhibition puzzle

Molt-inhibiting hormone (MIH) is a key component in regulating the crustacean molt cycle. This neuropeptide is secreted from the X-organ (XO) in the eyestalk ganglia, and acts on the Y-organ (YO) in the cephalothorax. MIH sustains the YO in its basal state, thereby inhibiting ecdysteroid synthesis and, consequently, molting. MIH belongs to the crustacean hyperglycemic hormone (CHH) superfamily, whose receptors have not been characterized in crustaceans. These receptors are predicted to be G protein-coupled receptors (GPCRs) because their downstream signaling mechanisms, such as cyclic nucleotide second messengers, have been shown to regulate molting. The goal of this research is to deorphanize candidate receptors to MIH and CHH expressed by the YO of the blackback land crab, Gecarcinus lateralis. Sequence homology to functionally characterized receptors for another member of the CHH superfamily, ion transport peptide, in the silk moth (Bombyx mori) was used to identify candidate MIH/CHH receptors. Previous research identified four candidates among >90 class A GPCRs from YO transcriptomes. This study classified three additional putative MIH/CHH receptor sequences in G. lateralis using phylogenetic analyses with a custom transcriptomic database of >190 crustacean species. The structures of MIH, CHH, and their candidate receptors are modeled to identify the best-fit pairs. The identification of target receptors for MIH will solve a big piece of the puzzle in the story of crustacean molting. Support: NSF (IOS-1922701).

1475 Alexandra Krak, Jason Bystriansky, Caleb McMahan

Salinity tolerance of the swordtail, Xiphophorus hellerii

The swordtail, Xiphophorus hellerii, is a freshwater fish species native to Mexico and Central America and is commonly used in the tropical aquarium trade. Swordtails have been shown to have limited survival in 6 ‰ salinity (Nanda et al., 2016), suggesting they may have a greater salinity tolerance than previously expected. Using a gradual acclimation method, we examined the salinity tolerance and swim performance of this species. Freshwater-reared female swordtails were housed in 29-gallon aquaria. A control group was held in freshwater throughout the experiment. For the experimental group, the salinity was increased by 2 ‰ every week for nine weeks, to a maximum of 18 ‰. Over this period, there were no mortalities. Critical swimming speed (Ucrit) was determined repeatedly for each individual fish (every second week) for both control and salinity acclimated (at 0, 4, 8, 12, and 16 ‰) fish to assess the impact of increased salinity on swimming performance. The critical swimming speed was stable throughout the study for the control group. An initial increase in swim performance was seen at 4 ‰ salinity but then decreased to control levels by 8 ‰ and was not different from control rates for the remainder of the experiment. Based on these results, swordtails can tolerate much higher salinity than originally thought, with minimal impact on their swimming performance.

883 Alexandra Kralick

Skeletal Variation in Adult Orangutans (Pongo sp.) Defies Expectations of Sexual Dimorphism

Orangutans are typically described as exhibiting high sexual dimorphism between males and females, although they also show pronounced within-sex size differences. All males eventually become flanged males, with large cheek pads (flanges) and throat pouches. Most males develop flanges during puberty, but not always. Some males delay the maturation of flanges for anywhere from a few to 20 years. These phenotypically "immature" but reproductively capable males are called adult unflanged males. Only males living in the wild are known to delay the maturation of flanges into adulthood, as male orangutans in zoos typically develop flanges within the pubertal transition. While assessing these maturational changes in captive populations has been possible, measuring body size in wild populations is challenging, limiting our knowledge about adult unflanged males. Orangutan skeletons from wild-shot individuals in museum collections thus offer a unique opportunity to measure features that correlate with aspects of body size, such as long bone length, strength, and bi-iliac breadth. We therefore measured 98 adult orangutan skeletons from 9 museums across the USA and Europe. Our results show that adult unflanged male sizes ranged between those of adult flanged males and adult females. These findings indicate that orangutans are not a sexually dimorphic species per se, and raise intriguing questions about the factors that shape male orangutan phenotypic and sexual maturation in the wild.

64 David Kramer, Frank Fish, Maura Sheehan

Thrust production and chordal flexion of the flukes of bottlenose dolphins performing tail stands

Dolphins are powerful animals capable of tail stands. Tail stands are where a vertically oriented dolphin produces thrust by horizontal strokes of the tail flukes to lift the anterior body out of water. Strong, efficient propulsion generates the force to support the weight above the water. To determine how thrust production, fluke flexibility, and stroke kinematics vary with effort, six bottlenose dolphins (Tursiops truncatus) were tested at three effort levels based on the position of center of mass (CM) relative to the water surface: low (CM below surface), medium (CM at surface), and high (CM above surface). Fluke flexibility was measured as a flex index (FI = chord length/camber length) at four points in the stroke cycle: center stroke up (CU), extreme top of stroke (ET), center stroke down (CD) and extreme bottom of stroke (EB). Video recordings were analyzed to determine the weight supported above the water (= thrust), peak-to-peak amplitude, stroke frequency, and FI. Force production increased with low, medium, and high efforts of 531.9N, 773.4N, and 976.9N, respectively. Amplitude remained constant at 33.8% of body length. FI decreased at ET and EB with increased effort. Changes in FI and stroke frequency allowed for increased force production with effort and the peak-to-peak amplitude was higher compared to horizontally swimming dolphins. Kinematics of tail stands exhibits similarities with hovering of birds.

679 Berit Kramer, Jessica Whelpley, Gustav Paulay, Abigail Uehling

Trans-basin Connection: A pair of Atlantic and Indo-Pacific Sea Cucumbers are Conspecific

The tropical West Atlantic (WA) has developed a largely endemic biota as it is separated from the great Indo-West Pacific (IWP) region by land and latitudinal barriers. Many species that were thought to be shared between these regions turned out to be divergent upon genetic scrutiny, although others appear connected (Bowen et al 2001). Other species thought to be separate between these regions show substantial resemblance. We tested the hypothesis that the similar sister species of sea cucumbers, Holothuria difficilis (Semper, 1868) in the IWP and H. parvula (Selenka, 1867) in the WA are conspecific. We sequenced the mitochondrial COI and nuclear H3 and ITS, from several populations of both species and analyzed the sequence data using a maximum likelihood and Bayesian framework. We also measured and compared button and table ossicles between them using principal component analysis (PCA). Results show minimal differentiation, indicating that H. difficilis and H. parvula are the same species. Some geographic clustering suggests that the broad range is not the result of anthropogenic transport, but of larval dispersal around the Cape of Good Hope.

1386 Anjali Krishna, Trina Chou, Mark Fossesca, Avani Desai, Megan Gall

Masking or Distraction? : how anthropogenic noise reduces songbird responses to predator threats

Natural and anthropogenic acoustic noise is known to disrupt anti-predator behaviors and social communication, but the mechanism by which responses are depressed is not yet clear. Noise within the same sensory domain as the predation cue, such as acoustic anthropogenic noise, can overlap with the frequency range of an anti-predator vocalization and may reduce responses via masking. However, noise across sensory domains may also result in distraction, such as acoustic noise distracting from the visual recognition of a predator. Here, we used a repeated measures experiment to determine whether masking or distraction is the primary mechanism underlying decreased response to predation cues. We found mixed support for both hypotheses. Black-capped chickadees (Poecile atricapillus) decreased the number of mobbing calls and decreased the number of D-notes per call in the presence of noise. The decrease was equivalent across visual and acoustic predator cues, suggesting that distraction rather than masking was at play. However, white-breasted nuthatches (Sitta carolinensis) decreased the number of alarm calls in noise when presented with an acoustic predator cue, but there was no effect of noise on calling rate directed towards a visual predator cue, suggesting masking rather than distraction. Overall, our results suggest that the mechanisms underlying noise-induced changes in anti-predator responses may depend on the intensity of noise, as well as the species-specific behavior of the organisms.

1834 Deepak Krishnamurthy, Rachel Pepper, Manu Prakash

Active Sinking Particles: Sessile Suspension Feeders affect Flow and Transport to Sinking Aggregates

Sinking or sedimentation of biological aggregates plays a critical role in carbon sequestration in the ocean and in waste-water treatment plants using "activated sludge" processes. In both these contexts, the sinking aggregates are "active", since they are hot-spots of biological activity and are densely colonized by microorganisms including bacteria and sessile protists, some of which generate feeding currents. However, the effect of these feeding currents on the sinking rates, trajectories, and mass transfer to these aggregates has not previously been studied. Here we use a novel scale-free vertical-tracking microscope (a.k.a. Gravity Machine, Krishnamurthy et al. 2020) to follow model sinking aggregates (agar spheres) with attached Vorticella over long distances while simultaneously measuring local flows. We find that attached Vorticella cause substantial changes to sinking trajectories, rotation rates, and also re-shape boundary layers near the aggregate. We postulate that these hydrodynamic effects are likely to lead to very different mass transfer rates than for particles without attached organisms, and are also likely to change the sinking dynamics of these aggregates, both in marine and fresh-water contexts.

781 Aaron Krochmal, Timothy Roth, Travis LaDuc, Brian Palmer, Josephine Cleverdon, Daniel Ardia, Aaron Place

Snake, Rattle, and (B)Roll: Animal responses to rattlesnake rattling revealed by field videography

The rattlesnake rattle is one of the most charismatic forms of animal communication thought to serve as an honest predatory deterrent signal. Surprisingly, we know little about rattle use and virtually nothing about how animals naturally respond to its sound. Furthermore, though several hypotheses addressing the evolutionary origin of the rattle have been proposed, none of them has been subjected to rigorous experimental scrutiny. To begin to fill in these gaps in our understanding of the origin of, roles of, and responses to the rattlesnake rattle, we observed the responses of free-ranging animals to the sound of the rattle across broad ecological and biogeographical contexts. Using remote videography coupled with automated audio playback, we recorded the responses of numerous vertebrate taxa to the rattlesnake rattle or several natural or anthropomorphic sounds in three areas: areas where animals were sympatric with rattlesnakes, areas in which rattlesnakes have been recently extirpated, and areas outside the historic distribution of rattlesnakes. Our analysis of thousands of videos provides the first exhaustive insight into how a wide range of vertebrate taxa across a wide biogeographic area respond to the rattlesnake rattle. Further, our results shed light on the behavioral and ecological forces that might contribute to this response and allow for the critical evaluation of current hypotheses explaining the evolutionary origins of this unique communication system.

574 Grace Kropelin, Clare Scott-Chialvo

Assessing the impact of novelties on a generalist species' (polka-dotted fruit fly) life history

Novel adaptations can significantly impact organisms' resource use, behavior, and evolution. One such class of novelty, tolerance to highly toxic compounds, is generally associated with losing the ability to feed on a wide range of hosts. Much work has been done to examine the connection between this type of novelty and host specialiation. However, far less is known about how a trait linked with specialization impacts the life history of generalist species in which it will experience inconsistent selection and potentially have fitness costs. One example of this form of toxin tolerance in generalist species is found in mushroom-feeding flies in the immigrans-tripunctata radiation of Drosophila, which are tolerant to deadly cyclopeptide toxins that are found in a small proportion of their hosts. While the occurence of this novelty within the radiation is well documented, its impact on life history and evolution is poorly understood. In this study, we used a combination of feeding and behavioral assays to assess whether one cyclopeptide tolerant species (Drosophila guttifera) is transitioning from a generalist to specialist feeding behavior. Our results indicate a potential preference for mushrooms that do not contain the toxins in both the female flies and larvae, thus raising further questions regarding how this novel trait is maintained within the species.

1014 Duyi Kuang, Stanley Wang, Sebastian Lee, Lawrence Wang, Robert Full

Kinematic paw adjustments of fox squirrels landing on curved surfaces

The remarkable ability to leap and land on unfamiliar and unstable surfaces is instrumental towards squirrels' survival in arboreal environments. Here, we examine the critical role of paw mechanisms of free-ranging fox squirrels (Sciurus niger). A field apparatus was constructed allowing high-speed cameras (500 fps) to image through transparent acrylic fixtures for high-resolution multi-view visualization of paw-surface interactions during landing. Jumping gap length and curvature of the landing surface were varied by using a flat acrylic plate and acrylic rods of different diameters (0.75, 1.625, 2.5 in). Kinematic modeling of the squirrel's paw was subsequently extracted through point-tracking of key landmarks on the plantar surface of the front paw including individual digits. For landing on a flat surface 50 cm away, extensive spanning of digits occurs upon touchdown with an average angle of $86\pm13^{\circ}$ between outermost digits. Comparatively, at the highest curvature rod, the span of the outermost digits decreased significantly by 37% to $51\pm8^{\circ}$. We observed similar trends across all curvatures at varying gap lengths for three individuals suggesting a spectrum of geometry-dependent landing strategies. On low curvature surfaces, contact traction is maximized by increased spanning of digits, whereas on high-curvature surfaces, maximum traction is achieved by an anterior paw placement producing increased palmar pad engagement. Dynamic contact area change is being quantified further using frustrated total internal reflection imaging.

636 Emelia Kudej, Paul Jerem, L. Michael Romero

Circadian rhythms of body surface temperature in juvenile and adult house sparrows

Thermal imaging of body surface temperature (BST) is increasingly used as a non-invasive method to infer physiological states in free-living animals. However, the physiological processes contributing to BST are not yet fully understood, which will be necessary for reliable interpretation of BST measurements. BST is known to exhibit a circadian rhythm. This rhythm primarily results from variation in metabolic heat loss associated with fluctuating energetic and thermoregulatory demands. Such demands are likely to vary between life-history stages. For instance, while juveniles must divert resources toward development – and may need to do so across the 24hr period to ensure timely maturation – this demand is already satisfied in mature adults. To investigate whether circadian rhythms of BST differ between these life-history stages we compared repeated BST measurements of two groups of captive house sparrows: pre-molt juveniles and mature adults. Eye region, bill, and mean whole-body BST were measured from each individual, every hour for three 24-hour periods using thermal imaging. Importantly, these results will determine if differences in circadian rhythm between life-history stages should be considered when taking BST measurements to infer the physiological state in free-living animals.

1072 Zoe Kulik, Christian Sidor

Age-structure in a Multitaxic Cynodont Assemblage from the Middle Triassic Manda Beds of Tanzania

Nonmammalian cynodonts were common components of paleocommunities during the Triassic, but their growth, body-size, and life history dynamics are underexplored, largely due to sporadic osteohistological sampling. Recently, hundreds of cynodont remains were recovered from the Manda Beds of Tanzania, including isolated elements referable to Aleodon, Cricodon, Luangwa, and Scalenodon, and permit the first assessment of life history and assemblage-wide age structure for these coeval taxa. We thin-sectioned over 30 individuals from an inferred ontogenetic series based on femora and tibiae. Importantly, our histologic sample spans the entirety of size classes recovered (~30%–100% maximum femoral length) and provides critical insight to determine whether large individuals have bone tissue compositions reflective of skeletal maturity. The multitaxic histologic sample is largely characterized by immature bone tissue, with abundant primary vascular canals in a mosaic of woven and parallel-fibered matrix. Within immature size classes, there is histo-variability in the amount of parallel-fibered and lamellar bone, as some elements record a shift from woven-parallel-fibered bone matrix to lamellar tissue along the subperiosteal edge. One partial femur tentatively referred to Scalenodon, that is ~75% maximum size, preserves a well-defined external fundamental system (EFS) indicative of skeletal maturity. To our knowledge, this is the first EFS reported for a cynodont and highlights the need for widespread histological sampling to accurately characterize the growth dynamics of nonmammalian cynodonts.

1301 Siddharth Kulkarni, Carlos Santibañez-Lopez, Prashant Sharma

Nailing the horseshoe: Reconciliation of Xiphosura gene tree-species tree reveals ancient hybridizat

Bifurcating trees have been a traditional choice to reconstruct evolutionary relationships which implicitly assumes that a speciation event results in two lineages. Interrogation of genes has shown in many cases that the evolutionary history is reticulated resulting from non-cladogenetic gene flow events such as introgression and hybridization. Reconstructing the reticulated genetic history compounds the intractability if the lineage has undergone whole genome duplications and deep divergences. Horseshoe crabs are the only marine arachnids and include four extant species, some of which are known to hybridize. This group has a rich fossil record, thus indicating old divergences and that the extants ones are “living fossils”. We used fossil-based calibrations to estimate divergence dates on two alternative placements Xiphosura in the phylogeny of Chelicerata. Exclusion of xiphosuran fossil increased the uncertainty in the dating of this group. We queried the genomes of all Xiphosura to detect signals for reticulation and found that allopolyploidy during the Jurassic-Triassic periods explains the source of polyploidy in this group.

949 SUNNY KUMAR, Victor Ortega-Jimenez, Ishant Tiwari, Saad Bhamla

Physical models reveal that nematodes harness kinks in their bodies as nonlinear springs for leaping

Nematodes are a superabundant taxon of tiny worms that surpass all individual animals over the planet. Most nematodes move across wet environments by swimming or crawling via undulatory propulsion. Amazingly, entomopathogenic nematodes which parasitize insects, are unique among roundworms because they can jump. Although the kinematics of this jumping behavior has been described nearly 60 years ago, the energetics of elastic energy storage and release have remained unknown. Here, we utilize soft robophysical elastic structures including polymeric-based elastic cylinders and fluid-filled balloons (shells) to uncover how the hydrostatic skeleton, cuticle, and muscles act as non-linear springs to store energy in the loop formation of the worm body prior to jumping. We specifically focus on the role of kinks (sharp folds) that are formed when these elastic cylindrical structures are bent beyond a critical radius of curvature. We show that kinks in these highly deformable bodies could serve multifunctional roles: acting as a “capacitor”, enabling slow energy buildup and fast release; creating a non-linear spring for low-force, yet high energy loading; and finally offering stability during loop formation. Our work sheds insight into both how organisms exploit elastic instabilities for ultrafast motions while offering design motifs for soft jumping robots.

577 Dian-Han Kuo, Fu-Yu Tsai

The origin of peripheral sensory neurons in the leech Helobdella

Stereotyped cell lineage is a prominent feature in leech embryogenesis. In the leech Helobdella, cell lineage in the segmental ganglia of the central nervous system (CNS) has been relatively well characterized, but little is known about the peripheral nervous system (PNS), especially prostomial peripheral neurons. To gain a comprehensive view of neural development in the leech, I generated a transgenic line of Helobdella austinensis, in which a reporter is under the control of a panneuronal cis-regulatory element of Hau-elav4. Elav is an evolutionarily conserved marker for post-mitotic neuron precursor and differentiated neurons. Although endogenous Hau-elav4 is only expressed in the CNS, the reporter activity is detected in both CNS and PNS neurons, suggesting that additional regulatory element(s) not contained in this reporter construct may repress Hau-elav4 expression in the PNS. Therefore, this reporter enables us to study the previously unexplored PNS in Helobdella. Interestingly, precursors of the prostomial lip sensory neurons were the earliest cell population expressing the reporter, at the late gastrula stage. They arise in the ventral-posterior territory of the prostomium and then migrate and expand dorsally and anteriorly to circumvent the oral opening after the proboscis has formed. Genes expression data suggests that the specification of peripheral neurons in the leech is Notch-dependent, whereas CNS neurogenesis is Notch-independent.

851 Sammy Kutsch, Megan Maloney, Marie Strader

Elevated temperatures reduce larval survival but enhance settlement in Cassiopea

Increasing ocean temperatures pose a significant threat to many marine invertebrates. However, Cassiopea adults are robust to high temperatures, possibly facilitating recent population expansions. Early life-history stages are thought to be more sensitive to environmental change, but it is unknown if this is true for thermally robust species such as Cassiopea. Additionally, Cassiopea adults exhibit a wide variety of coloration, which has anecdotally been associated with increased thermal tolerance. We characterized the effects of elevated temperatures on larval survival and settlement rates of Cassiopea, and if offspring from parental color morphs fared differently in elevated temperature conditions. Larvae in elevated temperatures (32°C) had higher settlement rates but reduced survival over time than larvae in ambient temperatures (26°C). Coloration of parents was not found to have a significant effect on settlement or larval survival. This suggests that any thermal tolerance associated with adult coloration is not transmittable to early life-history stages in the subsequent generation. These results show a complex perspective of elevated temperature on Cassiopea early life-history stages - de-

velopmental progress is enhanced in higher temperatures, in tandem with selection on larval thermal tolerance. This could imply that some marine invertebrates are capable of acclimating to warming induced by climate change.

1570 Adam Kuuspalu, Melina Hale

Newly discovered neural pathways provide direct connections among arms of octopuses

The nervous system of octopuses provides an alternative organization to other model taxa for sensorimotor integration and control of limb movement. Limbed species typically have a central nerve cord that lies along the anteroposterior axis of the body, with sensory and motor fibers extending from the cord into each limb. In contrast, octopuses possess multiple nerve cords in each of their arms, including two pairs of intramuscular nerve cords (INCs). We examined the paths of the INCs using immunohistochemical approaches in young Octopus bimaculoides to better understand their potential neural connectivity outside of the arm proper. The two oral INCs, ventrolateral in the arm, extend proximally from the arm in opposite directions connecting with the nearer oral INC of the arm that is two arms away. This provides an additional potential means for interarm signaling outside of the brain. The two aboral INCs, dorsolateral in the arm, stay close to the surface of the body between the muscle layers of the interbrachial membrane. The aboral INC on one side of the arm ultimately converges with and cross the neighboring aboral INC of the adjacent arm and extends beyond the arm of origin. These investigations identified additional features of the octopus nervous system at the base of the arm and show increased complexity in the neural pathways associated with interarm signaling.

1691 Yeipyeng Kwa, Maiko Sho, Julia Frederick, Rebecca Li, Gregory Davis

Induction of reproductive fate in the pea aphid

The pea aphid, Acyrthosiphon pisum, exhibits remarkable developmental plasticity in response to seasonal changes in photoperiod. In spring and summer, aphids reproduce asexually and are viviparous, yielding large numbers of genetically identical female offspring. The longer nights accompanying the fall induce these asexual aphids to produce sexual males and females, which mate to lay frost-resistant eggs. These eggs diapause through the cold winter months and hatch into asexually reproducing females in the spring, founding new clonal populations. Among other aspects of the reproductive polyphenism, we are interested in the process that specifies sexual versus asexual fate during embryonic development. Although previous evidence has implicated juvenile hormone (JH) as playing a role in specifying asexual fate, we present evidence suggesting that neither maternal JH nor the JH pathway in embryos mediates this process. This result has implications for the mechanism by which pea aphid strains from the southern United States fail to produce sexual progeny in response to changes in photoperiod, an evolutionary loss of plasticity which we also describe.

756 David Labonte

A dimensionless number for muscle dynamics

Muscle, the "prime mover" of the animal kingdom, is used for acts fast and forceful, contractions long-lasting and cyclical, and movements precise and reflexive. The diversity of mechanical muscle function is reflected in a vast array of physiological specialisations. How can we compare mechanical muscle performance across different physiological designs? I demonstrate that the force-velocity (FV) and force-length (FL) properties of muscle impose two distinct limits on the speed muscle can impart. Each limit depends on a different set of physiological and anatomical properties of muscle, and is relevant when muscle contracts against a mass that is either small or large compared to a critical mass, defined by its physiological properties. The FV and FL functions span a 3D landscape which visualises the solution of all possible equations of motion; the ratio between driven and critical mass, the effective inertia of the system, determines the contractile trajectory along this landscape as the muscle moves the mass. The effective inertia of a musculoskeletal system thus emerges as a dimensionless number which characterises the relative importance of FV and FL properties in muscle contraction dynamics. For isometrically scaled muscle, it increases strongly with size, and I discuss the implications of this scaling for muscle performance.

1444 Amy Lagorio, Mara Fields, John Fortner, Eden Mackereth, Christian Perez, Faye McGechie, Alec Wilken, Manuel Leal, Carol Ward, Kevin Middleton, Casey Holliday

New applications of 3D musculoskeletal modeling methods: a shared look inside the heads of Anolis

Emerging imaging, 3D modeling, and quantitative analyses are equipping evolutionary biologists with new approaches to understanding the variation and evolution of the musculoskeletal system. However, challenges with interpreting DiceCT data and higher order use of modeled muscles have not yet been explored, and thus the error and accuracy of some digital methods remain unclear. Here we test new approaches to quantifying the shape and function of muscles and bones in the heads of Anolis lizard species. Anolis is a model clade for exploring patterns in functional adaptation, ecomorphology, and vertebrate evolution. They possess numerous jaw muscles with potentially different anatomies that sculpt the adductor chamber of the skull and impact cranial performance. Here, a quarantined, virtual, academically-diverse graduate class collected 3D musculoskeletal data from two species of Anolis: Anolis sagrei and Anolis pulchellus. We describe comparative approaches employing DiceCT segmentation of jaw muscles, 3D surface attachment mapping, and 3D landmarking approaches with the aim of exploring 3D lever mechanics, 3D muscle fiber architecture, and sexual dimorphism of the skull. We compare interobserver variation and error in these 3D analyses while sharing new 3D musculoskeletal data from the Anolis feeding apparatus. These findings demonstrate the accessibility and accuracy of these emerging techniques and provide details of the musculoskeletal anatomy of the heads of Anolis ecomorphs for further study of comparative biomechanics and evolution in the clade.

745 Melanie Laird, Tim Hore

Genome-wide epigenetic reprogramming of the marsupial germline

During germline development in eutherian (placental) mammals, gamete precursors (primordial germ cells) undergo genome-wide erasure of epigenetic marks. This phenomenon, termed epigenetic reprogramming, enables normal gamete development by resetting parental imprints to align with embryonic sex. While critical to gamete development in eutherian mammals, recent evidence from zebrafish suggests that epigenetic erasure is not shared by non-mammalian vertebrates and arose later in the mammalian lineage. Marsupials—sister group to eutherian mammals—are ideal models to test this hypothesis.Here we present the first investigation of genome-wide methylation dynamics during marsupial germline development. Since marsupials are born highly altricial, germ cell development occurs post-natally. We used post-bisulfite adaptor tagging (PBAT) and deep sequencing to chart global levels of DNA methylation in PGCs of brushtail possums (Trichosurus vulpecula) throughout early development (2 to 80 days post-partum (dpp)). We found that PGC DNA methylation initially decreased from 62 to 41% between 2 and 13 dpp, developmentally equivalent to humans and mice. PGCs remained hypomethylated for approximately 10 days and methylation was restored (65%) by 38 dpp. Methylation loss occurred primarily at CpG islands while repeat elements retained almost all methylation, as for eutherian mammals.Our findings demonstrate that broad patterns of epigenetic reprogramming are conserved in both mammalian groups. However, since marsupial PGCs retain substantial global methylation (>40% compared with 14-7% in mice), the marsupial germline may hold unexplored potential for transgenerational epigenetic inheritance.

88 Gwendolyn Lam, Bradley Davidson, Hannah Gruner, C. J. Pickett

Evolutionary Conservation of Chordate Metamorphic Cues

Animal metamorphosis is generally regulated by hormones. It remains unclear when the usage of thyroid hormone for directing metamorphosis arose among chordates. Within the chordate phylum, tunicates are the closest invertebrate sister taxa to the vertebrates. Tunicate metamorphosis begins when a nonfeeding swimming larva settles by adhesion to a surface. Settled larvae tunicates undergo drastic morphological changes including tail absorption, body axis rotation, and expansion. Adult tunicates are tunic-covered tube-shaped sessile animals. Cues that initiate and regulate metamorphic organ development in tunicates remain poorly characterized. Previous research has shown a phylogenetic relationship between the vertebrate thyroid gland and tunicate endostyle and has indicated that thyroid hormone is required for tunicate metamorphosis. We investigate the hypothesis that tunicates retain an ancestral chordate metamorphic program that employs thyroid hormone. We found that inhibiting thyroid hormone synthesis resulted in a statistically significant delay in body axis rotation and heart development. There was a delay in the development of late metamorphosis traits like the width of the oral siphon. In contrast, preliminary studies involving inhibition of retinoic acid, a related hormone, did not result in a noticeable delay in organ development. Our results support the hypothesis that tunicates and vertebrates share a conserved, ancestral metamorphic program involving thyroid hormone. Future studies will explore rescue experiments and how thyroid hormone influences the gene regulatory network responsible for directing organ development.

1652 Andrew Lammers, Grace Schepelmann

Do quadrupeds conserve angular momentum during locomotion? A test using Rattus norvegicus

Angular momentum is a property of any rotating mass. It consists of three components: mass, angular velocity, and the radius of the rotating mass. It is likely that angular momentum augments stability during locomotion, which suggests that animals will maintain a minimum angular momentum while walking or running. We trained rats to run on a rope mill (the arboreal equivalent of a treadmill). We ran trials under three conditions: weighted bracelets (1.8 g each) on the wrists and ankles, which increase angular momentum by adding to the distal limb mass; sham bracelets, which lack the added weight; and no bracelets. We recorded video at 210 pictures per second via two cameras, and then selected 15 consecutive strides from each trial. We digitized the distal tip of the 3rd digit of the right hand and foot to obtain. For each stride, we calculated the distance swept by the hand or foot during its semi-elliptical movement. If angular momentum is conserved, then this circumference should be smaller when the limb is weighted (i.e., smaller radius and greater rotating mass). Preliminary data on forelimbs only suggest the opposite, that the circumference swept by the hand is significantly greater in the weighted bracelet trials compared with sham bracelet trials. It seems likely that the rats lose some precise control over their limbs when mass is added to the wrist.

1461 Scott Landman, Meredith Taylor, Todd Green, Kamal Moussa, Paul Gignac, Eugenia Gold, Akinobu Watanabe

Could congenital hydrocephalus lead to evolution of novel brain morphologies in domestic chickens?

Craniofacial and neuroanatomical dysmorphologies occur frequently, including hydrocephalus which occurs in 1 in ∼700 births. Understanding the mechanisms underlying these malformations are important; thus, a model system for interrogating these clinical conditions is crucial. Compared to the standard white leghorn chickens (WLC) and other modern birds, Polish crested chickens (PCC) have a unique brain configuration. Previous studies have hypothesized, with limited evidence, that hydrocephalus may be implicated in cerebral herniation and 'dumbbell-shaped' brain morphology characteristic of PCCs. Here, we use diffusible iodine-based contrast-enhanced computed tomography (diceCT) imaging on developmental series of PCCs and WLCs to reconstruct brain and ventricular space. If hydrocephalus results in cerebral herniation in PCCs, then we anticipate larger ventricles in PCCs than in WLCs, while brain tissue volume remains similar between breeds of comparable developmental stages. Our reconstructions indicate that ventricular size is highly variable in PCCs compared to WLCs using this approach. Notably, PCCs exhibit smaller brains, and clear evidence is lacking for PCCs possessing larger ventricles. Therefore, our study does not phenotypically support the hypothesis that hydrocephalus is a major cause of cerebral herniation and novel brain configurations in PCCs. However, using diceCT imaging on PCCs for the first time reveals new brain and vascular traits that further demonstrate PCCs as excellent models for the development and evolution of novel cephalic anatomy.

1092 Zachary Lane, M. Zachary Darnell

Energetic costs, thermal benefits, and variations in structure of fiddler crab mating burrows

The fiddler crab Leptuca (= Uca) pugilator lives in the intertidal zone of sandy, vegetated shorelines where the males of the species compete over and protect small territories centered on specialized mating burrows. Mating burrows are complex structures that are built by the males, but males often come into possession of an existing burrow by forcefully evicting the previous owner, thus eliminating the energy investment associated with burrow construction. Mating burrows serve several functions. First and foremost, the burrow serves as the site of copulation and clutch incubation in this species, provides a suitable microclimate for timely egg development in females, and males very rarely mate successfully without a burrow. Additionally, the burrow serves as a refuge from the thermal and desiccation stress experienced while courting females on the sediment surface. Here, we aim to address the inter- and intrapopulation variation in burrow structure across the climatic range of the species; measure the specific thermal properties of mating burrows and determine their direct effects on body temperature relative to the surface environment; estimate the time costs of burrow construction; and record the colonization rates of courting males in unoccupied areas of preferred mating habitat.

1234 Samuel Lane, Ben Vernasco, Taylor Fossett, Isaac VanDiest, Heather Watts, Kendra Sewall

Effects of urbanization and brood parasites on avian telomere length across sexes and age classes

Urban environments provide an opportunity to understand how wild songbirds are impacted by rapid anthropogenic environmental change. Urban habitats are associated with increased food and water and decreased predation levels compared to rural. However, they also contain persistent, novel stressors for adults and developing young (e.g., increased light at night, ambient noise, human disturbance, decreased nutrient availability, increased rates of brood parasitism). Many studies have examined how urban habitats influence demographic and behavioral processes, but the consequences of urbanization for cellular-level processes are

much less well known. Telomeres provide a novel opportunity to understand the consequences of urbanization as they are a well-established metric of biological state that can be associated with differences in residual lifespan, health, and behavior. Sampling wild birds across 6 field sites and 4 years, we explore the relationship between urbanization and blood telomere lengths in adult and nestling song sparrows (Melospiza melodia), a North American songbird found in both urban and rural habitats. Urban song sparrows experience high rates of brood parasitism by brown-headed cowbirds (Molothrus ater), allowing us to also explore how the presence or absence of a brood parasite relates to adult and nestling telomere lengths. Examining relationships between telomere lengths, habitat types, age classes, sexes, and developmental environments will provide insight into the somatic consequences of urbanization, including an understanding of when in life such relationships arise.

134 Marissa Langager, Dana Hawley

Sociality as a potential form of behavioral tolerance in Mycoplasma gallisepticum-infected songbirds

For gregarious animals, maintaining social groups carries costs and benefits. While group membership may increase pathogen infection risk, sociality may also augment foraging opportunities and predator protection. Extensive work has investigated benefits of sociality for uninfected individuals, but few studies have examined how group membership benefits infected animals in particular. In some cases, sociality may facilitate behavioral tolerance for infected group members if sociality offsets costs of sickness behaviors like lethargy, anorexia, and decreased anti-predator responses. Previous work found that house finches infected with Mycoplasma gallisepticum (MG) prefer foraging near a flock more so than uninfected controls, indicating potential benefits of sociality during infection. To test whether group membership alters foraging or anti-predator behaviors during infection, house finches were housed in isolation (n = 8), or in flocks of five (n = 8 flocks), and inoculated with MG. One additional bird per flock (n = 8) and 8 additional individually-housed birds served as sham-inoculated controls. For both infected and control birds housed alone or in groups, we quantified foraging behaviors using novel feeder and novel object tests, and assayed anti-predator behaviors in response to visual predator cues 11-17 days post-treatment (peak infection). We also quantified individual pathology and pathogen load throughout infection. The results of our study will provide further understanding of the benefits of social grouping for infected individuals, possibly increasing their likelihood of survival through behavioral tolerance to pathogens.

839 Hana Larkins, Emily Carrington, Matthew Reidenbach, Kindall Murie, Kelsey O'Donnell

The effect of flow on filtering and gaping behavior in Mytilus galloprovincialis

As ecosystem engineers, mussels create habitat for many species by ameliorating harsh environments, like extreme wave forces and temperatures. In low flow conditions, however, mussel aggregations may alter their local chemical environment via respiration and calcification, creating hypoxic conditions within the interstitial gaps between mussels. Thus, the local flow regime may play a large part in whether mussel aggregations are beneficial or detrimental to other species. However, how mussel filtering and gaping behavior may prevent the development of harsh chemical conditions by increasing mixing in the intertidal zones and the surrounding water is still unknown. To better understand how mussel behavior may influence changes in water chemistry we quantified the effects of flow on mussel behavior. We used Hall effect sensors to quantify gaping by mussels and found a positive linear relationship between mussel gaping and filtering speed. Flow (up to 20 cm/s) had no significant effect on gaping, although mussels positioned further downstream within an aggregation tended to gape wider. Our results indicate that individual variation in behavior due to spatial position maybe be more important than flow in determining gaping activity, thus having consequences for how mussel behavior influences change in chemistry within the interstitial zone.

304 Olivier Larouche, Ricardo Betancur-R, Jacob Daane

Do morphological differences between benthic and pelagic snappers correlate to genomic variation?

Studies focusing on a wide array of taxonomically diverse systems have demonstrated the fundamental importance of evolutionary transitions between habitats in shaping observed patterns of lineage, ecological and morphological diversity. Ecological theory predicts that such habitat transitions may facilitate the adaptive radiations of new migrants by providing novel ecological niches, which can then lead to increased rates of lineage and morphological diversification. Among fishes, transitions between benthic and pelagic habitats have repeatedly occurred across various taxonomical scales, often with predictable morphological outcomes. Fishes from benthic and pelagic habitats generally differ in several traits, including overall body shape, head shape, eye size, mouth position, fin shapes and gill raker morphology. However, little is known about the genetic mechanisms underlying the development of these traits. In this study, we compiled whole genome sequencing data from 28 species of snappers (Lutjanidae), which have repeatedly undergone benthic to pelagic transitions. The dataset comprises 14 benthic and 14 pelagic species and captures at least 5 independent habitat transitions across the phylogeny of snappers. Each species was also scored for ecologically and functionally relevant cranial and postcranial traits obtained from analyzing photographs and CT-scan data. Using this integrated genetic and morphological dataset, we aim to identify genetic loci underlying the deterministic patterns of trait evolution observed during habitat transitions and to identify genetic bases of body shape variation in fishes.

1557 Tracy Larson, Will Tucker, Susanna Shepard, John Boyd

Astrocyte plasticity in a sensorimotor nucleus controlling singing: a role in future plasticity

The birth and incorporation of new neurons and astrocytes into neural circuits in the adult vertebrate central nervous system is a fundamental process of neural plasticity. Given the relationship between neural plasticity and the maintenance of behavior, it is crucial to understand the functional relationships within and across cell lineages in the brain. In the sensorimotor nucleus HVC of the song circuit in Gambel's white-crowned sparrow (Zonotrichia leucophrys gambelli), extreme plasticity in neuronal number coincides with singing behavior quality. We find that supporting an increase of HVC neuron number during breeding season, astrocytes too scale in number within and across seasons. Interestingly, we find that astrocytes decrease upon transition into nonbreeding conditions shortly after the nonbreeding season decrease in neuron number and that this initial decrease in astrocyte numbers dips below the number in stable, homeostatic nonbreeding conditions. These results suggest that astrocytes might participate in the clearance of dead neurons and then die to allow new astrocytes to repopulate HVC. To elucidate whether or not previously described reactive proliferation following neuronal death in HVC generates astroctyes that restore nonbreeding season homeostasis, we performed a lineage trace study of the progeny from nearby proliferating neural progenitor cells. Identification of seasonal plasticity in astrocytes will lay the groundwork for examining the role of astrocytes in restoring homeostasis and future re-growth of neural tissue.

1819 Ben Larson

Regulation of form in choanoflagellates and the evolutionary cell biology of morphogenesis

Choanoflagellates, the closest relatives of animals, can form multicellular colonies of various shapes and sizes. This diversity, the simplicity of multicellular forms, and their important phylogenetic position makes choanoflagellates an ideal system for studying the evolution of morphogenesis. Comparisons between choanoflagellates and animals have begun to shed light on animal origins. However, because most work has focused on genetics and genomics, little is known about cellular and biophysical mechanisms underlying the regulation of multicellular form in choanoflagellates. Through the quantitative characterization of the biophysical processes underlying the development of rosette colonies in Salpingoeca rosetta, we found that rosettes develop reproducibly despite underlying stochasticity of cell lineages. Perturbative experiments coupled with biophysical simulations demonstrated the fundamental importance of a basally-secreted extracellular matrix in physically sculpting morphogenesis, yielding a morphospace for multicellular colonies consistent with observations across a range of choanoflagellates. Our biophysical perspective helps illuminate the interplay between cell biology and physics in regulating morphogenesis. Another choanoflagellate, the recently described Choanoeca flexa, forms cup-shaped colonies. Colonies rapidly invert their curvature in response to changing light levels. Inversion is mediated by cell shape changes requiring actomyosin-mediated apical contractility and allows alternation between colony behaviors. C. flexa thus rapidly converts sensory inputs directly into multicellular contractions. In this respect, it may inform reconstructions of hypothesized animal ancestors that existed before the evolution of specialized sensory and contractile cells.

612 Luke Larter, Michael Ryan

Call elaboration may insure calls against unflattering overlap in túngara frog choruses

In chorusing species, signals from nearby males can interact to influence the attractiveness of these signals to females. As such, males signal strategically to maximize signal attractiveness within the signaling milieu. Túngara frogs produce a 2-part advertisement call: a whine followed by 0-7 chucks. We show that when calls overlap, females strongly discriminate against leading calls when the leading call's chuck is overlapped by the first 150ms of the lagging call's whine (when the whine is highest in amplitude). Call overlap of this nature was common in experimental choruses of various sizes and came to be the predominant call-timing pattern in the largest choruses. Calls with a greater number of chucks appended were more likely to have at least 1 chuck remaining free from such overlap, particularly in larger choruses, suggesting that additional chucks may ser ve to prevent complete chuck overlap. Although calls with chucks are more attractive than calls without chucks in túngara frogs, results have been mixed as to the attractiveness benefits of additional chucks beyond one. We suggest that additional chucks may also promote attractiveness by acting as insurance against having all chucks obscured by rivals when calling in the dense choruses this species forms in the wild.

1583 Jacob Lasala, Beth Brady

Spatial diversity of seagrass habitats on the Gulf of Mexico

Seagrass beds are a vital habitat for multiple marine species, including manatees and sea turtles. These habitats can be monitored for quality and growth using a variety of methods. Seagrass habitats in Sarasota Bay, Florida are monitored aerially every two years and then ground-truthed by citizen scientists annually. This method provides managers with long-term targets for seagrass recovery, but can also result in gaps of regions across Sarasota Bay that cannot be readily accessed. Further, because surveys are biennial, small scale changes or fluctuations due to harmful algal blooms (HABs) over the course of the year could be missed. Some areas of the bay are seeing the proliferation of a potentially invasive macroalgae (Caulerpa spp) and it is unknown how these species are impacting seagrass growth in the region. Commercial drones and hydrophones were deployed on the bay to map difficult to reach areas and identify if there are acoustic differences in usage between primarily seagrass and macroalgal sites. Multiple sites across time periods are compared to assess if changes have occurred and future surveys will focus on expansion of study sites and the potential impact of HABs on these habitats.

937 Emily Lau, Nicholai Hensley, Arnab Mukherjee, Todd Oakley

Functional testing of luciferases in ostracods challenge the ortholog conjecture

A common assumption for the genetic basis of phenotypic evolution is that orthologs (homologous genes resulting from speciation events) are better predictors of function than paralogs (homologous genes resulting from gene duplication events), often termed 'the ortholog conjecture'. Under this conjecture, the evolution of function is correlated with orthologs, while paralogs are often disregarded. However, orthology is determined phylogenetically, which does not always equate to similarity in function. Here we propose that a functional paralog shift occurred during the diversification of bioluminescent courtship in ostracods. We use transcriptomic data, recombinant protein expression, and in vitro functional analyses to compare light-producing functions of homologous bioluminescent proteins (luciferases). Our results reveal that bioluminescent courtship signals may sometimes diversify by using paralog switches as a mechanism for functional divergence, demonstrating how the ortholog conjecture can often be misleading when linking molecular evolution to phenotypic diversification, especially for organism-level functions.

83 George Lauder, Yangfan Zhang

Fish schools as environmental turbulence filters

Schooling is a collective behavior of many fish species often studied to understand the rules governing group behavior in organisms and the ecological and biomechanical advantages of group locomotion. But fish schools could also filter out environmental turbulence and reduce the energetic cost of group swimming compared to individuals swimming alone. We tested this "turbulence filtering hypothesis" by quantifying the energetic cost of swimming in schools of giant danio (Devario aequipinnatus) and solitary individuals swimming in both laminar and turbulent (generated by a passive turbulence grid) conditions over speed range of 0.25–8 body lengths/sec. We measured oxygen consumption before, during, and after exercise to quantify aerobic and anaerobic costs of swimming in turbulent flows, and simultaneously recorded locomotor kinematics. Individual fish exhibited substantially greater aerobic energetic costs when swimming in turbulence, especially at higher speeds, and nearly a 3x increase in anaerobic energy use. In contrast, schools of 8 danio did not show increased costs and did not exhibit any increase in anaerobic energy production when swimming in turbulent flows. These data support the turbulence filtering hypothesis, suggesting that active directional schooling behavior allows fish to dampen externally imposed turbulent flow perturbations and lowers the energetic cost of swimming. The intraschool hydrodynamic mechanisms that allow turbulence filtering remain unknown, but could include damping of incoming eddies by the undulatory motion of neighboring individuals.

262 M. Ellesse Lauer, Aaron Schrey, Lynn Martin, Elizabeth Sheldon, Daniella Ray, David Tevs, Emma Simpson, Haley Kodak

Epigenetic buffering in recently introduced house sparrows indicated by variance in DNA methylation

Epigenetic buffering allows introduced populations to generate the phenotypic variation necessary to respond to novel stressors through stochastically increased epigenetic variation, without immediate effects on genetic variation. If a species uses DNA methylation for epigenetic buffering, greater variance is expected in the novel environment. The house sparrow (Passer domesticus) has colonized most continents within the last 170 years and displays phenotypic differences among individuals across introduced ranges, among introductions, and between native and introduced populations. Introduced house sparrows show a compensatory relationship between epigenetic and genetic diversity that dissipates with increasing time since initial introduction. Yet, it is unclear whether DNA methylation has facilitated epigenetic buffering and the global spread of this species. We screened DNA methylation with epiRADseq in house sparrows from recently introduced, established introduced, and native locations to determine if methylation patterns are indicative of epigenetic buffering. We found variance in DNA methylation is greatest in recently introduced sparrows, while house sparrows with the longest time since introduction had DNA methylation characteristics similar to native birds. Our results support increased variance in DNA methylation taking an active role in epigenetic buffering for the house sparrow's capacity to respond to novel locations.

1348 Julia LaValley, Cheyenne Tait, Paul Katz, Gianna Misuraca, Kelsi Watkins

The structure and function of the oral tentacle of a nudibranch mollusc

The oral tentacles are paired, flexible sensory appendages on the face of aeolid nudibranchs. Here we describe the structure and function of the oral tentacle in the aeolid Berghia stephanieae. We found that it was supported by a hydrostatic skeleton with multiple muscle layers. It was innervated both directly by neurons in the cerebral ganglion and by a small peripheral oral tentacle ganglion. Immunohistochemistry, HCR, and other staining techniques revealed a large number of diverse cell types in the oral tentacle including several distinct sensory cell types. In experiments testing the oral tentacles necessity to locate prey, the oral tentacles did not appear to play a role in distance chemoreception but were used for tactile exploration. We found expression of an putative ionotropic chemoreceptor (IR) in oral tentacle cells, suggesting a role of the appendages in contact chemoreception. The tentacle exhibits different movements during behaviors such as exploration, foraging, and mate recognition. When the central brain was surgically removed, the oral tentacle still moved in a manner comparable to unmanipulated Berghia, though at a greatly reduced speed. However, when the central brain was left intact and the oral tentacle's connection to the central brain was severed, the speed was less impaired. Moveover, the denervated oral tentacles continued to withdraw to tactile stimuli. Further experimentation is planned to determine the neural control mechanisms.

40 Chris Law, Emily Blackwell, Abigail Curtis, Edwin Dickinson, Adam Hartstone-Rose, Sharlene Santana

Decoupled evolution of the cranium and mandible in carnivoran mammals

The relationship between skull morphology and diet is a prime example of adaptive evolution. In mammals, the skull consists of the cranium and the mandible. Although the mandible is expected to evolve more directly in response to dietary changes, dietary regimes may have less influence on the cranium because additional sensory and brain-protection functions may impose constraints on its morphological evolution. Here, we tested this hypothesis by comparing the evolutionary patterns of cranium and mandible shape and size across 100+ species of carnivoran mammals with distinct feeding ecologies. Our results show decoupled modes of evolution in cranial and mandibular shape; cranial shape follows clade-based evolutionary shifts, whereas mandibular shape evolution is linked to broad dietary regimes. These results are consistent with previous hypotheses regarding hierarchical morphological evolution in carnivorans and greater evolutionary lability of the mandible with respect to diet. Furthermore, in hypercarnivores, the evolution of both cranial and mandibular size is associated with relative prey size. This demonstrates that dietary diversity can be loosely structured by craniomandibular size within some guilds. Our results suggest that mammal skull morphological evolution is shaped by mechanisms beyond dietary adaptation alone.

1600 Austin Lawrence, Kevin Middleton, Jamie Hall, Jacob Thomas, Trent Guess, Carol Ward

A novel workflow for quantifying 3D skeletal anatomy of living humans for morpho-functional analysis

Accurate and repeatable assessments of three-dimensional (3D) skeletal morphology are critical to interpretations of vertebrate functional anatomy. In skeletal specimens, these goals can be accomplished using in-silico models derived from 3D laser scan, photogrammetry, or computed tomography (CT) data. Assessments of skeletal morphology in living subjects, especially humans, are more challenging and are often either cost-prohibitive (e.g., magnetic resonance imaging) or expose subjects to high doses of ionizing radiation (e.g., CT). Here, we present a new, open-source method for assessing 3D skeletal morphology of living human subjects using ultra-low dose biplanar radiographs. Biplanar radiographs are obtained using an EOS Imaging System (EOS Imaging, Inc.) with the subject standing so that the relative positions of skeletal elements are captured in a loaded, functional position. Landmarks are manually placed on features of interest in radiographs using the StereoMorph package for R. Landmark coordinate data are then processed, undistorted, and scaled using custom R scripts. We combine this workflow for assessing skeletal morphology with established tools for 3D motion analysis to directly test hypothesized form-function relationships in the human postcranial skeleton. This approach provides a safe (i.e., lower radiation) and lower cost solution for analyses of musculoskeletal form and function applicable to multiple human cohorts, as well as to other biplanar radiograph platforms and study organisms.

901 Viet Le, Benjamin Cellini, Rudolf Schilder, Jean-Michel Mongeau

The abdomen of the hawkmoth Manduca sexta regulates wing-generated flight torques for yaw control

Many animals use body parts such as tails to control their posture. For instance, in flying insects, redirection of the legs and abdomen can fine tune flight trajectories or stabilize posture. For the hawkmoth Manduca sexta, its abdomen is approximately 50% of its body weight. Thus, flexion of the abdomen can be effective to inertially redirect flight forces. However, how torques generated by the wings and abdomen interact in flight control is not well understood. We quantified forces generated during the yaw optomotor response of hawkmoths using a torque sensor. By studying tethered moths with ablated wings and a fixed abdomen, we resolved abdomen and wing torques and revealed their individual contribution to overall yaw torque production. Using frequency domain analysis, we found that abdomen torque is overall smaller than wing torque, although the abdomen torque was ~80% of the wing torque at higher visual stimulus frequency. Experimental data and modeling suggest that the wing and abdomen torques are transmitted linearly. Using numerical simulation of a planar two-link system, we show that abdomen flexion can amplify movement of the thorax by up to ~2.5 times to add constructively to wing torques. Taken together, the hawkmoth abdomen can fine tune wing torques in free flight, which could modulate flight trajectories and increase maneuverability.

1142 Kristianna Lea, Jessica Fox, Bradley Dickerson

Direct control of fly haltere movement by optogenetic activation of haltere steering muscles

Many sensory systems, including all active sensory systems, are under direct control of an animal's muscles; an animal can manipulate its sensory input by muscle contraction or relaxation. In flies, essential mechanosensory information is gathered by sensilla on the haltere, a modified hindwing that is oscillated during flight and controlled by a small set of steering muscles. The halteres provide rhythmic feedback to the wing steering muscles, which in turn control the wing stroke. Previous studies have shown that the haltere muscles receive excitatory input from the visual system, but little is known about whether or how these muscles might control specific haltere movements.To test how haltere muscle activation changes haltere motion, we optogenetically activated two different pairs of haltere muscle motor neurons and measured haltere kinematics with high-speed videography. Activating each set of muscles had distinct effects on the haltere's movement. These movements could alter mechanosensory input because the haltere afferent neurons are highly sensitive to small changes in haltere movement. The movements we observed were accompanied by changes in wingbeat frequency and amplitude, consistent with prior measurements of haltere influence on wing motion. Our results illustrate the function of a circuit by which flies could thus use their haltere steering muscles to gain active control over their haltere mechanosensory input and its resulting reflexive behaviors.

1095 Ariel Leahy, Robin Dunkin, Bernd Zechmann, Samuel Rivera, Sarah Kienle

Methods and anti-methods of morphologically analyzing a complex arterial structure in odontocetes

Odontocetes (toothed whales) have numerous anatomical and physiological adaptations that underly their impressive diving abilities, with some decreasing the effects of diving-related illnesses by altering gas exchange and storage. One unique anatomical feature previously described in five odontocetes is the thoracic rete mirabile (TRM)— a densely woven network of arteries lining the ribcage. While the TRM dampens arterial blood pressure entering the brain, it has been hypothesized to also function as a nitrogen sink. However, this hypothesis has not been tested, and the TRM has yet to be compared between species. Here, we compared the gross and fine-scale morphology of the TRM across and within species by conducting detailed dissections, using scanning electron microscopy, and applying cryo-histological techniques for light microscopy analysis. Our preliminary results show the TRM is a well-developed structure across multiple lineages of odontocetes, including two new taxa: common dolphins and Risso's dolphins. The TRM appears to be homologous across odontocetes. While the convoluted folds of the TRM are similar in structure, there is intra- and inter-specific variation in location, shape, and size. Despite this variation, harbor porpoises, overall, have the largest and most well-developed TRM when compared to body size. Our next steps are to morphologically examine this structure in additional species and conduct metabolomic analyses of the TRM to examine its potential role as a physiological adaptation for safer diving.

1379 Gordon Leary, Pierre Le-Pabic, Anthony Long, Tom Schilling

Morphological diversification of the teleost skull through endochondral growth

Little is known about the roles of postembryonic development in the morphological diversification of vertebrates. Skeletal morphology often changes during larval and juvenile stages through bone remodeling and localized growth, which takes place at growth zones (GZ). To better understand how GZs mediate morphological evolution, we focus on two cichlid species of the Lake Malawi radiation: Copadichromis azureus (CA) and Dimidiochromis compressiceps (DC). CA and DC adults have dramatically different head shapes which appear during larval development, consistent with a GZ contribution. We find that two factors underlie differences in skeletal morphology in the DC and CA skulls: endochondral GZ proliferative rate and size at larval stages. Using the genetic potential of Lake Malawi cichlids, we mapped larval GZ size to one large effect quantitative trait locus (QTL) on linkage group 5. We then proceeded to test the function of candidate genes located in this QTL by CRISPR-cas9 mediated mutagenesis in the zebrafish model. Our results identify a member of the retinoic acid signaling pathway as modulator of endochondral GZ size in teleosts.

467 Alice Leavey, Laura Porro, Christopher Richards

Modelling the effect of different skeletal proportions on hindlimb mechanics in frogs

Amphibians employ a diverse array of locomotor styles in a variety of ecological niches, making them ideal organisms for investigating the relationship between morphology, function, ecology, and phylogenetic history. Previous studies and findings from our own research indicate that hindlimb segment proportions differ between species utilizing different locomotor modes. Each hindlimb segment has therefore been hypothesised to perform discrete functions. Uncertainty remains in what the biomechanical implications are of these differences in musculoskeletal anatomy due to the high complexity of the frog hindlimb. Using skeletal measurements obtained from 3D digital dissections of micro-CT scans, we have modelled jumping motion for over 160 taxa from all 56 recognised anuran families. We then used computational models to hypothetically explore how each hindlimb segment contributes towards motion. The data obtained forms the foundation for the construction of future musculoskeletal dynamics models. Additionally, our model indicates the potential to infer the locomotor behaviours of extinct taxa using fossil measurements. Overall, this work contributes towards obtaining direct mechanical evidence for how variations in limb segment proportions influence locomotor multi-functionality across the frog phylogeny.

619 David Ledesma, Melissa Kemp

Of molecules and morphology: Identification of Quaternary fossil salamanders from Central Texas

Fossils identification methods impact the way we reconstruct the past using paleontological data. Well supported fossil identifications are paramount for making robust interpretations of past evolutionary and ecological processes and therefore deserve thorough consideration. We use the speciose salamander genus Ambystoma as a case study to examine the level of confidence different fossil identification methods lend for distinguishing taxa. We identified fossil Ambystoma from a late Quaternary locality in Central Texas using quantitative morphological analyses as well as paleogenomic analyses with ancient DNA. For our morphological analyses, we determined our ability to differentiate species of Ambystoma using linear and geomorphic morphometrics while considering intracolumnar and interspecific variation. We found that significant morphological differences exist between taxa; however, patterns of intraspecific and intracolumnar variation made fossil identification at the species level dubious in many cases. Even so, we identified fossils as belonging to the tiger salamander species complex and were able to make interesting biogeographic observations. We next extracted ancient DNA from fossils to determine what species the fossils represent. We incorporated our ancient genetic data into a phylogenetic analysis with extant species of Ambystoma which corroborated our morphological fossil identifications and recovered fossils as most closely related to species that today live more west and south compared to the fossil locality. These results demonstrate the merit of well-supported fossil identifications when leveraging paleontological data.

1238 Cristina Ledón-Rettig

Developmental causes and evolutionary consequences of phenotypic plasticity

Developmental outcomes are shaped by interactions between genes and environmental signals, from diet availability and quality to members of one's social group. Our lab uses spadefoot toads – which have environmentally responsive larvae (i.e., tadpoles) – to understand how such early-life environments shape developmental outcomes, and how these outcomes affect fitness across life stages. Specifically, spadefoots of the genus Spea possess tadpoles that, in response to density and dietary cues, can develop as an aggressive and cannibalistic morph that specializes on shrimp and other tadpoles. We first used a transcriptomic approach to characterize how this novel behavior arises developmentally, and found that the expression of cannibalistic behavior likely relies on novel patterns of brain gene expression that include components with conserved behavioral functions. Second, to determine how early-life diet type influences later-life fitness, we assessed behavioral and physiological carry-over effects in juveniles that either consumed the ancestral diet of detritus or the derived diet of shrimp as tadpoles. We found that juveniles derived from shrimp-fed tadpoles are worse predators as juveniles and exhibit higher levels of the stress hormone, corticosterone. Thus, while consuming the novel, alternative diet is adaptive for larvae, doing so effects juvenile phenotypes in a way that may recalibrate overall fitness. Our current work seeks to identify hormonal mechanisms linking early-life responses to later-life outcomes, and their implications for the evolution of plasticity.

223 In Hae Lee, Anthony Lee, Laura Duvall

Seasonal regulation of reproductive physiology and behavior in Aedes albopictus mosquitoes

Aedes albopictus is a globally invasive mosquito species that contributes to the spread of human disease. One key to their ability to invade diverse ecological spaces is the females' capacity to sense seasonal change and produce developmentally-arrested diapause eggs that can survive harsh winter conditions. Daylength is a critical seasonal cue, likely detected by clock cells. However, which components of the clock network are important and how these affect reproductive behaviors is unclear. Using genetic and molecular approaches, we are anatomically mapping clock cells in Ae. albopictus and testing the role of circadian genes period and pigment-dispersing factor in diapause egg production. We have validated protocols to efficiently induce diapause, characterize egg development and oviposition behavior, and confirm diapause status. Fall-reared females producing diapause eggs show delays in egg-laying and retain a significant number of eggs compared to their spring-reared counterparts. We are currently comparing ovarian development and nutritional provisioning between fall- and spring-reared females. Using the Q-binary system, we are generating transgenic Ae. albopictus lines that allow us to label, manipulate, and record from clock cells. Our results will reveal clock circuitry in Ae. albopictus and test their role in detecting seasonal dynamics to activate the dramatic reproductive switch to produce diapause eggs.

864 Sang-im Lee, Yewon Yun, Hyunsang Yu, Bohyun Kim, Heeso Noh, Piotr Jablonski

Iridescence in the elytra of the flower chafers (genus Protaetia)

Iridescence is defined as the change in the hue depending on the angles of vision and is especially widely found among the birds and beetles. In contrast to well-studied species/lineages with strong iridescence, the nature and origin of variation in the iridescence in weakly iridescent species is not well elucidated. In this study, we aimed to reveal the inter- and intra-specific variation in the mechanism for iridescence among the flower chafers (Protaetia; Cetoniinae; Scarabaeidae). We collected the specular reflectance and sought the correlation between the structural and optical characteristics among the species. For the internal structure, we recorded the number and the thickness of the helicoidal layers of chitin fibers from the cross-sectional TEM images. These insects showed well-developed helicoidal layers composed of chitin fiber stacks and the total thickness of helicoidal layers, the number of layers, and the trend of thickness change varied both between and within species. Also, the total thickness of the helicoidal layers was thicker in species/morphs with thicker epicuticle and many helicoidal layers. Except for the positive correlation between the wavelength measured at low incidence and epicuticle thickness, the correlation between structural and optical characteristics was low. Our results suggest that no single rule explains the iridescence in the genus Protaetia and imply a species-specific modulation of helicoidal layers may be responsible for the production of iridescence in this group of insects.

1175 Sebastian Lee, Stanley Wang, Duyi Kuang, Hannah Stuart, Robert Full

Jump distance effects on landing kinematics, forces, and torques in free-ranging fox squirrels

Survival of fox squirrels can depend on effective leaping and landing in arboreal terrains. Landing is a high-impact behavior which determines whether a squirrel can achieve stable balance on a branch. To understand how squirrels land, we trained four free-ranging fox squirrels (720±80g, N = 4) to land on a 0.75" diameter instrumented rod. We recorded synced high-speed video (500fps) and force/torque data (3000Hz) of squirrels landing with front legs followed by hind leg touchdown. The take-off rod was adjustable to vary the gap distance between 50cm, 75cm, and 100cm. Five flights per individual were recorded at each distance. As gap distance increased, the maximum landing force doubled (20.6±1.5 N/kg at 50cm to 43.6±4.4 N/kg at 100cm). The time to hindfoot touchdown nearly halved (124±15ms at 50cm to 70±10ms at 100cm). The maximum rod torque variation nearly tripled (64±57 Nmm/kg at 50cm to 141±171 Nmm/kg at 100cm). The velocity angle increased 1.5-fold (20.9±2.1° at 50cm to 30.9±2.5° at 100cm for three individuals). Linear regression showed that both angular momentum about the rod and gravity torque at touchdown explain ~80% of the torque variation at 100cm, suggesting possible control of foot torque. Future research will examine squirrels landing on freely-rotating rods and developing a robophysical model of a squirrel-inspired leg and foot to understand the role that friction plays in landing and balancing.

1406 Leah Hyee Ryun Lee, Robert Dudley

The Role of Elytra in Flight of Oedemeridae

Flight and miniaturization have contributed greatly to the evolutionary diversification of the Insecta, as exemplified by the extraordinary diversity of the Coleoptera. Beetles represent ~25% of all known animal taxa, with over 400,000 described species. A synapomorphy of Coleoptera is the presence of hardened, sclerotized forewings (the elytra). Functional roles of elytra are generally postulated to involve both physical protection as well as aerodynamic force production during flight. Here, we evaluate role of elytra in coleopteran flight for two species of Oedemeridae (Sessinia livida and Eobia bicolor) via progressive elytral ablation and assessment of subsequent takeoff flights as filmed with high-speed video cameras. Possible hindwing compensation following removal of elytra is also assessed. Preliminary data suggest that elytra contribute non-trivially to aerodynamic force generation and weight support but may also be involved in the control of flight.

1458 Andrew Lee, Leigha Lynch, Dominik Valdez, Brandon Vera-Covarrubias

Effects of climate on the shape and robusticity of forelimb bones in the North American river otter

The North American river otter (Lontra canadensis) is a semiaquatic carnivoran that occupies a broad geographic range of river habitats across the continent. Previously, we showed that geographic variation, likely associated with climate variables, influences the shape and internal geometry of limb bones in river otters. Here, we explore that relationship further using higher resolution morphological and climate data. We analyzed micro-CT scans of the humerus, radius, and ulna from adult specimens collected in Alaska (n = 6), Washington (n = 7), Tennessee (n = 7), and Florida (n = 8). Bone shape was measured using 3D geometric morphometrics, and cross-sectional robusticity was measured in 1% increments along the length of each bone. We assumed that each specimen lived for 12 years and assembled climate records spanning the 11 years prior to death in the county from which each specimen was collected. The resulting climate variables included minimum and maximum temperature, temperature range, number of ecoregions occupied, coefficient of variation in annual precipitation, and coefficient of variation in vegetation index. Using 2 block partial least squares regression, we found a significant correlation between climate variables and bone form. These results suggest that individuals occupying habitats with increased ecoregions and swings in precipitation tend to have gracile limb bones, presumably related to flexibility in swimming behavior.

1125 Layne Leggett, Robert Podolsky

Microplastics Act as a Vehicle for Ingestion of Adsorbed Toxins by Aquatic Organisms

Microplastics are small particles of variable polymer composition that result from manufacturing or breakdown of larger plastics. As they accumulate in the environment, the consumption of microplastics has become of increasing concern because of their potential to leach endogenous toxins and interfere with normal feeding. One unexplored concern is that they might also act as a vehicle to increase the ingestion of environmental contaminants that adsorb to their surface. Because aquatic organisms are regularly exposed to both microplastics and contaminants, it is essential to understand how they impact organisms independently and synergistically. We tested the hypothesis that microplastics can exacerbate the negative effects of environmental toxins using sea urchin larvae, which consume algal cells in a similar size range. We exposed larvae to 5 treatments: polyethylene microbeads at low concentration, dissolved phthalates (a demonstrated toxin), beads and phthalates introduced separately, beads incubated in phthalates before introduction, and a seawater control. In the first trial beads alone had little effect on larval growth, whereas beads in the presence of phthalates reduced growth and increased arm asymmetry significantly more than phthalates alone. The second trial produced similar patterns but without statistically significant interactions between beads and phthalates. Our results suggest that microplastics can have an underappreciated indirect negative impact on organisms even when at low concentrations that have little direct effect.

452 Derrick Leong, Juan Liu

The Cephalic Lateral Line System of a Tetrapodomorph from the Middle Devonian, Red Hill, Nevada

Red Hill, Nevada has produced Middle Devonian (late Givetian) tetrapodomorph fossils, with some assigned to both Tinirau clackae and Bruehnopteron murphyi. We examined the sensory canal systems of the tetrapodomorph skulls (UCMP 117884, 118283, 118605, 190999) under the microscope and through X-ray Computed Tomography. Among them, UCMP 190999 and 118605 (assigned to Tinirau) are partial skulls with exposed sensory canals, whereas UCMP 117884 and 118283 (assigned to both Tinirau and Bruehnopteron) share the same skull morphology and similar preservation, albeit UCMP 118283 is four times smaller in size and deemed a juvenile. Our results suggest two morphotypes of cephalic sensory canals co-occurred in all specimens. One features branches radiating in a random, entangled manner with moderate networking (Type I), while the other is characterized by numerous elongated branches radiating in a more organized, interconnected network (Type II). Three-dimensional segmentation of sensory canals reveals that Type I is abundant anteriorly and Type II is predominant posteriorly. However, UCMP 118283 differs from the others in overall degree of branching with a milder Type I and extensive Type II, which could be a result of ontogeny. Furthermore, preliminary comparison with other tristichopterids, Eusthenopteron and Hyneria, show additional morphotypes matching neither described here. We conclude that the branching and extension of cephalic sensory canals are highly varied in early tetrapodomorphs probably as a result of their phylogeny and ontogeny.

1781 Kyle Leong, Allyn Nguyen, Anthony Cobos, Natalie Holt

Contratile Properties of Iliotibialis Muscles Compared to Jaw Muscles in Southern Alligator Lizard

Elgaria Multicarinata, the Southern Alligator lizard, exhibits an extreme mating behavior where males grip females' heads for long periods of time, sometimes for up to 48 hours. Previous research has shown that the jaw muscles of E. Multicarinata exhibit unusual contractile properties. They develop sustained force between contractions in endurance tests, and preliminary data indicate they contract slowly. Histological studies of the musculature of this species show that fibers from the jaw muscles appear to contain a tonic myosin isoform, while those fibers from thigh muscle do not. Here we examine the contractile properties of a thigh muscle, Iliotibialis, to compare to previous measurements in the jaw muscle. The Iliotibialis muscle was dissected out of recently euthanized lizards and immersed in oxygenated Ringers solution. Isometric twitch and tetanic contractions, a series of isotonic contractions from which force-velocity properties could be determined, and an endurance test were performed. Twitch rise and half relaxation times were 0.0263 and 0.023 respectively, and maximum shortening velocity (Vmax) was 21.764 mm/s. The V max of the jaw muscles was 40.247 mm/s. The Twitch times are faster than those measured in jaw muscles (0.059 and 0.062 s), but slower than previously reported for several species of Anolis lizards.

797 Faith Leri, Laura Stein

Signal Detection Theory: Testing Predictions in Naturally Occurring Uncertainty

Environmental cues provide information that contributes to behavioral expression, but how does behavior change when organisms are uncertain about cue reliability? How environmental uncertainty influences behavior is a concern in the age of climate change, as an organism's ability to respond to information can influence survival and fitness. Signal Detection Theory (SDT) is a framework that predicts how organisms should alter their behavior in response to uncertain environments, but few field studies have empirically tested these predictions due to challenges in manipulating natural uncertainty. Using threespine stickleback fish (Gasterosteus aculeatus) as a model, we utilized west coast drought conditions to test two SDT predictions: phenotypic variation should increase as uncertainty increases (generating generalist/specialist phenotypes) and individuals with lower thresholds (a generalist phenotype characteristic) should show increased neophobia. In pooled (increased certainty) and connected (increased uncertainty) areas of the Navarro River, we evaluated paternal care differences and used scototaxis assays to assess juvenile boldness. We then measured aggression by exposing territorial males to familiar and unfamiliar intruders. In accordance with SDT, we predicted that individuals from connected areas would express greater variation in paternal care, reduced boldness, and higher levels of aggression compared to individuals from pooled areas. By investigating SDT predictions in natural conditions, our study aims to provide a better understanding of population persistence to novel information in a rapidly changing climate.

708 Emily Lessig, Hans Hofmann

Know thy neighbor: Decision-making in a dynamic social world

Social animals resolve conflicting external demands with context-appropriate behavior that increases their fitness. Both salience and valence of any social stimulus influence decision-making as they determine which stimuli to attend to, and whether to approach or withdraw. The ability to recognize individuals is often required for a range of social interactions. While territorial intrusions and mating opportunities have been examined in diverse taxa, few studies have investigated how animals respond to these stimuli when they are simultaneously present and/or when the stimulus individuals are familiar. Consequently, our understanding of the neural and molecular mechanisms by which the brain processes and responds to socially salient information is limited. Here, we quantified behavior, circulating hormones, and neural activity in key nodes of the Social Decision-Making Network to assess i) how dominant males of the highly social African cichlid fish, Astatotilapia burtoni, respond to the simultaneous presence of an intruder male and a gravid female and ii) whether they exhibit individual recognition. We show that A. burtoni males engage with both intruder males and gravid females when they are presented simultaneously. Additionally, aggression levels in A. burtoni are mediated by familiarity where males are more aggressive to unfamiliar versus familiar males. This work expands our understanding of how the brain interprets and responds to socially salient information by manipulating social contexts and examining behavioral, hormonal, and neural responses.

105 Danielle Levesque, Ana Breit

Non-torpid heterothermy in mammals: another point along the homeothermy-hibernation continuum

Heterothermy, variability in body temperature, is now recognized to be widespread among endotherms with true homeothermy being the exception rather than the norm. A wide continuum of body temperature patterns exist ranging from strict homeothermy, to occasional use of shallow torpor, to deep seasonal hibernation with many points in between. What is often lost in discussions of heterothermy in endotherms is the benefits of non-torpid variations in body temperature, which would perhaps be better termed "thermolability." Endotherms that do not use torpor can still obtain extensive energy and water savings from flexible body temperatures. Energy savings via increased flexibility in body temperature regulation outside of torpor are well documented in large endotherms (>5kg) but can be complicated in smaller species where the lines between torpor and thermolability are unclear. We discuss the varying uses of the terms heterothermy, thermolability, and shallow torpor to describe differences in the amplitude of body temperature cycles and make suggestions as to how to interpret, define, and account for shallow drops in body temperature in small endotherms.

1289 Erin Lewis, Alison Webb, Spencer Hudson, Karen Kapheim, Charles Knapp, John Iverson, Susannah French

Anthropogenic effects of wildlife-feeding on the physiological health of Bahamian Rock Iguanas

The feeding of wildlife has become a pervasive human-wildlife conflict that has varying degrees of impact on individual, population, and species level health. Diet has been shown to play key roles in different physiological measures, exacerbating the potential effects of human-caused dietary shifts. In the past several decades tourism has increased drastically, particularly for the Bahaman Rock Iguanas in the Exumas, Bahamas. Feeding of these iguanas has become an essential aspect of the tourist experience on the islands and has developed into a daily occurrence for many populations. We have monitored these Rock Iguana populations for many years, with a recent focus on physiological condition and the overall impacts of increased tourist activity on the long-term health of the species. Across three years, we collected blood plasma and measured a variety of physiological and immune measures, including, glucose, corticosterone, energy metabolites, oxidative stress, and bacterial killing ability. Our results have highlighted significant differences between consistently fed iguana populations and populations with no tourism and in turn, no wildlife feeding. The implications of such results are important for both in conservation management of the species, as well as furthering the research and knowledge of physiological responses to human activity in free-living species.

1491 Patrick Lewis, Michael Minicozzi

Are there functional tradeoffs between swimming performance and tail-flip jumping ability in fishes?

A variety of fish taxa spend some portion of their life on land. Because these fishes must balance both terrestrial and aquatic locomotion, we asked the question, are there performance tradeoffs between swimming performance and terrestrial locomotion in amphibious fishes? To answer this question, we compared terrestrial tail-flip jump distance to aquatic critical swimming speed across fish species. Fishes were first elicited to jump and recorded using a high-speed camera filmed at 600 fps and used to measure the duration of the behavior, takeoff angle, and curvature coefficient. Fishes were also elicited to jump in a small arena for 30 seconds and the longest jump produced was used in analysis. Fishes were then subject to a critical swim speed test to determine each individual's maximum sustained swimming speed. The critical swimming speed procedure was standardized across each individual with 20 min acclimation of no flow and 20min of low flow (7.5cm/s). After acclimation, the speed was increased every five minutes by 1 cm/s until the fish was swept against the downstream barrier. Despite having to balance locomotion in disparate environments, amphibious fishes do not appear to show tradeoffs between swimming and terrestrial locomotion. These data imply that amphibious fishes can produce relatively long-distance jumps while maintaining relatively fast critical swimming speeds.

1840 Kelsey Lewis, Sam Sharpe

Roundtable discussion: sexual diversity and variation

What are the implications of misunderstanding sex as a binary and why is it essential for scientists to incorporate a more expansive view of biological sex in our teaching and research? This roundtable will include many of our symposium speakers, including biologists and intersex advocates, to discuss these topics and visiblize the link between ongoing reification of dyadic sex within scientific communities and the social, political, and medical oppression faced by queer, transgender, and especially intersex communities. As with the symposium as a whole, this conversation is designed to bring together empirical research and implementation of equity, inclusion and justice principles which are often siloed into separate rooms and conversations at academic conferences. Given the local and national attacks on the rights of intersex and to access medical care and bodily autonomy, this interdisciplinary discussion is both timely and urgent.

69 Peishu Li, Nicholas Gidmark, Zhe-Xi Luo, Callum Ross

XROMM reveals tongue base retraction mechanism during swallowing in Didelphis virginiana

In anthropoid primates, tongue base retraction (TBR) is critical for bolus propulsion and airway protection during swallowing. In macaques, hyoid protraction and elevation during swallowing reduce oral volume, squeezing the tongue to produce TBR. This hyoid-powered hydraulic TBR mechanism implies that hyoid size and position are relevant for TBR performance. However, macaques' derived craniofacial and hyoid morphology begs the question whether similar TBR mechanism exists in other mammals. Here we use XROMM to infer TBR mechanism in Didelphis virginiana through high-resolution 3D hyolingual kinematics. Similar to macaques, Didelphis has an incomplete hyoid cornu, but unlike macaques, Didelphis' hyoid has a more posterior resting position. We find that Didelphis deploys TBR during the first opening (liquid) or slow-open phase (solid) of the gape cycle. Hyoid protraction and elevation start before and continue throughout TBR, suggesting the oral volume may also be decreasing. In contrast to predictions of muscular hydrostat hypothesis, we find regional tongue volume change during TBR, with decreasing posterior tongue volume but increasing tongue base volume. Extrinsic lingual muscles are also unlikely to drive TBR in Didelphis, given their insertion sites are minimally retracted. Our data suggest that while TBR may be evolutionarily conserved across therian mammals, its mechanism can vary between taxa with different hyolingual anatomy. This work extends our understanding of the form-function relationships of hyolingual apparatus and swallowing biomechanics.

478 Yichen Li, Gayatri Raina, Benjamin Jarrett, Christine Miller

The effect of male-male competition and group living on female injury

Across many species, sexual selection has driven the evolution of weapons that males use to compete for access to females. Contests between males can be violent, and when females are present, they may get harmed in the process. However, few studies have examined the consequences of male-male competition and group living for female injury. In this study, we began the process of understanding the physical consequences of male-male competition for females. We used the leaf-footed cactus bug, Narnia femorata (Hemiptera: Coreidae). Males in this species engage in resource defense polygyny and fight viciously using their spiny hind legs over access to cactus territories that females need for feeding and egg-laying. Rivals commonly approach mating pairs, attacking both the male and the female of the pair, and they often disrupt the mating. In this study, we found that females received various types of injuries after living in groups, including damaged eye, punctured wing, torn wing, broken spines, missing appendages, and leaked body fluid. Among these, broken spines, missing appendages, and leaked body fluid are the most frequently occurred injuries on the females. Our next step is to more fully determine if male-male competition is responsible for these injuries and if the physical condition of females can help prevent injury.

537 Cheng-Yu Li, Jessica Bowers, Theresa Alexander, Scott Juntti

Identification of an olfactory receptor for the reproductive pheromone in an African cichlid fish

Pheromones play essential roles in communication and reproduction in many species. In most fishes, prostaglandin F2α (PGF2α) acts as a female reproductive hormone, and in some species, as a sex pheromone. Our work shows that, instead of using PGF2α as a sex pheromone, the female cichlid, Astatotilapia burtoni, produces novel PGF2α derivatives, which signal its fertility status to conspecific males. However, how the male perceives these reproductive cues remains unclear. We first designed a dichotomous choice paradigm that tests male preference for olfactory cues. We discovered that males exhibit a strong preference for female reproductive odors, while anosmic males show no preference for the same type of odors, indicating that male cichlids detect these odor cues through the olfactory system.To understand the neural mechanisms underlying the perception of reproductive odors, we silenced two major populations of olfactory sensory neurons (OSNs), ciliated and microvillus OSNs, using the CRISPR to knock out sensory transduction channels, cnga2b and trpc2b, respectively. We found that only the males null for cnga2b are insensitive to reproductive odors, and have minor defects in courtship behavior, suggesting that ciliated OSNs play a key role in sensing reproductive cues. Lastly, we discovered a subset of ciliated OSNs which express an olfactory receptor, Or113a, that is only activated by female reproductive odors, revealing the potential role of this particular receptor in detecting female reproductive status.

1288 Richard Li, Walter Jetz

Temporal dynamics of realized niches during biological invasion

Biological invasion is a temporally-dynamic process. The spatial distribution of an invasive species can change drastically through its invasion history, ranging from a highly geographically constrained locality of first introduction, to a whole continent. Though we have frameworks for understanding the spatial spread of invasive species over time, the same is not true for their environmental niches, despite the importance of the niche to invasion modeling and projection. We lack an understanding of how the signal of the realized niche changes during the invasion process, and the extent to which changes to the detected realized niche reflect the gradual lifting of dispersal barriers and colonization of previously inaccessible areas, versus actual niche shift within the invaded range. Here, we combine species occurrence data with environmental layers for a number of current invasive species to characterize short-term changes to the detected abiotic niche of invaders. For these species we explore the relationship between geographic expansion and niche expansion, to investigate if the former necessarily drives the latter. We additionally look at the contemporary environmental niches of invasive species introduced in different eras, to make inferences about the long-term (century-scale) niche dynamics of invasive species. We lastly propose a general framework for interpreting the niche signal of invasive species in a temporal context.

1786 Tairan Li, Martha Paskin, Mike Schindler, Yen Png, Dave Cade, Venkata Surapaneni, Daniel Baum, Jeremy Goldbogen, Sean Hanna, Mason Dean

Lessons from really big fish: integrating incomplete data to reconstruct 3D coherent skeletal model

Understanding the ecologies and physiologies of the ocean's largest species is challenged by the difficulty of simply observing the animals' behaviors and anatomies in nature. In our study of basking shark feeding, for instance, the species' enormous size even restricts observation of basic movements (e.g. mouth opening/closing) and understanding of simple anatomical relationships (e.g. individuals being too large for conventional tomography or the flexible gill arches distorting under the animal's bulk). Decoding the kinematics of basking shark mouth movements, however, is essential to understanding the mechanics and structure of the gill arches and their arrays of comb-like rakers, and in turn their roles in this species' high-throughput filtration. To overcome the shortcomings of individual techniques, we integrate data from diverse physical and digital specimens (e.g., tag videos, CT, and photogrammetry), gathered worldwide. Building from CT scans of the feeding apparatus in closed-mouth configuration, we describe kinematic linkages and reconcile them with surface scan and tag-video data from feeding animals, allowing reconstruction of a coherent 3D skeletal model with mouth open. This model acts as a primary scaffold that can be digitally populated with thousands of gill rakers. Our 3D models, augmented with behavioral observations of swimming sharks and characterizations of gill raker shape and microstructure, drive our multi-scale CFD simulations to understand bulk flow patterns and filtration efficiency.

386 Shenni Liang, Emily Blackwell, Sophia Wolfe, Irby Lovette, Donald Powers, Anusha Shankar

Differential gene expression analysis across organs during daily torpor in Anna's Hummingbirds

Hummingbirds often need to save energy at night given their low energy stores. They use a strategy called torpor, dropping their metabolism and lowering their body temperature to ambient levels. While previous research has studied how torpor affects the physiological function in mammals like squirrels, Syrian hamsters, and mice, the metabolic pathways involved in avian torpor have not been studied. We proposed that Anna's hummingbird's daily torpor is correlated with shifts in the gene expression related to physiological functions. RNA sequencing shows that, across tissues from lungs, heart, pectoral muscle, liver, and guts sampled during normothermy, transition, and deep torpor, 41 genes experience upregulation when 98 undergo downregulation. We employed enrichment analysis to study gene clusters related to specific pathways. The most significantly upregulated pathways involve circadian rhythm, cation-coupled chloride cotransporters (involved in blood pressure regulation), and FSH signaling pathways (involved with reproductive system development). Keratin metabolism, Phenylalanine, tyrosine, and tryptophan biosynthesis, Chk1/Chk2(Cds1)-mediated inactivation of cyclin B are downregulated. Interestingly, the pathways concerning cell cycle regulation are downregulated during deep torpor, which hints that cells which lack tumor-suppressing activities and have impaired DNA can accumulate in torpor. These results help us understand how hummingbirds manage to lower metabolism by 90% and body temperatures to $\sim 10^{\circ}$C regularly and survive. To further explore, we can investigate more prominent patterns of variation in birds entering and exiting torpor.

378 James Liao, Monica Corraggioso, Leonardo Demarchi, Faustine Ginoux, Miguel Paço, Gautam Sridhar, Olivier Mirat, Claire Wyart

Fine motor kinematics of larval zebrafish in laminar flow

Larval zebrafish display a functional lateral line system within few days of hatching. While the basic mechanism of upstream flow orientation, referred to as rheotaxis, has been described, their fine kinematic response and the role of the swim bladder have not yet been investigated. We leveraged a customized recirculating flow tank and high-speed kinematic analysis to analyze the strategies used by larval zebrafish in response to flow. The active bouts of individual larvae were tracked to extract head orientation and tail angle over time in response to repeated flow stimuli. Fish responded to the onset of flow by re-orienting to the current first using small angle turns, followed by forward bursts aligning the animal to stay upstream. Fish repositioned themselves away from walls during flow. When we ablated the lateral line system, fish did not swim spontaneously and did not display rheotaxis. In larval zebrafish deprived of a gas bladder, fish swam more often at baseline and showed no increase in response to the flow. Interestingly, zebrafish deprived of a gas bladder responded to the flow with numerous low-angle turns but did not show the subsequent forward locomotion. Our study refines the kinematic response of larval zebrafish to flow and reveals the impact of the swim bladder for stabilizing larval zebrafish fish and enabling them to perform proper rheotaxis.

1382 Kennedi Light, Frank Smith

An fgf8 ortholog may regulate gut patterning and leg development in tardigrades

Tardigrades are microscopic invertebrates, known for their unique body plan. We are interested in how the highly derived body plan of Tardigrada develops. Fibroblast growth factor 8 (fgf8) codes for a highly conserved developmental signaling ligand. This gene is known to regulate gut patterning and limb development in some bilaterians. To explore the function of fgf8 within the tardigrade species Hypsibius exemplaris, we performed Hybridization Chain Reaction in-situ. To better characterize the expression pattern of fgf8, we compared it to the expression patterns of two gut markers, forkhead, which is expressed throughout the gut, and Hepatocyte Nuclear Factor 4, which is expressed in the midgut. Our results indicate that fgf8 is expressed at the intersection of the developing foregut and midgut, and also in the developing legs. Our results suggest that fgf8 regulates gut patterning and leg development in tardigrades. Next, we will use RNA interference to directly test the roles of fgf8 in H. exemplaris development.

1500 Isaac Ligocki, Matthew Salena, Brett Culbert, Marian Wong, Sigal Balshine, Ian Hamilton

Joint Predation Activity in Lake Tanganyikan Fishes

Joint predation activity between Mastacemblid eels and piscivorous cichlids in Lake Tanganyika have been reported anecdotally for decades. While these putative interactions have apparent similarities to well-documented examples in marine fishes and invertebrates, there have been no formal investigations in Lake Tanganyika aimed at understanding the costs and benefits of these joint predatory interactions. We observed over 170 hours of video footage of territories of two substrate brooding Lamprologine cichlids (Neolamprologus pulcher and Telmatochromis temporalis) offshore of Mutondwe Island (Zambia) in Lake Tanganyika to characterize these interactions. Specifically, we documented 1) whether these piscivorous predators were observed together on prey territories more frequently than would be expected by chance, 2) whether individuals of one species are more likely to initiate movement and predation events, and 3) what evidence exists for communication behaviors which could facilitate cooperative behavior. We found that joint predation events occurred heterogeneously across groups; in some territories these interactions occurred frequently (>10x per hour) whereas on other territories they never occurred. When a "leader" of movement could be identified, it was invariably the eel. Piscivorous cichlids tended to follow eels and join them in foraging forays once these had already been initiated. We did not find any evidence of signals or gestures between the two species that would suggest they coordinate these behavioral interactions.

1612 Dana Lim, Kayla Goforth, Catherine Lohmann, Kenneth Lohmann

The magnetic field in which hatchling sea turtles initially swim affects subsequent orientation

Loggerhead turtles (Caretta caretta) from Florida use Earth's magnetic field to guide their migration around the North Atlantic gyre, a circular current system that flows around the Sargasso Sea. In previous experiments, hatchling turtles that had never entered the ocean responded to magnetic fields that exist along the gyre by swimming in directions that would, in each case, help them remain in the gyre and along their migratory pathway. One possibility is that turtles recognize specific magnetic fields in the gyre by assessing the difference between these fields and the magnetic field the turtle first encountered when entering the ocean and swimming offshore. As a first step toward investigating this hypothesis, we allowed naïve loggerhead hatchlings from Melbourne, Florida, to experience their first swim in one of three different magnetic fields, after which we monitored orientation responses of all turtles in a magnetic field that exists near Cape Verde in the eastern Atlantic. Turtles that swam first in their natal beach field (Melbourne) oriented westward in the Cape Verde field, a direction consistent with their normal migratory movements. By contrast, turtles that swam first in a magnetic field that exists near Barbados or near Cape Verde oriented randomly. The results suggest that early experience swimming in the magnetic field of the natal beach plays a role in the ontogeny of magnetic navigation in sea turtles.

475 Cody Limber, Gunter Wagner, Richard Prum

Single Cell Transcriptomics Reveals a Diverse Set of Feather Germ Cell Types

Feathers are among the most complex epidermal appendages. Given their complicated developmental mechanisms, the morphological complexity of feathers likely involves the development of ten or more distinct feather cell types. Although feather morphology is well characterized, research on feather development at a transcriptional level is limited. We sequenced transcriptomes of individual developing chick feather cells at H&H embryonic stage 37 to characterize the gene expression states associated with different feather cell morphologies. Using k-means clustering, we found 21 clusters from plucked feathers that segregate primarily into epidermal and dermal derived cells. The epidermal derived clusters show the most heterogeneity as fully grown feathers contain only epidermal derived cells but also prove the most challenging to identify as there is little pre-existing literature. Of these clusters, marginal plate epithelium, which are involved in the formation and fusion of, and likely establishing polarity within, barb ridges–is easily identified by the strong SHH expression and weaker more localized expression of BMP2 in line with Harris et al. 2002. Despite looking morphologically homogeneous, dermal derived cells also show some heterogeneity. The dermal papilla, responsible for dermal pulp production, shows an activated fibroblast-like transcriptome pointing to a possible connection between wound healing pathways and evolution of the feather. An atlas of cell types in a developing feather will provide a baseline for studying the development of the diversity of feathers.

51 Nathan Lin, Lisa Brown

Production of hydrogen peroxide against systemic bacterial infection in the cat flea

Fleas (Order Siphonaptera) are arthropod vectors for pathogenic bacteria that cause several human diseases, such as cat scratch disease, murine typhus, flea-borne spotted fever, and plague. Although fleas are susceptible to infection, they also possess an immune system that provides defense against invading microbes. The production of reactive oxygen species (ROS), such as hydrogen peroxide (H_2O_2), is an essential component of the local immune response to pathogens in the flea gut; however, the generation of ROS has not been examined in the flea hemocoel – a major oversight because flea-borne pathogens that infect the salivary glands must first travel through the hemocoel. In this study, cat fleas (Ctenocephalides felis) were given a systemic infection with model species of bacteria (Micrococcus luteus, Serratia marcescens, and Escherichia coli), and subsequent levels of H_2O_2 were measured from extracted hemolymph at 24 hours post-infection. Additionally, flea survival rates were measured following a range of doses for S. marcescens at the same time point. Our results show that a systemic bacterial infection did not influence H_2O_2 levels at the time point examined, but that flea survival decreased significantly in response to S. marcescens infection. Overall, further investigation at earlier time points is likely needed to better understand the role of ROS in the flea hemocoel.

1393 Nick Lin, Avita He, Myana Keusch, Noelle Black, Naomi Fernandez, Dakota Lazore-Swan, Sarah Corp, Alexander Schreiber

Thymus gland size changes with frog metamorphosis, and with stress and thyroid hormone treatments

Metamorphosis in amphibians is a form of post-embryonic developmental that is accompanied by simultaneous increases in both thyroid and glucocorticoid hormones that mediate virtually all aspects of this process. During frog metamorphosis the immune system, which includes the thymus gland, remodels such that the tadpole immune repertoire is destroyed and replaced by a new adult component. To study changes in thymus size during spontaneous metamorphic climax, when glucocorticoid and thyroid hormones concentrations rise, we measured thymus surface area in Niewkoop-Faber (NF) stage 57-66 tadpoles. In order to study the influence of hormones on metamorphic thymus remodeling, we measured thymus surface area from prometamorphic (NF stage 54) tadpoles following 48 hours of individual or combined glucocorticoid (2 uM dexamethasone, DEX) and triiodothyronine (5 nM, T3) treatment. During spontaneous metamorphosis, thymus size decreased by 48% from just prior to the start of climax (NF 57) to the end of climax (NF 66). In prometamorphic tadpoles thymus glands decreased in size by 20% following treatment with either DEX alone or T3 alone. However, thymus glands of tadpoles treated with a combination of DEX + T3 decreased in size by 40%. These findings show that thymus gland remodeling during spontaneous metamorphosis is accompanied by an overall reduction in thymus size. Furthermore, glucocorticoids and thyroid hormones appear to act synergistically to reduce thymus size during metamorphosis.

1777 Eugene Lin, Yishun Zhou, Luke Moon, Andrew Gordus, Chen Li

Robophysical modeling of spider vibration sensing of prey on orb webs

Most spiders that make webs to catch prey are functionally blind and use legs to sense prey vibrations on the web. When doing so, they often dynamically adjust leg posture. Previous studies elucidated how vibration sensing depends on many factors of prey-web-spider system components, including prey vibration profile, web geometry and silk properties, and spider leg vibration sensor properties. However, how these components integrate to permit vibration sensing is less known, because it is challenging to make different kinds of measurements simultaneously. In fact, most studies of web vibrations lacked a spider or treated it as a point mass; the one study on static leg posture had no web or prey. Here, we created a robophysical model to begin to address this challenge. It consists of a robotic prey, a physical web with qualitatively similar geometry and material properties as a spider web, with stripes trackable in high speed videos, and a robotic spider with active legs equipped with accelerometers. As a first step, we compared the robotic spider staying stationary versus it dynamically adjusting leg posture and varied the robotic prey's vibration direction. Web vibration amplitudes decreased towards the robotic spider. This reduction was less in radial threads than in spiral threads. Dynamic leg posture adjustment had complex effects on vibration propagation. We are currently studying whether this is a form of active sensing.

1843 Hans Lindahl

Sex diversity: from medicalization to affirmation

Intersex is a political, social, medical, and identity term used to describe individuals born with sex characteristics that do not conform to binary understandings of sex. Given the complexity of human sex development, there are many opportunities for variation across different sex characteristics and developmental pathways, resulting in a spectrum of intersex traits. Although many intersex variations are associated with medical issues requiring treatment, sex traits that differ from the binary are not themselves pathological. However, intersex bodies have been pathologized for centuries due to the threat they pose to heteronormativity, eugenic projects, and racial hierarchies created by white Europeans and early settlers. Views of intersex bodies as monstrous have not fundamentally shifted in over 140 years, though technological developments have made possible the cosmetic surgeries now performed on an estimated 1 in 1000 births to "normalize" genital differences. Such surgeries consistently result in extensive follow-up procedures, scarring and sensation loss, and psychological trauma. Attempts to ban these surgeries for young children continue to be met with substantial pushback due to deeply entrenched beliefs in the supremacy of heterosexual potentiality, with which intersex bodies are seen as incompatible. Substantial shifts in understandings of sex and gender, increased intersex competency throughout scientific and medical fields, and individualized treatment of intersex patients are all essential steps to ending the discrimination, pathologization, and medical mistreatment of this population.

1396 Alexis Lindsey, Beth Roberts, Mark Sandfoss, Kristin Hinkson, Steve Reichling, Tonia Schwartz

Non-Invasive Genetic Sampling for Parentage Analysis in the Endangered Louisiana Pinesnake

With global biodiversity falling at a critical rate, genetic analyses for population monitoring and captive breeding can assist species recovery. However, with especially fragile populations, invasive sampling can be stressful and sometimes detrimental to the animal and the health of the population. Many studies have shown success using eDNA, skin swabs, hair, etc, for genetic analysis. Reptiles offer especially useful non-invasive genetic material through skin sheds and eggshells, which can be retrieved without ever touching or interacting with the organism. In this study, we aimed to determine parentage of Louisiana pinesnakes (Pituophis ruthveni) clutches, an endangered species, hatched at the Memphis Zoo through a captive-bred breeding program. We demonstrate the utility of skin sheds, blood spots, embryos, egg membranes, and blood samples for DNA isolation and consistent microsatellite genotyping. We performed parentage analysis with known and unknown possible parents for 22 clutches from 2019 to 2022. We contrast the number of loci and allelic diversity of the loci in their utility for discerning multiple paternity starting from a breeder population with low genetic variation. Further, we calculate inbreeding and genetic relatedness indices to characterize the diversity of this next generation to inform future decisions for release and breeder potential. Together our results demonstrate the utility of non-invasive sampling for genetic analyses of fragile reptile populations and aid in the conservation of the Louisiana pinesnake.

1236 Austin Link, Gavin Woodruff

Interrogating the evolution of host-microbe interactions with fig worms

Animals live in a microbe-rich world, and host-microbe interactions influence fitness and health. Caenorhabditis nematodes have been a biomedical model system for decades. Laboratory cultures of such animals are reared on Escherichia coli bacteria for food. As rotting plant bacterivores, this is an ecologically artificial environment implemented for experimental convenience. Only recently has the natural microbial context of these organisms been considered. How can natural microbial associates inform the biology of longstanding experimental systems? To understand the evolution of host-microbe interactions, we have isolated forty-four strains of wild microbes associated with the nematode C. inopinata in nature. C. inopinata is the closest known relative of C. elegans and is associated with figs and their pollinating wasps. Here, we aim to rear C. inopinata on these isolates and measure nematode fecundity and growth rates to discover how microbes in its natural context impact nematode fitness. We also aim to perform similar experiments with C. elegans to describe how host-microbe interactions evolve. Once characterized, we will implement forward mutagenesis screens to discover the genes (in worms and microbes) important for microbe-dependent fitness effects. In this way, we will use ecologically-relevant laboratory contexts to unearth novel functions of unexplored genes and understand the genetic bases of host-microbe interactions.

418 Marilyn Lionts, Becca Young, Andy Zhou, Daniela Zurita-Paredes, Andres Romero-Carvajal

Functional inference from transcriptomics in non-traditional models: A case study in amphibians

Modern 'omics approaches have revolutionized research on the development and evolution of complex phenotypes. It is now possible, in principle, to obtain high throughput sequencing data (e.g., RNA sequencing) from any tissue in any organism. However, in amphibians (among other groups) inference from next-generation sequencing in non-traditional model species presents challenges due to the limited number of species with available genomic tools. While traditional model species have been paramount to characterizing the molecular and genetic processes underlying embryonic development, identifying the rules by which variation in the genome gives rise to phenotypic variation requires systematic investigation of these mechanisms in diverse species. Here, we developed transcriptomics data analysis pipelines aimed at comparing gene expression patterns in non-traditional model amphibian species. We take two complementary approaches to analyze RNA sequencing data from several species of amphibians. We align RNA-seq and 3'tag-seq reads to the Xenopus tropicalis reference transcriptome and de novo assembled transcriptomes. In each species, we compare potential biological inferences of our two approaches using a novel pipeline for mining functional annotations from Xenbase (www.xenbase.org), an open access resource containing biological, genomic, genotype, and phenotype data available from Xenopus. Our approach provides an unbiased assessment of the potential and the similarity of inferences gained from the complementary approaches.

67 Sara Lipshutz, Jess McLaughlin, Kinsey Brock

Multimodal models of animal sex: breaking binaries to better understand reproductive behaviors

"Sex" is often reduced to a binary to describe a suite of phenotypic and genotypic traits related to reproduction. However, not all of these traits – gamete type, chromosomal inheritance, physiology, morphology, behavior, etc. – are necessarily linked, and the rhetorical collapse of variation into a single term elides much of the complexity inherent in reproductive phenotypes. We argue that consideration of "sex" as a constructed category operating at multiple biological levels opens up new avenues for inquiry in our study of biological variation. We apply this framework to several case studies: white throated sparrows with four sexes, color polymorphic side-blotched lizards, and polyandrous shorebirds. We argue that instead of assuming binary or bimodal sex in these systems, some may be better categorized as multimodal. Finally, we conduct a meta-analysis of terms used to describe sexual phenotypic diversity in the scientific literature, to highlight how a more inclusive and expansive framework for multimodal sex can clarify, rather than cloud, studies of sexual diversity within and across species.

1279 Anna List, Sarah Wofford-Mares, Tabitha Siegfried, Melissa Cook

Disproportionate rates of incidental sea turtle bycatch at fishing piers in the Florida Panhandle

Increasing rates of incidental sea turtle capture has been a concern in the United States, with yearly increasing numbers being associated with coastal fishing piers. Given the suite of anthropogenic pressures sea turtles face, increasing bycatch rates and potential for fatal injury are of deep concern. The northern Gulf of Mexico currently lacks up to date, baseline abundance and demographic sea turtle data. This project aimed to provide insight into the increasing bycatch rates at fishing piers by examining angler fishing practices in the Florida Panhandle. Two local piers were selected due to similar geographic locations and constructions. The Navarre Beach Fishing pier currently has the highest rate of incidental sea turtle captures in the state of Florida. Meanwhile, the nearby pier on Okaloosa Island sees drastically lower rates of bycatch. Angler surveys were deployed using methodology previously employed by NOAA along the Mississippi coast. The survey addressed questions related to bait types, gear setup, and angler response to a hooked turtle to obtain a more holistic view of angler behavior. Twice monthly surveys were administered via tablet at the target locations for 3 months across peak sea turtle nesting season and tourist season. Data from this study can be used to increase collective understanding of the influence of angler behavior on sea turtle bycatch rates which can better inform angler education and conservation efforts.

1141 Jack Litle, Emily Carrington

An Integrative Assessment of Life-Stage Specific Thermotolerance in a Variable Environment

Accurate predictions of how environmental change will impact organisms with complex life cycles depend on measurements of how well-matched the physiological tolerance of each life stage is to the environment it experiences. To assess this match, we applied an integrative field/laboratory approach to study two species of marine gastropod, Haminoea vesicula and Melanochlamys diomedea, that undergo early development in gelatinous masses in intertidal marine habitats. In the field, we measured egg mass deposition, embryonic survivorship, and temperature in deposition habitat to show that embryos experience high (> 15°C) thermal variability on short (daily) and long (to seasonal) time scales and regularly high (> 25%) mortality. In laboratory experiments, we measured embryonic growth, developmental rate, and survivorship across a range of temperatures to generate thermal performance curves and determine critical temperature thresholds for embryonic performance. We show embryos of both species regularly experience transient temperatures that exceed their critical thermal maxima by 4-6°C. However, the extent to which embryos exceed their critical thermal maxima in nature depends on the timing and location of adult deposition behavior. This study suggests a possible mechanism for selection for transgenerational thermoregulatory behavior (ie. adults that deposit in cooler microhabitat or at cooler times have higher lifetime R0), and demonstrates the importance of assessing match between adult reproductive strategy and early developmental stage physiological tolerance.

503 drew little, Rafael Rodriguez

Maternal effects on mating signals and mate preferences in Enchenopa treehoppers (membracidae)

We explored whether and how maternal effects influence courtship and mate preference in adult offspring. We worked with Enchenopa treehoppers, herbivorous insects that communicate with plant-borne vibrational signals. We manipulated the egg-laying density of females, which lay their eggs in aggregations on the stems of their host plant. We experimentally created aggregations of mated females at low, medium, and high egg-laying densities. We then reared the offspring that hatched in standard density treatments and described the signaling behavior and mate preferences of the adults using laser vibrometry and vibrational playbacks. We found no difference in development rates or survivorship associated with egg-laying density treatments. Male offspring of females from low density aggregations invested more energy into signaling. We will also discuss the effects of the egg-laying density treatments on the mate preferences of females and relate them to the effects of nymph rearing density and experience, which are important causes of signal-preference plasticity in Enchenopa.

387 Yujie Liu, Toshi Tsunekage, Iris Levin

What predicts telomere dynamics in adult barn swallows (Hirundo rustica erythrogaster)?

Life history theory states that organisms allocate their energy and resources to meet the demands of growth, reproduction, and survival. The resulting trade-offs and strategies are often related to various organismal traits, including telomeres, which are repetitive non-coding sequences of DNA located at the ends of chromosomes. Telomere length represents the balance between the eroding process caused by oxidative damage and the anti-eroding processes mediated by antioxidants. Our aim was to investigate factors associated with telomere length or the change in telomere length (dynamics) in adult barn swallows (Hirundo rustica erythrogaster). We focused on five potential predicting factors: age, a sexual signal (ventral plumage color), sex, survival, and reproductive success. We obtained blood and feather samples from adult barn swallows caught at multiple breeding colonies in Knox County, Ohio from 2019 to 2022. Quantitative PCR was used to measure relative telomere length for returning birds. To measure plumage color, we used a UV/Vis spectrometer to generate brightness, chroma, and hue values for each individual. Plumage color was measured each year, as ventral color changes throughout a bird's lifetime. Reproductive success for females was determined by the number of surviving nestlings they produced. Within individuals, relative telomere length was repeatable between years. Preliminary results show no relationship between telomere dynamics and plumage color or change in plumage color between years.

774 Patrick Liu, Catherine Loudon, Cameron Crook, Tommaso Baldacchini, Lorenzo Valdevit

Using microfabricated surfaces to trap bed bugs

Bed bugs are a persistent pest that have surged in infestations in recent decades due to increases in travel. There is an interest in producing an environmentally friendly and pesticide free method of controlling these pests that could be safely used long term. Bed bugs have been shown to be physically and permanently entrapped by microscopic hooked hairs (trichomes) on bean leaves. However, the leaves quickly dry, causing them to lose their ability to entrap bed bugs. Using nanoscale 3-D printing, we produced artificial hooks with the aim of replicating the bug-trapping phenomenon using a material with greater longevity.

Hooks were printed via two-photon polymerization using photoresin on a glass surface. We were able to document bed bug locomotion impeded by some legs being temporarily snagged using high-speed videography. Subsequent analyses using scanning electron microscopy showed evidence of bed bug feet (tarsi) being damaged.

1063 Jasen Liu, Carlos Nunes, Paulo Milet-Pinheiro, Santiago Ramirez

Patterns of evolution in floral volatile composition across a specialized pollination system

Floral volatiles play key roles as signaling agents that mediate biotic interactions between plants and animals. Despite their known importance, few studies have investigated broad patterns of volatile variation across groups of plants that share pollinators, particularly in a phylogenetic context. The "perfume flowers", Neotropical plant species exhibiting exclusive pollination by male euglossine bees in search of volatiles, offer an intriguing system to investigate these patterns due to the unique function of their chemical phenotypes as both signaling agents and rewards. Critically, as different bee species exhibit different preferences in the volatiles they collect, changes in floral chemistry can generate assortative mating between plant populations, creating the opportunity for incipient speciation. We leverage recently-developed phylogenies and knowledge of biosynthetic pathways along with over 50 years of chemical ecology research to characterize axes of variation in perfume flower volatiles, as well as understand their evolution at finer taxonomic scales. We find that most species exhibit perfumes dominated by compounds of either the phenylpropanoid or terpenoid biosynthesis pathways. Furthermore, we find these patterns to be consistent within 2 diverse independent radiations of perfume flower orchids (the Catasetinae and the Stanhopeinae). Within these clades, we also detect evidence for elevated rates of evolution in chemical traits that are inconsistent with Brownian motion, further highlighting their role in mediating prezygotic isolation.

1243 Kathy Liu, Jasmin Graham, Jayne Gardiner, Tonya Wiley, Catherine Macdonald

Bonnethead shark (Sphyrna tiburo) cephalofoil morphology in Biscayne Bay and Tampa Bay, Florida

Bonnethead sharks (Sphyrna tiburo), a small hammerhead species recognized by its rounded spade-like head shape, is the first documented shark species to exhibit sexual dimorphism in the cephalofoil. Males have a more distinguishable, pointed frontal bulge than females which is thought to develop in tandem with clasper calcification when approaching sexual maturity. Their total length varies throughout their range in temperate and tropical waters on both coasts of the Americas. Unpublished preliminary data has found bonnetheads in Biscayne Bay, Miami to differ from previously published sizes. This project is the first to establish the distinctive physical characteristics of bonnetheads in Biscayne Bay and use morphometric comparison with individuals from Tampa Bay to identify morphological differences. Bonnetheads were sampled in Biscayne Bay, FL (25° N 80° W) using longlines and with gillnets in Tampa Bay, FL (27° N 82° W). Body measurements (precaudal, fork, and total length, girth, and cephalofoil width) and photos of the cephalofoil were taken to plot specific landmarks in ImageJ. When multiple factors are considered, preliminary analysis suggests that Biscayne Bay bonnetheads do not display clear patterns of sexual dimorphism, however, in isolation, traits such as total length, eye-to-eye width, and bulge curve slope are statistically significant between sexes. This project is an initial step in longer-term research to assess bonnethead populations in Biscayne Bay.

847 Ethan Livingston, Alyssa Head, Eric Gangloff

Swimming beneath the Sahara: The thermal biology of Scincus scincus, the sand-swimming skink

Little is known about the natural history of the sandfish skink (Scincus scincus), despite its range spanning two continents and being common in the pet trade. In arid and hot environments across North Africa and the Arabian Peninsula, these lizards spend up to 90% of their day beneath sand and are uniquely adapted to this environment. However, much about the basic biology of this species remains unknown, especially in regard to its adaptations to its thermal environment. To better understand how the sandfish skink thermoregulates, we studied their thermal preferences and their use of sand horizons as a method for body temperature regulation. We monitored individual lizard body temperatures throughout the day in an environment where they had the ability to pick their ideal temperature. Additionally, we quantified the thermal dependence of performance by recording sprinting speed and diving speed, important for prey capture and predator avoidance, across a range of temperatures. We then tested the hypothesis that thermal preferences and the optimal temperature for diving and sprinting performance are correlated, suggesting co-adaptation of behavior and physiology. Overall, these data provide understanding of how this unique ectotherm survives in the extreme thermal conditions of a scorching hot desert.

1116 Alfredo Llamas, Todd Jones, Jennifer Phillips

How does sensory pollution and urban vegetation affect avian diversity and nesting success?

Anthropogenic sensory pollution, such as light and noise, can have various effects on animal behavior, such as song structure and thus mate choice. Little is known about nest site selection in relation to these combined sensory pollutants. Nest visibility and begging calls can cue predators, which will determine the overall survival of a clutch, and vegetation characteristics and sensory pollution may determine whether migrants pass through urban habitat. Thus, understanding which specific characteristics of habitats, soundscapes, and lightscapes attract migratory and nesting birds is useful to urban land managers. We investigate how sensory pollution and vegetation affect avian diversity and nesting success across an urban-rural gradient in San Antonio, Texas. We measured received noise levels and light (lux) at nests and 18 point count locations using a Larson Davis 831 meter and a Minolta t-10A light meter, respectively. Using point intercept vegetation plots, we measured canopy cover percentage, diversity of flora, and height of foliage across 50-meter circular plots, around each nest and point count location. Preliminary results show that adult birds tend to nest near sources of light but shows no effect on nest daily survival rate, whereas sources of noise tend to increase nest survival. Vegetation data are currently being analyzed. We predict that native vegetation, canopy cover, and vegetation diversity will promote avian diversity and nesting success.

857 Lauren Lock, Kristin Dyer, Dmitriy Volokhov, Brock Fenton, Nancy Simmons, Daniel Becker

Longitudinal impacts of habitat fragmentation on Bartonella and hemoplasma dynamics in vampire bats

Habitat fragmentation can have negative effects on wildlife populations, including implications for disease emergence and wildlife health. Bats have been recognized as pathogen reservoirs, and evidence suggests many bat species can be affected by habitat fragmentation. In order 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) in an intact and fragmented habitat in northern Belize across seven years. DNA from 406 blood samples were screened for Bartonella and hemotropic Mycoplasma species through PCR amplification of the gltA gene and the 16S rRNA gene, respectively. General linear mixed models will be used to test if the effect of habitat varies with capture year to influence the likelihood of infection; to identify additional key predictors of infection or pathogen genotype such as age, sex, and reproductive status; and to determine if these parameters influence infection status alone or by interacting with one another. We predict that (i) infections will be more common but less diverse in the fragmented habitat and in later years in response to increased anthropogenic habitat degradation, (ii) infections will be more prevalent and more diverse in reproductive females than in males or non-reproductive females, and (iii) infections will be less prevalent and less diverse in adult bats than in younger bats.

761 Brian Lomeli-Garcia, Abigail Cahill

Genetic Diversity of the introduced aphid Aphis nerii - are they superclones?

Aphis nerii, also known as oleander aphids, are expected to have low genetic diversity which is due to the female aphids being able to clone themselves. Despite this life history, A. nerii is a successful invasive species on milkweed plants in North America. To see if A. nerii has low genetic diversity within its introduced range, we compared the COI barcode sequences from populations within the United States (in Georgia, Illinois, Michigan, Ohio, and Pennsylvania, collected over multiple years). We sequenced over forty A. nerii individuals from seven populations, and analyzed haplotype diversity and genetic diversity in both space and time. Our results showed low genetic diversity in both space and time, consistent with the clonal life history of A. nerii, and a phylogenetic tree showed low clustering based on geography. Genetic distance between sites did not relate to physical distance between sites. We also found a relatively high rate of parasitism of the aphids by the wasp Lysiphlebus testaceipes, though parasitism was not found equally in all populations. Our data allowed us to explore Aphis nerii and their reproductive system to further understand their clonal life cycle and its impacts on their ecology and dispersal.

92 Patricia C. Lopes

To be aware of danger before danger: the effects of disease risk on animal physiology

Behavioral avoidance of diseased animals by healthy animals is a common mechanism to reduce the likelihood of becoming infected. However, various reports have been demonstrating that interactions with diseased animals lead not only to changes in behavior, but also to changes in physiology. I will highlight studies in vertebrates and invertebrates that have shown these physiological effects and propose neuro-immune-endocrine pathways that may be involved in eliciting these responses. I will also discuss the implications of physiological responses to disease risk and conclude with future steps that will help clarify when, how and why these physiological responses should take place.

442 Jesus Lopez, Ashley Teufel, Robert Page

Understanding anuran life cycle ecology and evolution through agent-based modeling.

Most Anuran species have a complex life cycle in which larvae grow and develop in a deteriorating environment. Larvae must balance consuming resources and metamorphosing quickly enough to escape their shrinking pond. Using agent-based modeling, we have created a simulation capturing key features of the ecology and evolution of many anuran life cycles. In our model, agents have three developmental stages: larva, juvenile, and adult. Each agent is characterized by parameters for age, energy, stress, sex, speed, energy consumption, metamorphic risk, and two diploid chromosomes carrying genes that can be parameterized to contribute additively to metamorphic risk or to be functionally neutral. The agents' environment consists of patches with varying mortality risk, landscape features that affect dispersal, ponds with adjustable locations and hydroperiods, and food energy for each patch type. The model is capable of custom configurations for various applications and modeling different species and environments. We have used the model to study gene flow and natural selection under varying spatial scenarios: a single pond with no landscape features, two ponds with unique hydroperiods separated by impermeable terrain, and several ponds with a gradient of hydroperiods. We examined data from replicate runs based on these scenarios to further understand how ecological pressures affect the evolution of metamorphic timing.

1565 Lan Lou, Nicole Wynne, Shajaesza Diggs, Karthikeyan Chandrasegaran, Chloe Lahondere, Zhijian Tu, Clément Vinauger

The role of the timeless gene in regulating olfactory rhythms and sleep patterns in Aedes aegypti.

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 that are 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.

1541 Michael Lough-Stevens, Caleb Ghione, Matthew Dean

Gestational investment and pseudopregnancy are evolutionarily correlated

In mammals, gestation is a physiologically demanding cost that should be avoided if offspring are absent. Nevertheless, non-pregnant females from a diversity of species can enter "pseudopregnancy", a physiological state resembling pregnancy. Here we compile data from 70 mammalian species to shed light on the evolution of pseudopregnancy. We find that all mammal species exhibit at least some level of pseudopregnancy. Pseudopregnancy length – which we define as the lifespan of a functional corpus luteum in non-pregnant females – was positively correlated with gestation length in normally pregnant females. However, species with the longest gestation times fell into two groups; species that undergo embryonic diapause (where fertilized embryos delay implantation for sometimes months) show pseudopregnancies that are much longer than expected, while species that do not undergo embryonic diapause show relatively short pseudopregnancies. Taken together, our study indicates that species with relatively long gestation are also at higher risk of entering pseudopregnancy, but that some species with especially long gestations have evolved mechanisms that minimize it.

504 Caleb Loughran, Michael Kearney, Blair Wolf

Modeling evaporative cooling and the potential for extended activity in lizards under future climate

Lizards use behavioral mechanisms to maintain body temperatures that optimize physiological performance and activity times. Recent research, however, has shown that physiological mechanisms (i.e., evaporative cooling via panting) may play a greater role in lizard thermoregulation than previously realized. Evaporative cooling may thus have important ecological consequences for lizards by potentially increasing activity times. We use the mechanistic niche model 'NicheMapR' and physiological data to explore how panting abilities and distributional limits potentially affect activity times in five species of Sceloporus lizards under current and future climate scenarios. Our results indicate that panting can significantly extend lizard activity periods, and that this effect is most pronounced for species that inhabit higher elevations where average air temperatures are cooler. Furthermore, species that are most effective at evaporative cooling can potentially extend their activity hours more than those that have limited cooling abilities. When accounting for climate warming, those species with significant evaporative cooling abilities and that live at higher elevations show the greatest extension of activity hours - potentially increasing survival in the face of rapid climate warming.

888 Michael Loukeris, Matthew O'Neill, Nathan Thompson

Do chimpanzees modulate substrate-to-body distance during vertical climbing?

Large-bodied arboreal mammals are characterized by a suite of anatomical specializations, including relatively long forelimbs and short hind limbs. The classic static model of vertical climbing suggests that these features help position the body's center of mass close to the foot contact point and substrate via highly flexed hind limbs. Long extended forelimbs then allow the animal to lean away from the substrate, creating sufficiently high contact forces for propulsion. Here, we used 3-D kinematic marker data from two male chimpanzees during vertical climbing and quadrupedal walking to test this model. We calculated body-to-substrate distance using a lower trunk marker. Elbow and knee angles were calculated using markers overlying joint centers.During climbing, body-to-substrate distance was ~25% lower compared with quadrupedalism (45±2 v 60±1 cm). Over a stride, elbow and knee joints were ~30–40 degrees more flexed during climbing than quadrupedalism. During quadrupedalism, the knee and elbow maintained relatively constant joint angles (elbow: ~150°; knee: ~160°) during their respective stance phases. During climbing the elbow flexed dramatically over stance phase (by ~30–70°). Peak flexion coincided with minimum body-to-substrate distance, with the knee slightly extended (by ~20°) during limb-substrate contact. Our results show that chimpanzees reduce body-to-substrate distance during climbing as expected, but contrary to model predictions, with the forelimbs having a more substantial role in modulating this distance than the hind limbs.Funded by NSF BCS-0935321

1299 Nya Love, Matthew Fuxjager, Doris Preininger

Testosterone levels in foot-flagging frogs at the breeding site

Social competition among males is thought to drive an increase in circulating plasma testosterone (T), a steroid hormone that regulates sociosexual interactions. Here, we study these effects in the context of Bornean rock frogs (Staurois parvus). Males of this species have evolved a multimodal display, which they use to compete with rivals in loud waterfalls and fast-flowing streams where they breed. The most interesting display they produce occurs when males wave their hindlimbs at rivals to expose white interdigitated foot webbing (i.e., the foot-flag display). Males also direct calls at competitors alongside these waving displays. Here, we tested whether males who are actively producing these displays at a breeding site have higher levels of T compared to nearby males, who are listening and watching displays but not producing them. We measured T from water-borne samples that we collected from individuals after watching them at the breeding waterfall at the Vienna Zoo. We predict that displaying males will have higher levels of T, providing further evidence that periods of social instability are positively associated with elevated levels of this steroid hormone. This study will reveal the extent to which social experience influence sex steroid levels in an amphibian.

265 Kathleen Lu, Kyra Ricci, Benjamin McLaughlin, Jessica Hua

Impact of art on public perception and student comprehension of disease ecology research

Art is becoming a common approach for communicating science, yet it remains unclear the extent towhich science-art can benefit varied audiences in varied contexts. To examine this gap, we developed anart exhibit based on the findings of two scientific papers in disease ecology. In Study 1, we asked visitorswith varying STEM backgrounds to complete a survey about their interest in science research before andafter viewing the exhibit. After the exhibit, visitors who did not report a career or major in STEM showeda 26% increase in research interest while visitors who did report a career or major in STEM showed an11.15% increase. In Study 2, we recruited upper-level ecology undergraduate students to receive one ofthree treatments: (1) engage with the art exhibit, (2) read the abstracts of the papers, or (3) do neither.Students completed a comprehension quiz immediately after their learning treatment and again twoweeks later. Following the treatment, comprehension quiz scores were 22.7% higher for students in theabstract group than students in the art exhibit group. Overall, these findings suggest that (1) visiting anart exhibit can improve perceptions of research, (2) audience identity influences the magnitude ofchange in perception, and (3) for ecology students, traditional means such as reading scientific papersmay be more effective for achieving knowledge acquisition goals in higher education.

928 Lauren Lubeck, Paul Gonzalez, Christopher Lowe

Wnt signaling in an indirect developing hemichordate

In most classical model systems the adult body plan is formed directly during embryogenesis, a life history strategy called direct development. However, the life history strategy of most metazoan phyla is more indirect, meaning the embryo first becomes a larva that has a body plan often radically different to that of the adult. Hemichordates are a phylum of marine deuterostomes that contain representatives of both of these life history strategies. In the indirect developing hemichordate, Schizocardium californicum, the larva corresponds to the anterior territories of the adult (head larva) while the posterior trunk regions are only added later during metamorphosis. The mechanisms of trunk development have been studied in detail in the direct developing species Saccoglossus kowalevskii and are known to be under the control of Wnt signaling. We hypothesized that the delay in anteroposterior trunk patterning in an indirect developer is controlled by differences in the timing of activation of Wnt signaling. To investigate this possibility, we identified and characterized the expression of components of the Wnt signaling pathway in multiple stages of development in S. californicum. We compared these expression patterns with corresponding stages in S. kowalevskii. These expression patterns suggest that Wnt plays a role in AP patterning in the S. californicum head larva despite the lack of trunk region, similar to its role in the adult AP axis in S. kowalevskii.

1748 Emily Lucas, Jennifer Taylor

Papillae Retraction in Octopus bimaculoide

The California two-spot octopus, Octopus bimaculoides, relies heavily on the use of camouflage via rapid changes in the color and texture of their skin. The latter is accomplished by individually extending and retracting a series of papillae along their body, mantle, and tentacles. While papillae extension is known to occur through muscle contraction, the retraction mechanism has not yet been characterized. We sought to describe papillae action in O. bimaculoides, with emphasis on the retraction mechanism, using a combination of behavioral observations, mechanical testing, and histology. Specifically, we examined the potential use of elastic energy stored in connective tissue in papillae retraction. Papillae extension and retraction on different regions of the body were observed in detail using high speed videography, while skin elasticity was examined through tensile testing. We used histology to examine how the organization of muscle and collagen facilitates retraction. Preliminary[jj1] [e2] data indicate that individuals express their papillae in unique ways, but all tend to more quickly and noticeably express and retract the papillae on their bodies, suggesting potential differences in papillae morphology across regions of the body. Preliminary tensile tests of the body skin show high extensibility and elasticity that would facilitate papillae retraction[jj3] . While papillae extension is an important camouflage tool, retraction helps octopuses rapidly streamline their bodies for quick movements, as may be necessary to avoid predation.

260 Thomas Luhring, Lyndsie Wszola, Grant Connette, Christopher Schalk

Droughts reduce growth and increase vulnerability to increasingly frequent and severe drying events.

Aquatic organisms are persisting through increasingly severe and frequent droughts. While much attention has rightfully been directly at the acute effects of severe droughts and drying events, not all droughts lead to drying events. Here we investigate the effects of drought severity in years without drying events on sex-specific growth rates of aquatic salamanders (Greater Siren, Siren lacertina) across 11 years of a mark-recapture study in the Southeastern United States. Larger S. lacertina are able to estivate through longer drying events than smaller individuals (endogenous energetic reserves increase disproportionately with size). Thus, growth rates determine how quickly new individuals recruit into drying event resistent size refugia. Although females reached the same asymptotic size as males, they grew more slowly. Mild to moderate drought conditions universally decreased growth rates. Increasingly prolonged drying events will require a larger minimum size to persist through which means that it will take longer to reach sufficient size in good conditions for males. Increased drought frequency and severity thus leads to an ecological catch-22 whereby becoming more resilient to increasingly severe drying events necessarily increases demographic vulnerability (e.g., prolonging time for recruitment) to increasing drying event frequency.

1181 Linnea Lungstrom, Mark Westneat, Jonathan Huie, Matthew Kolmann, Karly Cohen

Sink Your Teeth into the Puncture Performance of a Payara Pendulum

Piscivory has evolved many times in fishes, resulting in a wide range of related morphologies. Vampire tetras (Cynodontidae) are piscivorous fishes with characteristically long, sharp canines used to impale prey during feeding. While all three extant cynodontid genera co-occur, the types of fishes they hunt varies. Additionally, the size, spacing, and surface area of the conical teeth among cynodontid genera differ. This suggests that although these teeth are superficially similar in shape, their biomechanical functions differ according to the leverage and stress they experience during feeding (functional heterodonty). We tested the degree to which different genera are functionally heterodont using micro-CT scans and computational modeling as well as investigated puncture performance of the canines using 3D printed models affixed to a ballistic pendulum. With 5 N of input force applied to the jaw inlever, we found that cynodontid teeth exhibit highly variable stress values (7.05×104-1.11×108Pa), and the number and position of functionally heterodont teeth differ among species. Canine performance varied among genera with respect to work-to-puncture (2.36-3.75 J) and puncture depth (3.14-3.93 cm/J) with Cynodon gibbus canines having the lowest values of work-to-puncture and Hydrolycus armatus canines having the highest values of puncture depth. We conclude that cynodontid canines are strongly functionally heterodont, and subtle changes in morphology may lead to big changes in performance, facilitating ecological coexistence among fishes occupying the same dietary guild.

395 Yi-Jyun Luo, Eunice Wong, Mikhail Matz

Development of neuronal diversity in coral larvae as they become competent to settle

The mountainous star coral Orbicella faveolata is one of the major reef-builders in the Caribbean, but for the past several decades it consistently fails to produce new recruits, which contributes greatly to the region-wide reef decline. Here, we used single-cell RNA sequencing to look into cell type composition changes as O. faveolata larvae acquire settlement competence. We see multiple, mostly neuronal, cell types appearing between the time when the larva becomes a fully-formed swimming planula (5 days post fertilization, dpf), to swimming planulae not yet capable to settle (11dpf), to when first settlers appear (19 dpf), despite the lack of visible changes in larval morphology. The neuronal cell types each express a specific set of G-protein-coupled receptors, highlighting the diversity of sensory modalities, including one type that expresses five opsins. We also track expression or neurotransmitter precursors and transcription factors. This is the first time the neuronal complexity has been profiled in a maturing coral larva in connection with settlement competence, which sets the stage for comparative analysis with coral species that are more successful at recruitment.

830 Keegan Lutek, Emily Standen

Locomotor transitions in Polypterus senegalus

Moving within and between media requires behavioural adjustments that tune kinematic movements to the environment. Such transitions can occur across ’gaits’ (i.e. within a single media due to differences in speed) or across ‘modes’ (i.e. across habitats or broad categories of locomotion); however, these distinctions are traditionally defined by discrete changes in kinematic patterns without any thought to the underlying neuromuscular control. Here, using Polypterus senegalus, an amphibious actinopterygian fish, I present data describing kinematics and neuromuscular control across the locomotor transition from water to land and characterize changes in gait depending on swimming speed. Our results suggest that swimming and walking may be opposite ends of a neuromuscular control spectrum, and that fin and body use varies depending on swimming speed and environment. We will discuss the implications of these results for neuromuscular control in amphibious fish and their implications for the magnitude of changes required to move from an aquatic to a terrestrial life history.

1363 James Lynch, Ethan Wold, Andrew Mountcastle, Simon Sponberg, Nick Gravish

Wing collision mitigation through stretch-activated muscle dynamics in flying insects

Bumblebees rely on self-excited, asynchronous muscles to drive wingbeats during flight. This adaptation is thought to enable high-power, high-frequency wingbeats and improved efficiency thanks to mechanical resonance, but may also have an underappreciated role in mitigating perturbations. We recorded bumblebees colliding with vertically-oriented tripwires and observed that they are capable of rapidly halting flapping during wing-obstacle collisions. In extreme cases, bees completely arrest wing motion within two flapping periods (∼10 ms). Based on those observations, we asked if such fast collision responses could be achieved purely through asynchronous muscle's intrinsic dynamics. In previous work, we described a combined model of stretch-activated muscle and flapping insect anatomy that produced self-excited flapping and implemented it on a robotic system. Here, we use the same robotic system to uncover relationships between flapping system parameters and collision response. We find that collisions perturb the asynchronous wingbeat and result in a significant reduction in flapping amplitude depending on collision timing and the strength of the muscle relative to the obstacle. Like in bees, we observe that wings can completely halt flapping within just two wingbeats purely through the asynchronous muscle dynamics, without sensing the perturbation itself. We connect the biological and robotic observations and suggest that asynchronous muscle plays an important role in simplifying control by passively responding to collisions without the need for additional sensory feedback.

782 Ana Lyons, Kevin Roberts, Kylie Cheng, Lily Shang, DéJenaé See, Caroline Williams

Mechanisms of cold tolerance in tardigrades (Hypsibius exemplaris)

Little is known about tardigrades' tolerance to cold and ice formation. Here, we develop new methods to investigate the interaction of exposure time, low temperature, and ice formation on the survival of hydrated, adult Hypsibius exemplaris. Visualization of SYTOX Green uptake in cold-exposed tardigrades allows us to quickly and accurately quantify the survival of thousands of animals under a range of ecologically-relevant low temperatures (-10°C, -15°C, -20°C), exposure times (2-120 hours), and induced ice formation. We then implement a comparative proteomics pipeline to characterize how protein abundances in H. exemplaris shift in response to non-lethal cold (-10°C) and perform ice-affinity purification (IAP) to identify candidate ice-binding proteins. Tardigrades exposed to -10°C show high survival (absent ice formation), while survival varied at -15°C. Tardigrades froze at -20°C, with survival exponentially decreasing with time. Interestingly, exposing tardigrades to ice-nucleating bacteria significantly improves survival, indicating tardigrades' tolerance to environmentally inoculated ice. Next, high-sensitivity DIA mass-spectrometry on cold-treated tardigrades identified 2,776 proteins, with 89 being differentially abundant (q-value < 0.1). GO enrichment analysis suggests changes in neural function, calcium balance, metabolism, and cuticle maintenance in response to cold. IAP identified a ranked list of novel candidate ice-binding proteins. Overall, this work identifies foundational mechanisms that tardigrades' use to survive cold and freezing on a physiological and molecular level—highlighting the critical but understudied role of environmental ice-inoculation in tardigrade survival.

783 Ana Lyons, Grace Chiu, Hannah Gemrich, Saul Kato

Building a framework for transgenics & systems neuroscience in tardigrades

Tardigrades' microscopic size, transparent bodies, and ability to locomote in coordinated gaits make them interesting candidates for neuroscientific study using cutting-edge, live-animal microscopy techniques. Genetic tools and transgenic methods needed for tardigrade use as an emerging model, however, are lacking. Identifying and evaluating various tardigrade-compatible genetic promoters, with a diversity of expression patterns, is a first step to establishing transgenic tardigrades. Leveraging existing promoters in sister taxa (C. elegans, D. melanogaster, and other invertebrates) and the Hypsibius exemplaris genome, we establish a list of candidate promoters for use in tardigrades related to widespread expression, scoring phenotypes of successful transgenesis, and finally neuronal expression. We identify H. exemplaris homologs of functionally important genes in each of these three categories using BLASTp (E-value < 0.05) and subsequently generate an additional list of tardigrade-specific candidate promoters by taking 100–1000bp upstream of these homologs' start codons. Next, we propose methods to functionally verify expression patterns of each candidate promoter by expressing plasmids containing GFP, which are transfected into wild-type H. exemplaris and C. elegans, via a range of cargo delivery methods. Our curated list of candidate promoters for tardigrade transgenics provides dozens of sequences for future experimental validation and applications. Establishing functional promoter sequences and molecular cargo delivery methods for tardigrades is a first step into their untapped potential for an assortment of future genetic and behavioral studies.

611 Molly Ma, EJ Huang, Gabriel Bever, Amy Balanoff

Comparative Shape Analysis of the Hyoid in Vocal Learning vs. Non-vocal Learning Birds

Birds and mammals evolved their relatively large brains independently, a convergence that extends to numerous complex behaviors, including vocal learning. Although morphological changes in the hyoid have been hypothesized as necessary for vocal production in mammals such as humans, similar changes are unknown in birds. Parrots are of particular interest because, like humans, they have been observed utilizing their tongues to adjust sounds. With this in mind, we undertook a comparative analysis of the morphology of the hyoid skeleton to understand the role it and its associated musculature play in sound production in vocal-learning birds. We constructed three-dimensional surface renderings using CT scans of alcohol-preserved specimens and positioned discrete landmarks on these models. We then used PCA to evaluate the primary sources of 3D shape variation and if this variation is able to discriminate between vocal versus non-vocal learning birds. Our results show that the paraphyletic assemblage of vocal-learners fall within a narrow range of variation, indicating that these data do convey a functional signal. Parrots, although within this range of morphospace, differ significantly from all other birds, suggesting the hyoid may play a unique role in their sound production. The next steps in this project include the alignment of muscles to those regions of the hyoid that experience the largest morphological changes to better understand their functional role during vocalization.

1698 Inbar Maayan, Dan Bock, Anthony Geneva, R. Graham Reynolds, Alyssa Vanerelli, Scott Edwards, Jonathan Losos

In situ diversification of a classic adaptive radiation: phylogenomics of Jamaican anoles

Understanding diversification is a major goal of evolutionary biology, and the study of adaptive radiations has been a key part of this pursuit – especially replicate adaptive radiations, the natural experiments that help us illuminate the course of evolution. The four replicate radiations of Greater Antillean anole lizards have become a classic example of the power of such natural experiments. Yet, despite all we know about these four faunas, much remains unknown about the series of events that gave rise to each of these assemblages. Here, we examine the lineage relationships and evolutionary history of the Jamaican anoles, the youngest of these four radiations, as the first step toward understanding the processes shaping the patterns of ecological, morphological, and genomic diversity we observe today. With most species exhibiting considerable intraspecific variation and co-occurring across a variety of habitat types, this clade is ideal for studying diversification as it plays out across a heterogenous landscape. Using a large multilocus dataset based on the most comprehensive sampling of this clade to date, we reconstruct novel nuclear and mitochondrial phylogenies and address the previously-proposed discordance between them. Furthermore, we show that genetic variation is considerable within several presently-recognized species, demonstrate how this variation is partitioned across the landscape, and build a framework for investigating the evolutionary and phylogeographic story of the Jamaican anoles and their sister radiations.

705 Ian Maccourt, Suzy Renn

Retention of Conditioned Behaviors in A. Burtoni

Behaviorists and ethologists birthed the modern field of animal behavior through collaboration. Today we can still learn a lot about the natural behavior of animals using the controlled and quantifiable approaches pioneered by behaviorism. In order to study the neural mechanisms that control and allowed for the evolution of the mouth-brooding form of parental care, the Renn lab firsts needs to quantify hunger without feeding the organism. We use the emerging model for social behavior, A. Burtoni, an east African Cichlid fish well known for mouth-brooding and constructed an Arduino microcontroller which trains and measures feeding behaviors. Our previous research presented at SICB demonstrated cichlids trained on this system and retained normal swimming and social behaviors, thanks to a program of variable feeding, but failed to mention what would happen when these feeding behaviors are forgotten by the organism. Our current research focuses on reintroduction of a behavior after extended periods of time away from the Arduino system itself, focusing in on how long the behavior is retained for and how fast can this behavior be reintroduced. After initially training for a two-week period, fish were returned to a general population tank for periods of 2, 3, or 4 weeks before returning for testing in the Arduino system. The speed at which the fish relearned the protocol for food in comparison to the intial

2_weeks_is_quantified_by_their_latency_to_approach_ the_LED_after_the_Arduino_system_has_started_a_trial. _This_research_will_allow_use_to_quickly_retrain_fish, _allowing_for_more_chances_for_these_females_to_ become_mouth-brooding_as_quantifying_the_differences _in_latency_to_the_LED_when_mouth-brooding_versus _gravid_is_the_end_goal_of_our_Arduino_system.

194 Adrian Macedo, Jacob Hutton, Jason Dallas, Robin Warne

Glucocorticoid effects on thermal acclimation capacity in a frog

Thermal acclimation to shifts in local environmental temperatures is an example of reversible phenotypic plasticity which enables an organism to quickly shift their thermal tolerance without a significant loss in performance. However, the hormonal and regulatory mechanisms that underlie thermal acclimation in ectotherms remain unclear. Glucocorticoid (GC) hormones, such as corticosterone (CORT), are one potential homeostatic regulator that potentially contribute to coping with thermal stress. We collected wild Blanchard's cricket frogs (Acris blanchardi) and recorded their heat tolerance capacity following exposure to different temperature and exogenous CORT treatments. Frogs were placed in one of two different acclimation temperatures (18° or 28°C) for 6 days and given either 3 doses (chronic) or 1 dose (acute) of exogenous CORT to identify how GCs interacted with temperature to influence heat tolerance as assessed by CTmax assays. Frogs acclimated to 28°C increased their heat tolerance by >3°C, compared to those acclimated to 18°C. Heat tolerance was independent of exogenous CORT treatments, but there was a negative relationship between urinary corticosterone metabolites (UCM) concentrations and CTmax. These findings may have resulted from a negative effect of CORT on heat shock protein expression, a suite of molecular chaperones associated with thermal tolerance. This suggests that CORT may influence thermal tolerance plasticity, but this effect is dwarfed by thermal acclimation effects, indicating that mechanisms beside GCs are likely more relevant to CT-Max.

914 Meghan Maciejewski, Eva Fischer, Alison Bell

Neural correlates of divergent reproductive behavior in two ecotypes of threespine stickleback

Parental care has evolved repeatedly in vertebrates. Once care evolves, it is rarely lost, as offspring evolve to rely on care. An outstanding question is whether the mechanisms recruited when care is gained are also recruited when care is lost (e.g., changes in the number and/or activity of certain neuronal populations). In threespine stickleback fish (Gasterosteus aculeatus), males typically provide uniparental care. However, in an atypical ecotype of stickleback (the "white" ecotype), males have evolutionarily lost parental care. After fertilization, males of the white ecotype pick their eggs up in their mouths and disperse them outside their nests, providing no further care. We investigated the neural basis of this evolutionary loss of caregiving by comparing males of the white and the common, uniparental ecotype at three different stages during the breeding cycle. We observed the behaviors of each male before collecting brains for immunohistochemistry. We characterized general neural activity in the preoptic area (POA) with phosphorylated ribosomal protein S6 (pS6) as a marker for neural activation. Additionally, we co-stained for galanin and isotocin (the fish homolog of oxytocin), two neuropeptides associated with parental care behavior in vertebrates, to identify ecotypic and stage differences in the number of galanin- and isotocin-positive neurons as well as their activity. The results of this study provide a rare look at the neural basis of a loss of caregiving.

592 Joseph Mack, Alexandra Bely

Regenerative and non-regenerative annelids maintain their resting metabolic rate after amputation

Many animal phyla have species with extraordinary regenerative abilities, but most groups also include species that have puzzlingly lost the ability to regenerate. One explanatory hypothesis argues that regenerative ability is lost when the costs of regeneration outweigh its fitness benefits. However, this idea remains poorly tested. While there are comparisons of molecular responses to amputation between closely related regenerators and non-regenerators, physiological comparisons are sparse. Here, we ask if regenerative species have a metabolic response to amputation that is distinct from a non-regenerative relative. We employ micro- respirometry to measure and compare metabolic rates after amputations in regenerative and non-regenerative species of water nymph worms, a group of freshwater annelids notable for interspecific variation in regenerative ability. We also report results from experiments designed to determine if whole-body cell proliferation is associated with differences in metabolic rate. Surprisingly, preliminary work indicates that there is no change in metabolic rate following amputation in the poor regenerator Chaetogaster diaphanus and the good regenerator Stylaria fossularis. Thus, our data does not support a correlation between regenerative ability and metabolic rate in the water nymph worms. Unlike other invertebrates, these annelids appear to be metabolically unperturbed by amputation. Considering this, we predict that our cell-proliferation assays will indicate that these worms have a constant pool of proliferating cells that is redistributed between regeneration, asexual reproduction, and growth.

593 Joseph Mack, Alexandra Bely

Metabarcoding of gut contents clarifies the evolution of carnivory in a genus of predatory annelids

The transition into carnivory is a profound dietary shift that has occurred numerous times in animals. However, underlying mechanisms for this transition are poorly understood. Lineages that have recently adopted predatory lifestyles are thus compelling models for understanding the evolution of animal carnivory. Within the phylum Annelida, ancient origins of carnivory have led to highly successful groups like leeches, while recent acquisitions have also occurred. Chaetogaster, a genus of small, freshwater oligochaetes, is one widespread example with two recent origins of carnivory. However, it is unknown how the predatory Chaetogaster species are descended from their detritivorous ancestors. To understand how carnivory evolves from non-carnivorous diets, we employ a metabarcoding gut-content analysis of eight Chaetogaster species and a detritivorous outgroup. To identify gut-contents, we sequenced 18S from multiple individuals of each species and inferred prey taxa from the reads. From the metabarcoding data, it is apparent that carnivory has evolved two different ways in Chaetogaster. The generalist predator C. diaphanus is closely related to species with diets intermediate between detritivory and carnivory. Meanwhile, the mollusc parasite C. limnaei A is closely related to likely detritivorous species. This suggests that transitions into carnivory can occur with or without intermediate steps, even among closely related carnivorous lineages.

1241 Alayna Mackiewicz, Kayla Goforth, Catherine Lohmann, Kenneth Lohmann

Effect of radiofrequency magnetic fields on the geomagnetic sense of flounder

Diverse animals, including various fish, reptiles, and birds, detect Earth's magnetic field and use it as a cue to navigate during long-distance migrations. Despite extensive evidence for magnetoreception in many species, how animals detect and process magnetic field information remains an unsolved mystery of sensory biology. One hypothesis is that complex chemical reactions involving radical pairs provide the physical basis for a magnetic compass, which provides directional information and is used by animals to maintain headings. Consistent with predictions of the chemical magnetoreception hypothesis, oscillating magnetic fields within the 0.1 to 10 MHz range (also referred to as radiofrequency or RF) disrupt the ability of birds to use their magnetic compass. Whether RF fields also disrupt the compass sense of fish, however, has not been investigated. The Gulf flounder (Paralichthys albiguttata) is an unusual bottom-dwelling flatfish with a well-developed magnetic sense. As a first step toward investigating the mechanisms underlying magnetoreception in flounder, swimming direction and orientation of fish were recorded in the ambient magnetic field, in a reversed magnetic field, and in the ambient field in the presence of RF. Results will provide insight into how fishes detect magnetic fields.

257 Bryan MacNeill, Michael McKain, Aaron Rodriguez, Eduardo Ruiz-Sanchez

Dissecting pollinator-driven floral-trait evolution in Agave subg. Manfreda

Agave is one of the most species-rich genera in the family Asparagaceae. The genus expanded through a radiation marked by two diversification events: adaptation to arid environments and the emergence of novel pollination syndromes. Agave subg. Manfreda has its center of diversity in Mexico and exhibits highly-variable floral architecture. Manfreda comprises approximately 52 species of the ∼250 in Agave and is split into sections, Polianthes and Herbaceae, presenting various pollination syndromes and attracting a wide array of pollinators like bats, hummingbirds, and hawkmoths. Despite multiple taxonomic studies looking at morphological characters of the group, subgenus Manfreda does not have a robustly sampled molecular phylogeny to support these studies. Given the variation in pollination syndromes in the group and the absence of sufficient sampling of taxa in molecular phylogenies, the rate of pollination syndrome shifting in Manfreda is unknown. To better describe the evolution of pollination syndrome in Manfreda, we reconstructed a chloroplast genome phylogeny to investigate molecular evidence of relationships among species. We sampled multiple individuals within species with varying pollination syndromes using herbarium specimens. Here we present the first chloroplast genome phylogeny for the group, determining the phylogenetic relationships of species in Manfreda. These results demonstrate how pollination shifts occur within Manfreda and identify areas of future research in how interactions between pollinators

and plant genomes can result in repeated origins of pollination syndromes.

103 Jason Macrander, Alyah Bennett, Katie Statile, Kerry Broderick

Clownfish Influence on Differential Levels of Gene Expression in Sea Anemones

Connecting ecological interactions with molecular processes that shape complex phenotypes is challenging. Consequences of these interactions are of broad interest in biology, as they influence genome structure, gene expression dynamics, and overall phenotype complexity. As a phenotype, venom presents a complex mixture of proteins that work synergistically with one another across the tree of life across varying ecological shifts. Within Cnidaria, changes in venom composition have likely evolved in response to predators or prey, but within clownfish hosting anmeones (Cnidaria: Actiniaria) mutualistic relationships between clownfish and their venomous hosts provide an alternative mechanism of predatory defense and excess nutrients, while also being venom targets. This dynamic interaction presents a dramatic ecological shift, likely influencing venom phenotypes. We sought out to investigate how clownfish symbionts may influence on overall gene expression ans toxin profiles in two species of sea anemones: a typical hosting species (Entacmaea quadricolor) and an atypical non-hosting species (Condylactis gigantea). We recovered differential gene expression of transcripts linked to metabolic pathways involved with nitrogen transport, lipid transport, lipid biosynthesis, glycolysis, and peroxidase activities among others. We also identified a dramatic change in toxin gene expression among the atypical non-hosting species actinoporins (pore forming toxins) which may be indicative of to their ability to host clownfish sybmionts. Overall, our results shed light on the influence of symbiont association on gene expression dynamics in a unique venomous system.

890 Jason Macrander, Conner Philson, Bryan MacNeill, Armita Manafzadeh, Kathleen Munley, Maria Stager, Jennifer Houtz, Anusha Shankar, Rebecca Varney, Emily Lessner, Adrien Arias

SPDAC PRESENTS: Questions you didn't know you had - The graduate student and postdoc edition

Graduate students and postdoctoral scholars make up an overwhelmingly large proportion of the attendees and presenters every year at SICB's Annual Meeting. As a society, SICB provides the infrastructure to foster collaborations, offers opportunities for networking and mentoring, and provides training opportunities for young scientists to grow within their various fields. Beyond these opportunities, however, every graduate student and postdoctoral scholar brings with them lived experiences and advice in which they can help guide others along their own path. The Student/Postdoctoral Affairs Committee (SPDAC) was created to support graduate students and postdocs society-wide; thus, we can collectively serve as a resource to address topics graduate students and postdocs may not know about or have not yet experienced. To facilitate this discussion (and answering questions you didn't even know you had), SPDAC is presenting an interactive poster featuring this topic, where graduate students and postdocs will be able to share knowledge and advice through lived experiences with others pursuing this path and post questions they wish they had asked when starting out in graduate school or as a postdoctoral scholar. The poster will serve as a point of discussion throughout the meeting, with the goal of facilitating conversation among current and former SICB graduate students and postdocs and providing a forum in which young scientists can share events that they have experienced during their academic journeys.

491 Autumn Magnuson, John Jacisin, David Ledesma, Melissa Kemp

Taxonomic and ecological signals in the morphology of North American snake lower jaws

Snakes have been an important part of a broad range of North American ecosystems for millions of years. To understand the evolutionary and ecological history of snakes throughout time, it is crucial to accurately identify their fossils, which are primarily isolated vertebral and skull elements. However, there is relatively little known about the interspecific variation of North American snake skulls, and few paleontological studies account for shifting geographic distributions when identifying fossil herpetofauna. In order to help address this lack of data, we documented the interspecific variation of the compound bone and dentary, both of which are recovered as fossils, in 68 snake species from 6 families across North America through a combination of osteological specimens and CT scans. We developed a matrix based on previously published characters and tested their diagnostic usefulness based on our data. We found that the majority of the selected character states were taxonomically informative for identification to the family level. Additionally, closely related snake groups were more similar in morphology, suggesting stronger phylogenetic over ecologic signal in the characters of our selected elements. The data from this research contributes to a modern comparative framework for better understanding the evolution and morphology of North American snakes through the lens of the fossil record.

1506 Anabela Maia, Amina Chamanlal, Zakiyat Djabakatie, Chelsea Yang, Tabitha Almeida, Jessica Clark

Correct stabilizing function of spiny dorsal fin requires local sensorimotor integration

When exposed to turbulence fish often rely on median fins to recover from perturbations. The spiny dorsal fin is a known stabilizer in bluegill exposed to streamwise turbulence. We assessed motor control and sensory perception of the spiny dorsal fin in bluegill through video kinematics and electromyography under turbulence and non-turbulence. Epaxial and spine erector muscles were implanted bilaterally followed by the injection of one of three treatments: lidocaine (to remove sensation), flaxedil (a muscle relaxant) or a saline control. We expected turbulence and flaxedil injection to result in the most instability as measured by center of mass displacement. We also expected non-turbulence and flaxedil to result in lower erector contraction intensity, duration and duty factor. As predicted, fish injected with saline under turbulence had higher fin displacement and relative velocity. This pattern was reversed under lidocaine and remained unchanged under flaxedil. Displacement of the center of mass increased under turbulent conditions and fish spent less time in a fully vertical position under lidocaine or flaxedil. Under turbulence, we observed longer burst duration and higher intensity of spiny erector muscles under control conditions. Erector muscle activity was considerably reduced when afferent information was absent, especially during perturbations, and the timing of muscle activation was also abnormal. This suggests a local level of fine motor control in the spiny dorsal fin guided by real-time afferent information.

324 Mark Mainwaring

The advantageous performance of individuals raised in disadvantageous conditions

The evolution of life histories and reproductive strategies has been extensively studied, yet that research has focused on dominant individuals, meaning that the life histories and reproductive tactics of subordinate individuals remains poorly understood. Here, I begin to redress this imbalance by highlighting the links between early life adversity and performance during adulthood, and those instances in which subordinate individuals out-perform dominant individuals during adulthood. Subordinate individuals are competitively inferior to conspecifics at any given point in time, having been raised under conditions of high predation risk, low food availability or many ectoparasites, whilst hatching last within asynchronously hatched broods. Subordinate individuals struggle to obtain parentally-provided food and so differentially grow those morphological traits that enable them to compete for food or to fledge rapidly, although links between early life conditions and performance during adulthood are scarce for subordinate individuals. During the breeding season, meanwhile, studies from diverse taxa show that subordinate individuals rely on ‘sneaky’ tactics, such as adaptive dispersal behaviours, competing for partners at optimal times and taking advantage of depleted energy reserves in dominant conspecifics, to acquire copulations whenever possible and thus maximise their reproductive success. In conclusion, there are few links between early life adversity and subordination during adulthood, although there is evidence that subordinate individuals employ ‘sneaky’ tactics that allow them to outperform dominant conspecifics during adulthood.

838 John Majoris, Fritz Francisco, Corinne Burns, Simon Brandl, Karen Warkentin, Peter Buston

Paternal care regulates hatching time and hatchling morphology in a coral reef fish

In oviparous species, hatching represents a dramatic life history transition, where embryos leave behind the protection of the egg capsule to experience the risks and opportunities of the outside world. Thus, the timing of hatching is a crucial decision, but for embryos with developing sensory systems, determining the optimal time to hatch is challenging. In species with pre-hatching parental care, parents can help their offspring by assessing environmental conditions and inducing their embryos to hatch when the time is right. We provide the first documentation of parental hatching regulation in a coral reef fish, demonstrating that male neon gobies (Elacatinus colini) directly regulate hatching by removing embryos from the clutch and spitting hatchlings into the water column. Paternally-incubated embryos hatched later in development, more synchronously, and had higher hatching success than artificially-incubated embryos. Artificially-incubated embryos displayed substantial plasticity in hatching times (range: 80 – 224 hours post-fertilization), suggesting that, when receiving parental care, embryos wait for male parents to induce hatching rather than hatch on their own. Finally, paternally-incubated embryos hatched with smaller yolk sacs and larger propulsive areas than artificially-incubated embryos, suggesting that parents play an important role in shaping the developmental trajectory and dispersal potential of their offspring. These findings highlight the complexity of parent-offspring interactions in fishes and may have important, and currently unstudied, consequences for fish population dynamics.

1761 Cassandra Maldonado

Characterization of Antibiotic Production and Microbial Diversity in the Soils of San Antonio

This study aimed to characterize the differences in soils sampled from highly developed urbanized areas with predominately non-native vegetation and undeveloped land with native vegetation. San Antonio, located in south Texas, is a rapidly expanding city with over 13,000 people moving to the city from 2020 to 2021. The increase in population has led to mass development on the city's north and south side. New construction has destroyed native plants and topsoil. Microbes from the soil have produced antibiotics. However, the widespread overuse of antibiotics in humans and animal agriculture has led to the prevalence of antibiotic resistance/multi-drug resistant bacterial strains. Staphylococcus aureus and Staphylococcus haemolyticus have multi-drug-resistant strains found in hospital and community gathering points. Soil samples collected in and around San Antonio, Texas, were tested for Antibiotic production against Staphylococcus aureus and Staphylococcus haemolyticus. Samples were diluted with PBS and then grown on Lb agar. Single colonies were chosen based on morphological differences and screened for antibiotic production. Colonies that produced zones of inhibition were then selected for further analysis. This study begins to establish a gradient across the San Antonio area for microbiological soil diversity and Antibiotic production capabilities of the soil microbe.

584 Katherine Malinski, Christopher Willett, Joel Kingsolver

Heat disrupts parasitic immunosuppression differently in wild vs. domesticated host populations

Understanding how extreme high temperatures impact host-parasite and host-symbiont interactions is a fundamental challenge. Immunity, like other biological processes, is temperature-dependent, which may impact the survival of endoparasitoids that rely on immunosuppression. Cotesia congregata is an endoparasitoid of Manduca sexta, relying on a symbiotic virus to immunosuppress its host. Exposure to high temperatures induces a thermal mismatch in which C. congregata, but not M. sexta, are killed. Here we ask: Do high temperatures kill parasitoid wasp eggs directly, or do they disrupt the parasitoid's viral immunosuppression, allowing the host's immune response to kill wasp eggs? We performed encapsulation and melanization immune assays and gene expression analyses in parasitized, heat-shocked hosts. Because domesticated lab hosts do not share a recent evolutionary history with C. congregata like wild hosts, we assayed both populations to compare and contrast their responses. We revealed that high temperatures led to a partial rescue of the immune response from parasitic immunosuppression in field M. sexta, but this pattern was absent in domesticated M. sexta. While the results of this study suggest thermal mismatch may be immune-mediated in field hosts, the occurrence of mismatch in parasitized lab hosts suggests the mechanisms of thermal mismatch may be multifaceted and complex in this host-parasitoid-endosymbiont system. Ongoing analyses of gene expression data will provide further insights to aid our understanding of this phenomenon.

964 Megan Maloney, Katherine Buckley, Marie Strader

Temperature acclimation and color influence Cassiopea xamachana thermal tolerance

Marine organisms are exposed to constantly changing environments. In some species, the ability to acclimate to different environmental conditions may be the difference between survival and extinction. Upside-down jellyfish (Cassiopea xamachana) are highly tolerant to environmental stress. Cassiopea are able to adjust their rates of bell pulsation and have morphological variations in pigmentation. Modulating bell pulsation may facilitate water flow to promotes feeding, oxygen exchange, and symbiont uptake. Cassiopea also exhibit conspicuous color variation, in both hue and the quantity of colored appendages, potentially functioning to shield from excess UV exposure. To test the capacity of temperature acclimation to influence thermal tolerance on different Cassiopea color morphs, adult medusa were collected from the Florida Keys, assessed for morphological traits, (color, size, sex), and maintained at one of in two temperatures (26°C or 33°C) for one month. After this acclimation period, animals were exposed to an acute heat stress in which the temperature was raised one degree per hour until lethality (27°C or 33°C - 42°C). Individuals acclimated at 33°C survived to significantly higher lethal temperatures compared to those acclimated at 26°C. Additionally, individuals with blue appendages survived to significantly higher temperatures and exhibited differences in bell pulsation rates compared to non-blue individuals. These results indicate Cassiopea can acclimatize to elevated temperatures and that coloration may play a role in survival during heat stress.

431 Rosalie Maltby, Michael Markham

A reduced cost approach to CRISPR in weakly electric fish.

Weakly electric fish emit electric signals to sense their environment and communicate. Studies of these fish harness this unique phenotype to answer a broad range of neuroethological questions about development, sensory neuroscience, sensorimotor integration, cellular physiology, ecology, evolution, and behavior. Recent genomic advances have facilitated a broad range of genotype-phenotype studies in weakly electric fish. These include numerous published genomes and the development of CRISPR/Cas9 techniques for genome editing in electric fish. Initial CRISPR procedures with electric fish have demonstrated the feasibility and utility of this approach, but high startup costs and complex spawning protocols create barriers to widespread application. Our goal was to expand the availability of CRISPR protocols in electric fish and to establish a low-cost toolkit for genomic editing. We successfully introduced genomic mutations that directly modified the electric signal characteristics in Brachyhypopomus gauderio using cloning free sgRNA/Cas9 generation, their natural spawning rhythms under reverse light cycle conditions, and inexpensive, widely available injection equipment. We confirmed phenotypic modification with electric signal recordings and confirmed homozygous genomic mutation via paired-end Illumina sequencing.

266 Armita Manafzadeh, Stephen Gatesy, Bhart-Anjan Bhullar

Joint surface interactions distinguish dinosaurian locomotor poses

Estimates of joint mobility play an essential role in reconstructing the movement of extinct animals, but are hindered by a lack of criteria for evaluating “proper articulation.” Here we argue that paleontologists have a centuries-old intuition about what joints should look like – it simply needs to be formalized. We thus propose a novel, automated analysis that measures 3D interactions among bony surfaces to generate a reproducible distribution of articulation scores across joint pose space. This approach harnesses morphological data from bones alone – with no assumptions about tissues like cartilage or ligaments – meaning it has the potential to be applied to fossil remains of extinct taxa. We first analyzed the articulation of Helmeted Guineafowl (Numida meleagris) and emu (Dromaius novaehollandiae) ankle and tarsometatarsophalangeal joints. Comparing these results with in vivo kinematics revealed that articulation analyses can not only rein in estimates of mobility – but can even distinguish the subset of joint poses used in terrestrial locomotion from among hundreds of millions of potential rotation/translation configurations. Building from these findings, we then conducted articulation analyses for twelve pedal joints of the paravian theropod dinosaur Deinonychus antirrhopus. Assuming that similar principles govern articular development across theropods, our results successfully constrain reconstructions of this extinct animal’s unique locomotor behavior. The methodological framework described here can be expanded to investigate the evolution of articular function throughout the vertebrate tree.

403 Finn Mander, Karly Cohen, Matthew Kolmann, Adam Summers, Lauren Simonitis

An assessment of the anti-fouling properties of Pacific spiny dogfish (Squalus suckleyi) denticles

Many marine organisms prevent biofouling (the adherence of other organisms to their bodies) through physical, chemical, or mechanical means. The denticles embedded in shark skin have been considered an anti-fouling surface, but the exact mechanism for this is unknown. Previous anti-fouling studies assessed the performance of synthetic replications of shark denticles and found that the shape of the replicated denticles reduced biofouling. We tested the anti-fouling performance of Pacific spiny dogfish (Squalus suckleyi) denticles to assess whether denticle shape alone is responsible for keeping these fish clean. We placed fixed shark skin samples off the docks at Friday Harbor Labs (San Juan Island, WA) at three sites with varying water current speeds. After two weeks we measured the degree of fouling using ultraviolet fluorescence and scanning electron microscopy. We found that after each experimental exposure both pristine and damaged denticles were fouled. The level of algal growth varied primarily by water current speed, with the fastest current site experiencing the most fouling. These findings suggest that other intrinsic factors to shark skin, such as mucus, may serve a complementary role to denticle shape in fully preventing biological fouling on Squalus suckleyi.

1812 Maitri Manjunath, Sanjay Sane

Mechanosensory feedback from cephalic hair coordinates flight initiation reflexes in hawkmoths

Flying insects sense air movement past their bodies via mechanosensory bristles on their body, which provide feedback to their nervous systems. Many insects including locusts and moths possess a set of bristles on their head called cephalic hair, which when stimulated rapidly elicit flight. During such rapid take-offs, diverse distributed flight-related reflexes are activated in a closely coordinated manner suggesting that they directly trigger diverse flight-related reflexes. We tested this hypothesis in the Oleander hawkmoth, Daphnis nerii by stimulating their cephalic hair with a sharp gust, and monitoring their flight response using high-speed videography, IR imaging and electrophysiology. Our experiments revealed diverse facets of cephalic hair-mediated flight initiation in the tethered moths. At the behavioral level, moths stimulated with an air puff directed at their head displayed robust and stereotypical flight initiation responses consisting of modular behaviors including leg extension, wing initiation, antennal positioning, head stabilization, and abdominal flexion. Cephalic hair-mediated flight initiation was rapid, and bypassed the need for warm-up behavior, typically required in larger moths including Daphnis nerii. Fluorescent dye fills of the cephalic hair revealed that the long primary afferents project into the meso and metathoracic ganglia. Electromyograms of the steering muscles innervated by flight motor neurons showed consistent activity elicited by cephalic hair stimulation. Together,these data show that the cephalic hair system is part of an escape-like response, which enables rapid flight initiation.

726 Stephen Manning, Mark Nohomovich, Jennifer Olori, Eli Amson, Roy Ebel

Are all caudates boneheads? Exploring lifestyle signals in the microanatomy of amphibian skull roofs

Tetrapod hard tissue structure repeatedly has been shown to evolve in concert with specific lifestyles. Such microanatomical correlates allow reconstruction of past lifestyle transitions and can shed light on tetrapod evolutionary history. One example is the recent discovery of lifestyle signal in squamate skull roof structure. However, we currently lack information on how roof microanatomy might reflect the variation in ecology, bodyplan, and life-history encountered in amphibians. We examined μCT scans of 18 salamander species and quantified six skull roof traits based on a new computational method. These traits comprise skull roof compactness and thickness, bone overlap, frontoparietal length ratio, and cranial diameter and elongation. Skull roofs were segmented in 3D Slicer and resulting volumes analyzed for structural trends in FIJI. Compactness exceeded 97% in all species, and a correlation between lifestyle and microanatomy was not supported. Although average values for the skull roofs lacked significant differences across lifestyle, there were indications of differences in specific regions of the skull roof. Contrasting with trends across squamates, size may play a stronger role in shaping microanatomy, or the relationship with lifestyle is more complex in salamanders due to frequent biphasic habitat use and strong burrowing capabilities in aquatic taxa. The addition of more taxonomically diverse anurans and fully fossorial caecilians will help refine our understanding of the major influences on roof microanatomy in amphibian evolution.

1828 Devanand Manoli, Ruchira Sharma, Kristen Berendzen, Amanda Everitt1, Kimberly Long, Nerissa Hoglen, Michael Sherman, Arthur Willsey

Dissecting the neural basis of social attachment

Social attachments play a central role in most, if not all, levels of human interaction. The analysis of social attachment has been resistant to genetic and neurobiological approaches, as traditional genetic lab model animals do not exhibit adult social attachment behaviors. Prairie voles display social attachment as adults such that mates form an enduring pair bond and display complex attachment behaviors including social monogamy and bi-parental care. Pioneering work in voles identified vasopressin (Avp) and oxytocin (Oxt) as critical mediators of pair bonding and social cognition and behaviors in humans. Nevertheless, how these and other genes function within these circuits to control specific aspects of complex social behaviors remains unknown. We generated prairie voles lacking mutant for the oxytocin receptor (OxtR) to understand how Oxt signaling controls attachment behaviors, and the associated changes in gene expression and neural activity in circuits that mediate attachment-related behaviors. Here we present our analysis of the behavioral, molecular, and physiologic consequences of loss of OxtR function on pair bonding and attachment behaviors. We find differences in the role of OxtR in the formation of pair bonds and promiscuity in males vs. females, and sex-specific effects of OxtR function on 1) reciprocal social behaviors mediating attachment formation, 2) the development of neurons that mediate pair bonding, and 3) patterns of neural activity in these populations during social and attachment behaviors.

693 Lianna Marilao, Paula Tran, Daniel Barta

The variable occurrence of Wormian (intrasutural) bones across Mammalia

Wormian (intrasutural) bones develop from separate ossification centers between cranial sutures and within fontanelles. They are an anatomical variation, with a variety of shapes, sizes, and locations documented among species. In humans, they are associated with osteogenesis imperfecta, hypothyroidism, and cleidocranial dysplasia. However, genetic and environmental factors that contribute to their formation in other vertebrates are not well understood. Whether Wormian bones in different sutures share a common developmental or functional origin remains an open question. To refine and test hypotheses about the origin of these bones in different sutures and taxa, a systematic survey of their phylogenetic distribution across vertebrates is needed.To document this variability we conducted a literature survey of Wormian bone occurrences among vertebrates. We plotted these occurrences on a cladogram to examine their phylogenetic distribution. We found that Wormian bones are mostly described within mammals. To explore this further, we examined 789 mammal skulls in the Sam Noble Museum (Norman, OK). In the mammals sampled, Wormian bones occur in approximately 20-30% of individuals in each species, except for a deer and rabbit species, which were nearly double. Our findings indicate that intrasutural bones are widely found across Mammalia and even in non-mammalian synapsids. Future work will involve sampling additional mammals for Wormian bones and to closely investigate potential selective pressures that increase occurrences of intrasutural bones in deer and rabbits.

70 Claire Marino, Tanisha Williams, Chris Martine

Solanum acanthophisum: a New Dioecious Bush Tomato Species from the Australian Monsoon Tropic

Estimates suggest that over 70% of the Australian flora and fauna has yet to be scientifically described. Numerous new plant species are still being described each year from across the continent. Here, we investigate a potential new species represented by just a few herbarium collections made in the remote Deaf Adder Gorge of Kakadu National Park, a biodiversity hotspot and UNESCO World Heritage Site. The new taxon was previously suggested as a possible localized variant of the functionally dioecious Kakadu endemic Solanum asymmetriphyllum and close relative of its sister species S. sejunctum. Using seeds removed from a herbarium sheet, a single ex situ plant was grown and used to assess more than 30 morphological characters to document the differences among S. asymmetriphyllum, S. sejunctum, and the putative new species. Morphometric analyses provide evidence that the three taxa are distinct from one another and support the segregation of the Deaf Adder Gorge variant as Solanum acanthophisum sp. nov. The specific epithet, "acanthophisum" is derived from the generic name of the sympatric death/deaf adder snake, Acanthophis praelongus. Solanum acanthophisum is now one of three recognized Solanum species occurring in Kakadu that exhibit functional dioecy, a sexual system in which morphologically bisexual flowers produce non-functional inaperturate pollen.

369 Jamie Marks, Mahaut Sorlin, Simon Lailvaux

The maternal energetic environment affects both egg and offspring phenotypes in green anole lizards

Animals exist in dynamic environments that may affect both their own fitness and that of their offspring. Maternal effects allow mothers to prepare their offspring for the environment in which they will be born via a number of mechanisms, not all of which are well understood. Resource scarcity and forced resource allocation are two scenarios that could affect maternal investment by altering the amount and type of resources available for investment in offspring, albeit in potentially different ways. We tested the hypothesis that maternal dietary restriction and sprint training have different consequences for the offspring phenotype in an oviparous lizard (Anolis carolinensis). To do this, we collected and raised eggs from adult females that were diet restricted (Low Diet (LD) or High Diet (HD)) or sprint trained (Sprint Trained (ST) or Untrained (UT)) and measured both egg characteristics and hatchling morphology. ST and LD mothers laid both the fewest and heaviest eggs overall, and ST, UT and LD eggs also had significantly longer incubation periods than the HD group. ST hatchlings were also the largest overall. Furthermore, both body mass of the mother at oviposition and change in maternal body mass over the course of the experiment had significant and sometimes different effects on eggs and offspring phenotypes, highlighting the importance of maternal energetic state to the allocation of maternal resources.

1291 Aleksey Maro, Robert Dudley

Non-random distribution of ungulate salt licks relative to distance from N. American oceanic margins

Terrestrial deposition of aerosol marine sodium declines with distance from coastlines. Salt deprivation in vertebrate herbivores and salt-seeking behaviors should hence increase with distance inland. We analyzed published geospatial data on ungulate-patronized salt licks to test whether they are non-randomly distributed relative to distance from oceans and elevation. We determined the land area and median elevation of 100 km increments from the North American coast. The null model of the expected number of licks within each interval was determined by the ratio of the interval's land area to the total land area, multiplied by the total number of licks. We asked whether the number of licks further from coastlines was significantly higher than chance and whether licks occur disproportionately at higher elevations. We found a strong positive relationship between salt lick patronage by ungulates and distance from the coast. Licks occurred significantly less often within, and more often beyond, 500 km inland, and at significantly higher elevations than would be expected by chance. These findings indicate that the patronage of salt licks is constrained geographically, and that the foraging behavior of ungulates and other phytophagous vertebrate taxa may be influenced over large spatial scales by sodium availability. Salt-seeking behavior varies on a wide biogeographical scale across North America, with concomitant implications for vertebrate herbivore behavior and ecology.

1524 Aleksey Maro, Robert Dudley

Field portable methods for the quantification of fruit ethanol concentrations

Human attraction to alcohol is thought to have originated as a result of our ancestral frugivorous diet over evolutionary timescales, due to the presence of low concentrations of ethanol within fruit produced by microbes and/or endogenously produced by fruits themselves. This line of research has led to the need to quantitatively evaluate fruit ethanol concentrations at remote field sites. Assaying fruit for ethanol is a novel challenge relative to more standard commercial and industrial methods for analysis of ethanol within various liquids. Here we quantitatively evaluate and cross-validate methods and results of five field-portable approaches of assaying fruit ethanol concentrations collected during three field seasons and five pilot studies and discuss the possibility of developing a reliable standardized assay method.

758 J. Andres Marquez, Kyra Anderson, Murray Duncan, Erik Sperling, Richard Stockey, Thomas Boag

Comparing the Hypoxia Tolerance and Temperature Sensitivities of Paleozoic and Modern Marine Fauna

In an analysis of the Phanerozoic fossil record, Sepkoski (1981) determined that metazoan marine classes can be categorized into three great evolutionary faunas: 1) the trilobite-dominated Cambrian fauna, 2) the brachiopod-dominated Paleozoic fauna, and 3) the mollusc-dominated Modern fauna. Increased diversity associated with the expansion of each new fauna coincides with an exponential decrease in diversity of the preceding fauna, but questions remain regarding the cause of these faunal turnovers. Here, we compare the temperature-dependent hypoxia tolerance of the Paleozoic and Modern marine faunas. Specifically, we perform respirometry experiments at different temperatures spanning 5-28°C to measure the absolute pO2 tolerance (Pcrit) and the temperature sensitivity of Pcrit for extant representatives of each fauna. These data suggest that representatives of the Paleozoic fauna may have greater hypoxia tolerance, but are also more vulnerable to changes in temperature than representatives of the Modern fauna. These physiological differences are hypothesized to relate to underlying respiratory anatomy: compared to the Paleozoic fauna, robust circulatory systems in the Modern fauna help increase water flow past respiratory structures and ameliorate the effects of warming, but come at a higher metabolic cost, resulting in higher Pcrit. Ultimately, these data can help us understand how members of the Modern and Paleozoic fauna may respond to modern ocean warming and deoxygenation and the physiological mechanism driving turnover events between evolutionary faunas through the Phanerozoic.

1830 Pedro Márquez-Zacarías, Kai Tong, Peter Conlin, Jennifer Pentz, Anthony Burnetti, William Ratcliff

Origins of nascent multicellular morphology from simple cell-level asymmetries

The evolution of multicellularity is one of the major evolutionary transitions. It transformed the biosphere giving place to many of the lineages harboring complex life. But this complexity is not universal in all multicellular organisms, and even in the complex lineages it required many innovations. At the earliest stages, multicellular organisms were likely simple, and lacked complex developmental pathways. In this work, we present a simple model of clonal multicellular development in which cell-level division patterns produce multicellular morphologies similar to these observed in the fossil record or in simple multicellular lineages. Our model tests the effect of cell shape and the geometric pattern of cell division in the growth and morphology of simple multicellular organisms, and thus accounts explicitly for spatial and geometric constraints that emerge naturally when many cells remain together after cell division. In addition, we used an experimental system of simple multicellularity, which we call snowflake yeast, to induce some of the geometric effects observed in our model, which align qualitatively with our model observations. We conclude that at the onset of multicellular evolution, there are simple principles guiding the morphological features of these nascent forms of multicellularity which do not depend on complex developmental mechanisms but primarily on physical constraints. Overall, our work emphasizes the relevance of cell-level features and physical constraints in the early evolution of multicellular development.

723 Susan Marsh-Rollo, Matthew Kustra, Kelly Stiver, Jennifer Hellmann, Molly Cummings, Jurek Kolasa, Suzanne Alonzo

Exploring cognitive flexibility in a wild living fish with alternative reproductive tactics

Comprehending the underlying mechanisms and evolution of cognition in animals has been furthered by research on numeracy, social preferences, and personalities in fishes. Research on fish cognition has been mainly conducted on domesticated or lab based strains of a few freshwater fish species. Our project explores cognition in the context of behavioural plasticity/flexibility in Symphodus ocellatus, a wild-living Mediterranean marine fish with male alternative reproductive tactics (ART's): nesting, satellite, and sneaker males. ART's in this species occur as part of the male life history pathway rather than by genetic determination. We ran lab-based forced-choice assays which can be later correlated with underwater observations of the social behaviours that occur during the spawning cycle of S. ocellatus. In the lab-based forced choice assay for familiar versus unfamiliar conspecific females, we found that, while time spent with each female was not significantly different between alternative male phenotypes, the number of side switches by satellite males was greater than for nesting males. The forced choice assay for a novel object revealed no differences in time spent or side switches across all male types. However, all male types preferred to spend time with larger groups of conspecific females in a group size choice assay. Ongoing analyses will compare individual performance in the lab-based assays with fish behaviour at actively spawning nests under natural conditions in the wild.

115 Christopher Marshall, Timothy Dellapenna, Justin Wilson, Eliza Perez, Kari Howard, Theresa Morris, Donna Shaver

Assessment of Optimal Sea Turtle Nesting Habitat On the Upper Texas Coast

Many biotic and abiotic factors play a role in sea turtle hatchling success. Data show that nest site, sand composition, and depth can impact temperature for development. Some regions of the world report an increase in nest temperatures due to climate change. To assess the critically endangered Kemp's ridley sea turtle (Lepidochelys kempii) nesting habitat on the Upper Texas Coast (UTC), we placed 90 experimental nests on the UTC and 15 reference nests in southern Texas near Padre Island National Seashore. Each nest contained 100 pseudo-turtle eggs and a HOBO-MX temperature datalogger. Grain size distribution and moisture content of sediment were collected from each nest. Grain size of sediment on the UTC ranged from 106-618 μm. The reference site had mean grain sizes that were 20-30 mm coarser than all UTC sites. East Galveston Island had significantly higher temperatures than other UTC sites and the southern reference site had significantly higher temperatures than all UTC sites. Nest temperatures were within the range expected in actual sea turtle nests. However, all experimental nests on the UTC would have been lost due to saltwater inundation from high tides. Well-documented high tide events corresponded with rapid drops in nest temperatures that would be expected when a nest is inundated with sea water. These data support the current conservation protocol to remove nests and transport them to safe locations.

1550 Rowan Marshall, Jason Macrander

Science Communication Through a Blog: A Case Study with ICB

Science communication is a growing field that has a significant impact on the relationship between scientists and the rest of society. Communication within the scientific community differs greatly when compared to other types of target audiences, oftentimes encountering difficulties when scientists communicate to the public with varying levels of science literacy and understanding. The general public's awareness of science relies heavily on effective science communication and receptivity of various scientific modes of communication. This project aims to use the Journal of Integrative and Comparative Biology (ICB) WordPress blog site to implement science communication strategies to determine which blog strategies are the most effective at reaching larger audiences. This process is being examined in a series of three parts: posting regularly, tracking traffic on the blog, and conducting statistical analyses of the data collected. We examined successful blogs in the past and compared these to recent posts focusing on one of three areas: the overall format of the post, the use of high traffic websites, and streamlining of content. Our results will aid future science communication strategies for the ICB blog and identify areas that have a significant impact on widening the audience for science communication to properly recommend effective science communication strategies moving forward.

77 Ezekiel Martin, Henry Steinmetz, Seo Baek, Frederick Gilbert, Nicholas Brandley

Rapid Shifts in Visible Carolina Grasshopper (Dissosteira carolina) Coloration During Flights

Some colorful structures are only visible when organisms are moving. For example, the primarily brown Carolina grasshopper (Dissosteira carolina) has contrasting black-and-cream hindwings that appear suddenly when it takes off, then oscillate throughout the main flight before disappearing upon landing. To examine how quickly this coloration appears to a variety of non-human observers, we performed frame-by-frame analyses on high-speed videos of D. carolina takeoffs and landings in the field, examining how the relative sizes of the different-colored body parts changed over time. We found that in the first 7.6 $\pm$ 1.5 ms of takeoff, the hindwings unfurled to encompass 50% of the visible grasshopper, causing it to roughly double in size. During the main flight, the hindwings transitioned 6.4 $\pm$ 0.4 times per second between gliding and active wing-beating (31.4 $\pm$ 0.5 Hz), creating an unstable, confusing image. Finally, during landings, the hindwings disappeared in 11.3 $\pm$ 3.0 ms, shrinking the grasshopper to 69 $\pm$ 9% of its main flight size. These takeoffs and landings occurred faster than most recorded species are able to sample images, which suggests that they would be near-instantaneous to most viewers. We therefore suggest that D. carolina uses its hindwings to initially startle predators (deimatic defense), then confuse them and disrupt their search images (protean defense) before rapidly returning to crypsis.

996 Katherine Martin, Katherine Mansfield, Anna Savage

Adaptive immune gene evolution and disease in coastal juvenile sea turtles

Characterizing polymorphism at the major histocompatibility complex (MHC) genes is key to understanding the vertebrate immune response to disease. Despite being globally afflicted by the infectious tumor disease fibropapillomatosis (FP), immunogenetic variation in sea turtles is minimally explored. We sequenced the α1 peptide-binding region of MHC class I genes (162 bp) from 268 juvenile green (Chelonia mydas) and 88 loggerhead (Caretta caretta) sea turtles in Florida, USA. We recovered extensive variation (116 alleles) and trans-species allelic polymorphism. Supertyping analysis uncovered three functional MHC supertypes corresponding to the three well-supported clades in the phylogeny. We found significant evidence of positive selection at seven amino acid sites in the class I exon. Random forest modeling and risk ratio analysis of C. mydas alleles uncovered one allele weakly associated with smooth FP tumor texture, which may be associated with disease outcome. Our study represents the first characterization of MHC class I diversity in C. mydas and the largest sample of sea turtles used to date in any study of adaptive genetic variation, revealing tremendous genetic variation and high adaptive potential to viral pathogen threats. Futhermore, the novel associations we identified between MHC diversity and FP outcomes in sea turtles highlight the importance of evaluating genetic predictors of disease, including MHC and other functional markers.

1235 Christopher Martin

How to swim across fitness valleys: the origins of scale-eating (lepidophagy) in pupfishes

Although novel evolutionary adaptations and ecological niches across the tree of life delight and inspire us, we rarely understand the microevolutionary context of their origins. Here I review a decade of my lab's work investigating the rapid evolutionary transition from a generalist algae-eating pupfish to a microendemic scale-eating specialist, two species isolated by a large fitness valley. We first show that colonizing this niche occurred in stages, beginning with selection on standing genetic variation for feeding behavior, then aided by adaptive introgression from diverse sources, and ending with selection on de novo mutations in key craniofacial genes. We next report the discovery of a new intermediate 'wide-mouth' scale-eating ecomorph, which helps to illuminate the transition from generalist to specialist. A few shared adaptive regions were shared by both scale-eating species. Finally, we reconstructed the genotypic fitness network for these species using survival and growth data from field experiments and show that although the scale-eater genotypes are the most isolated, accessible genotypic fitness pathways do exist. These rare adaptive walks connect generalist to specialist through viable intermediate steps of monotonically increasing fitness. Overall, our work provides a new microevolutionary framework for investigating how major ecological transitions occur in nature and how both shared and unique genetic variation can provide a life raft for navigating complex fitness landscapes.

1854 Chris Martine, Jason Cantley, Melody Sain, Tanisha Williams, Angela McDonnell, Ingrid Jordon-Thaden, Gregory Anderson

Fluidity and inconstancy: Australian bush tomatoes (Solanum) as an exemplar of non-normative sex expression in plants (and across life)

Solanum, a genus of ~1500 global species, is one of the more interesting plant groups in which to study reproductive biology and ecology. Overwhelmingly, species in this group express full cosexuality, where individual plants have flowers containing both fully-functioning "male" (staminate) and "female" (carpellate) organs. However, there have been multiple and widespread evolutionary transitions within the genus to non-normative variations on this ancestral condition. Australian bush tomatoes (ca. 40 species) are especially diverse in this regard, with uncommon variation and combinations of unisexuality and cosexuality – including, most notably, two sexual systems known as dioecy (unisexual male or female flowers on separate plants) and andromonoecy (combinations of male and cosexual flowers on every plant). This talk summarizes 40+ years of study and highlights some of the more intriguing observations/findings that make the bush tomatoes an ideal model system for examining plant sexual expression – including functionally "female" flowers (in which "male" organs are formed and pollen is produced, but that pollen serves only as a reward to pollinators and plays no other role in sexual reproduction), leaky "male" plants (in which "male" flowers sometimes express "female" function via functional pistils and thus become cosexual), the preponderance of vestigial opposite-sex organs in unisexual flowers, and species (such as the recently-described S. plastisexum) where variation in sexual expression is the norm rather than the exception.

99 Selena Martinez, Roxanne Armfield

Determining the affinity of fossil Xantusiid jaws with implications for post K-Pg squamate diversity

Xantusiidae (night lizards) is a lizard clade native to the southwestern United States and Baja California, Cuba, and Central America. There are three extant clades, Cricosaura typica (Cuban night lizard), Xantusia (desert night lizard), and Lepidophyma (tropical night lizard), and multiple fossil members have been identified. Xantusiids are well-known for their microhabitat specialization (inhabiting rock crevices, living in decaying plants), and this specialization has implications for their survival, and resultant speciation, of the Cretaceous-Paleogene Mass Extinction Event. "Palaeoxantusia" is a wastebasket taxon of Paleogene pan-xantusiids, though there is debate regarding the species of these fossils. Further uncovering the diversity of "Palaeoxantusia" is important for understanding why this clade was so successful following the extinction. Two-dimensional (2D) geometric morphometrics was used to determine intra- versus interspecies variation among Xantusiidae. This method was tested on extant xantusiids and then applied to fossil specimens. Individuals were found to cluster by clade, and by fossil or extant status, except in the case of outliers, such as Xantusia riversiana, and the species complex Xantusia vigilis. Fossil and extant taxa occupy separate morphospaces, suggesting that these animals may have occupied disparate ecological niches in life. Fossil xantusiids and the extant clade Lepidophyma were found to show morphologies consistent with generalist ecology. The modern clade Xantusia was shown to possess specialized morphologies that may be suited for their crevice-dwelling ecologies.

532 Alyvia Martinez, Micaela Rivera, Lilly Hall, Rosalyn Putland, Allen Mensinger

Freeze Dance! The Auditory Sensitivity of Elasmobranchs within the Egg Case

Elasmobranchs have an extensive lineage, however, relatively little is known about their auditory sensitivity, especially during development. While free swimming animals can escape localized sound sources, many elasmobranchs reproduce by laying eggs that remain fixed on the seafloor during development, making them vulnerable to anthropogenic sound exposure during critical developmental windows. The little skate (Leucoraja erinacea) has an incubation period of 5-6 months making it an excellent model organism for studying the potential effects of anthropogenic noise during elasmobranch development. Embryonic skates continuously beat their tail to aid in respiration. However, when a threatening stimulus is present, tail beating ceases to minimize detection. To test their auditory sensitivity, a behavioral assay examined tail beating rate in response to an auditory stimulus. Adult little skates have a hearing range of 100-500 Hz. Therefore, trials were conducted with a 300 and 400 Hz pure tone stimulus, as well as an engine playback recorded from a research vessel. Each stimulus was played at one of five decibel levels (134 to 147 dB) for 15 seconds followed by a 20-minute interval between stimuli. Results showed a significant decrease in tail beat rate in experimental versus control trials. Preliminary experiments with the chain catshark (Scyliorhinus retifer) showed similar responses. This research provides insight that elasmobranchs can detect sound within their eggcase which suggests anthropogenic noise could be affecting ontogenetic development.

1058 Karen Maruska, Chase Anselmo

Gonadotropin-releasing hormone as a modulator of vision in a cichlid fish

Visual communication during courtship and mating is important across many taxa. In species that cycle in

and out of breeding condition, visual capabilities can change to facilitate perception at specific times. Little is known, however, about which molecules and mechanisms are involved in this visual plasticity, and whether modulators act in the retina, the brain, or both. Here we investigate the role of gonadotropin-releasing hormone (GnRH) as a modulator of visual function in females of the African cichlid fish Astatotilapia burtoni, a species that shows improved visual sensitivity at ovulation and relies heavily on vision to mediate mating decisions. GnRH-immunoreactive axons are abundant in the retina and visual processing regions of the brain. Levels of GnRH receptors vary with the reproductive cycle in both the tectum and retina, and levels of GnRH receptors in the retina are positively correlated with female affiliation behavior. Calcium imaging on retinal slices of ovulated females shows responses to GnRH that are opposite those of GnRH antagonist, demonstrating modulation of retinal cell activity. Preliminary eye injections of GnRH agonist and antagonist into ovulated females also shows changes in affiliative behaviors towards males. Collectively, these data suggest that GnRH may modulate female vision at initial processing levels within the retina, as well as in central brain regions that process and relay visual information to decision centers during reproduction.

737 Quentin Mata-Figueroa

Effects of Microgravity on Cell Growth and Silver Nanoparticle Synthesis on Rhodobacter sphaeroides

Rhodobacter sphaeroides is a bacteria with metabolic versatility and has natural enzymes that can detoxify heavy metal salts. Because of this enzyme capability, this bacteria is able to synthesize silver nanoparticles biologically. Because of the unique metabolic capabilities of this bacteria, the experiment of growing it under microgravity conditions was possible. Upon further examination, it was discovered that the cells of Rhodobacter sphaeroides grown under microgravity conditions had a significant difference in size compared to those grown in normal gravity conditions. After analyzing 150 cells grown under microgravity conditions and 150 cells grown under normal conditions, it was found that the cells grown under microgravity conditions were significantly larger. Also, using methods to analyze the growth kinetics of both of these conditions, it was concluded that the microgravity cells grew much more rapidly than the normal gravity cells. Because of this conclusion, further research was examined to determine whether the accumulation of silver nanoparticles synthesized from microgravity was more, less, or the same compared to those synthesized from normal gravity cells. The results for that research was inconclusive and will be further studied, though, there is results found that show a semi-quantitative analysis of normal gravity grown cells accumulating more silver nanoparticles than microgravity.

1624 Teagan Mathur, Liyuan Zhang, Marianne Alleyne, Jake Socha, Sara Wilmsen, Kamel Fezzaa, Samuel Clark, Aimy Wissa

Latching, Loading, and Release in Click Beetles under Different Mechanical Constraints

In both nature and engineering, actuators are limited by the trade-off between force and speed. Small animals such as trap-jaw ants, mantis shrimp, and click beetles overcome typical muscle force-speed trade-offs by using a system of latches and springs to achieve accelerations of up to 106 m/s2. Click beetles use a unique hinge mechanism between the prothorax and mesothorax to bend their body extremely quickly, which results in a legless jump when the beetle is unconstrained. This fast bending maneuver, also known as the click, consists of latching, loading, and release phases. In this talk, we present two new major results using high-speed x-ray imaging conducted at the Advanced Photon Source, Argonne National Laboratory. First, we examine the latching, loading, and release in two species, namely, Parallelostethus Attenuatus and Alaus Oculatus species, which is several times larger than the Parallelostethus Attenuatus. Second, we investigate the effect of different mechanical constraints on each phase of the click. More specifically, experiments were performed on a constrained mesothorax and abdomen, a constrained prothorax, a constrained mesothorax, and an unconstrained beetle. The results of this study are used to determine the most suitable way to test and analyze the click maneuver and identify novel kinematics involved in the latching, loading, and release phases.

777 Shayle Matsuda

Centering transgender and non-binary experience, access, and safety in ecological fieldwork

In the wake of recent institutional efforts to make the ecological sciences more diverse, equitable, and inclusive, we must continue to identify who continues to be left out as well as act to rectify key inflection points where disproportionate harm may occur; recruitment in the absence of the guarantee of safe and supportive environments is not enough. In the ecological sciences, fieldwork is a fundamental component and often required for career advancement. However, for transgender and non-binary individuals, fieldwork can be disproportionately harmful, putting us in a precarious situation between our professional goals and our safety and wellbeing. Recently, attention towards barriers facing people from underrepresented groups in the field has grown. However, scholarship is lacking for LGBTQI+ individuals, and oftentimes, the nuances of trans and non-binary experience is lost within this discourse. Here, we discuss barriers and harm facing trans and non-binary individuals before, during and post fieldwork, discussed within the framework of intersectionality. Topics include navigating travel (national/international), accommodations (field stations, camping, vessel), access to medical care, and perceived and real threats (violence, transphobia, homophobia, racism, etc.) within the research team and surrounding communities. We discuss direct actions Principal Investigators can take to support early career trans and non-binary folks and actionable items to prepare trans and non-binary individuals in the field to remain as safe as possible, physically, emotionally and professionally.

1042 Shayle Matsuda, Brian Glazer, Ty Roach, Robert Quinn, Spencer Miller, Crawford Drury, Craig Nelson

Does coral structural morphology influence within-colony microbial spatial heterogeneity?

Reef-building corals exhibit immense diversity in their structural morphologies, shaping reef topology, slowing wave energy, and providing specialized habitats for hundreds of marine creatures. Further, each coral colony itself is its own diverse microcosm. Distinct attributes of the coral skeleton and the morphology of the colony create a landscape where abiotic factors differ within and across the colony surface, shaping biological responses. Consequently, this microhabitat variability may create microbial niches, causing microbial community diversification and differentiation within a single coral colony. Microbial community variability can have far-reaching implications for coral survival in the face of environmental challenges and flexibility in host-symbiont partnerships may increase thermal resiliency if thermally tolerant symbionts are present; however, a consortium of only thermally tolerant symbionts have fitness trade-offs during non-stressful conditions. Montipora capitata, a common coral in Kāneʻohe Bay, Oʻahu, exhibits flexible algal symbiont associations between types that confer different bleaching tolerances (Cladocopium and/or Durusdinium). We collected tissue biopsies at 16 distinct locations and identify algal symbiont assemblages and bacterial communities. Host genotype, sample location, and their interaction had a significant effect on microbial assemblages. Through the detection of these within-colony microbial patterns, we may be able to identify the mechanisms that make corals susceptible to stress and gain a deeper understanding of the ecological roles that microbial symbionts contribute to the ability of corals to successfully survive future climate conditions.

78 Benjamin Matthews

Molecular genetics of egg-laying behaviour in mosquitoes

Our lab is working to understand sensory-driven behaviours in mosquitoes using quantitative real-time behavioural assays coupled with molecular genetics, CRISPR-Cas9 generated mutations, and cell-type specific driver lines expressing genetically encoded sensors of neural activity. Egg-laying is a critically important behaviour for many animals including disease-vectoring mosquitoes. In this presentation, I will outline our work to understand the egg-laying preferences of the yellow fever mosquito, Aedes aegypti. Following a blood-meal, a female mosquito must decide where to deposit her eggs so as to maximize the survival of her offspring. She does this by first identifying water from a distance and then by evaluating the physical and chemical properties of a potential aquatic egg-laying site using contact sensory systems, ensuring that it is suitable for the survival of her aquatic offspring.We have developed and applied molecular genetic tools to explore two interacting sensory modalities controlling egg-laying in Ae. aegypti: mechanosensation (to evaluate surface texture, ensuring that eggs do not prematurely wall into the water) and contact chemosensation (to evaluate the chemical composition of the water and ensure maximal survival probability for their offspring). It is our hope that this work can provide a roadmap for bringing the power of molecular genetic techniques to bear on interesting and important neuroethological questions.

941 Dave Matthews, George Lauder, Terry Dial

Effects of altered Wnt expression on craniofacial morphology and feeding performance in zebrafish

Evolutionary research on morphological adaptation often focuses on form and function in adults, however, the way in which functional variation arises during ontogeny has great implications for both the extent of phenotypic divergence and survival to adulthood. Therefore, it is important to characterize the morphological and performance effects of ontogenetic variation in key developmental pathways in order to understand the adaptive potential of a population. Here we test the effects of variation in the Wnt signaling pathway, a putatively adaptive developmental pathway identified in fish trophic divergences, by altering the level and timing of Wnt signaling during zebrafish development. We quantify craniofacial morphology, kinematics, and suction feeding performance and identify the effect of varied Wnt expression on each factor through path analysis. We find that altered developmental timing has implications on morphological outcomes and that these altered outcomes affect feeding performance. Finally, we take a step back and consider how our results inform the evolvability of fishes along trophic axes and the implications that this could have in the diversification of fishes.

1762 Alex Mauro, Erica Rosenblum

Color, Aggression, and Correlations in Colonizing Fence Lizards

As species colonize new environments, populations can face novel, conflicting selective pressures that complicate the evolutionary response. To study this process, we investigated how different populations of the Southwestern Fence Lizard (Sceloporus cowlesi) that have colonized novel environments differ in traits that are known to be correlated and under selection. We compared color, aggression, and predator wariness between populations inhabiting environments that differed in substrate color and predator abundance. Specifically, we compared a lava flow population (black substrate) with many predators, a white sand dune (white substrate) population with few predators, and the ancestral desert (brown substrate) population with an intermediate number of predators. We found that the populations differed predicably in color with lava flow individuals being the darkest, dune individuals being the lightest, and desert individuals being intermediate. Further, we found that the populations differed in aggression with the darker lava flow individuals being the most aggressive and the lighter dune individuals being the least aggressive, supporting a correlation between aggression and color that has been documented across vertebrates. Surprisingly, we found an inverse relationship between predator abundance and predator wariness. This could be due to the difficulty in breaking trait correlations that are due to pleiotropy, like the correlation between color and aggression. Overall, our study highlights how different evolutionary and ecological factors interact during colonization.

147 Christopher Mayerl, Chloe Edmonds, Kendall Steer, Khaled Adjerid, Maxwell Johnson, Stephen Howe, Rebecca German

The function of the mammalian extrinsic tongue muscular in the transition from suckling to drinking

Mammals are defined by suckling as infants, which implies the need to transition to drinking from the ground and eating solid food. The structures involved in mammalian feeding, including the tongue, must thus function in several behaviors through development. During suckling, the infant's lips and tongue create a seal around the mother's nipple and generates a vacuum with dorsal/ventral pumping motions to draw milk into the mouth. In adult drinking, the tongue of most species primarily moves anterior/posterior to acquire liquid. How mammals undergo this transition is poorly understood. We evaluated the anatomy and physiology of the tongue from suckling in infancy through drinking as a juvenile in a pig model. We compared the anatomy of infants with newly weaned juvenile pigs using contrast-enhanced CT scanning, and the physiology of suckling and drinking using synchronized electromyography (EMG) and X-ray Reconstruction Of Moving Morphology (XROMM). We found substantive ontogenetic changes in the anatomy of the tongue, tongue movements (changes from dorsal/ventral to anterior/posterior), and relative timing of muscle activity between suckling and drinking. This work demonstrates how the same anatomical structures, with subtle changes, can produce different behaviors, suggesting extensive flexibility in the neuromotor system. An understanding of developmental flexibility and plasticity in the sensorimotor systems that control feeding is critical to further understanding the ontogeny of feeding in mammals.

1183 Lance McBrayer, Cheyenne Walker

Stop…then Go! Peak acceleration is the key tradeoff for intermittent locomotion

Intermittent locomotion is a commonly used locomotor mode in small vertebrates. Pausing is thought to aid in locating a predator or prey, enhanced crypsis, lowering energy costs, and/or maneuvering around obstacles or towards a refuge. Many lizards flee predators by turning as they pass a potential refuge and subsequently pause, presumably to conceal themselves. Intermittent locomotion may be associated with turning by allowing an animal time to assess its surroundings and/or decreasing the likelihood of losing its footing before or after turning. In this study we quantify locomotor performance and the use of intermittent locomotion in Florida Scrub Lizards (Sceloporus woodi) when navigating either a 45° or 90° turn. Lizards paused in 95.9% of all trials, and yet linear speed was not different before or after the turn. The angle of the turn had no effect on whether lizards paused, nor was there a relationship with pausing before or after the turn. Interestingly, the speed of the turn did not differ in trials with vs without pauses before the turn. We found that lizards use powerful acceleration following pauses to achieve similar performance and hence explain both why, and how, intermittent locomotion is such a common strategy in predator escape.

1250 Shelly McCain, Eddy Dowle, Gregory Ragland

Synchronization of developmental gene expression and morphogenesis during dormancy in a fly

Dormancy is a common strategy to synchronize life cycles with seasonal variation. Though some mechanisms governing the timing of dormancy have been well-described in animals, those that determine dormancy duration through developmental progression (rather than acute environmental cues) remain obscure. Our work on diapause (insect developmental dormancy) in the tephritid fly Rhagoletis pomonella suggests a clear developmental progression of gene expression during pupal dormancy that highly overlaps expression patterns associated with active morphogenesis. We have thus hypothesized that diapause may include some morphogenic development representing a highly extended version of a developmental program in non-diapause flies. Non-diapause pupal development for a fly involves massive remodeling of the Central Nervous System (CNS) during metamorphosis. We sought to identify if subtle changes in the CNS occur over time suggesting that slow morphogenesis accompanying dynamic gene expression. Our objective was to test whether changes in expression are coupled (or decoupled) with morphogenic development during diapause. We report on a developmental series of CNS morphology across winter and post-winter during diapause. Initial results suggest very little morphogenesis over an extended period compared to decidedly non-subtle changes in gene expression during the same period. We discuss these results in the context of the concept of physiogenesis, or physiological development decoupled from morphological development.

505 Jennifer McCann, Travis Hagey

Early Burst of Parallel Evolution in Gecko Toe Pad Morphology

Gecko lizards (Gekkota) possess highly diverse adhesive toe pads, which have been gained and lost multiple times throughout gecko's evolutionary history. Their unusual combination of convergent and divergent morphological evolution has been useful as a model for understanding the evolution of complex structures, including repeated convergent adaptation. Previous studies have organized geckos into groups that lack adhesive pads, two padded categories (basal and distal), and morphologies that appear as incipient adhesive pads, defined here to represent a phenotype reminiscent of both pad-less and padded morphologies. To investigate the diversity of adhesive toe pad structure, our study uses geometric morphometrics, quantifying toe pad shape for 52 genera (85 species) across all limbed families of gecko lizards plus Sphenodon. Our trajectory analysis compared differences in toe pad class across families. We found multiple examples of parallel differences in toe pad morphology across families. Significant parallel differences in toe pad shape suggests parallel evolution across families. We also used our geometric morphometric data to investigate how toe pad shape has evolved across geckos using a node height test to compare standardized phylogenetic independent contrasts through time. We found significant support for a model of early burst evolution, suggesting toe pad morphology evolved more rapidly early in the diversification of geckos.

1373 Dakota McCoy, Dale Burns, Elissa Klopfer, Liam Herndon, Baba Ogunlade, Jennifer Dionne, Sönke Johnsen

Windows in a clamshell: how heart cockles use fiber optics and condensing lenses for photosynthesis

One of nature's greatest innovations is photosynthesis, the engine that powers much of life on our planet. Many animals convergently evolved photosynthetic symbioses, including corals, sponges, and bivalves. Bivalves have obligate photosymbiosis in the giant clams (Tridacninae) and the heart cockles (Fraginae). Giant clams gape open to let light irradiate their symbionts, but heart cockles need not: instead, sunlight passes through transparent windows in their shells! Here, we show that heart cockles transmit 30-50% of sunlight to their symbionts through intricate shell windows that screen out potentially-harmful UV light. The windows are formed from specialized fibrous prismatic aragonite, natural fiber optic cables that are co-oriented along the mineral's c-axis perpendicular to the shell surface (optical simulations identify this as a superior orientation and shape for light transmission). We show experimentally that these aragonite spires act as natural fiber optic cables to project images with high resolution (>100 lines / mm) through to the soft tissues below. On the interior of each window, truncated lenses condense light into a beam to penetrate deeper into the symbiont-rich tissue. By researching optical adaptations in heart cockles and other photosymbiotic animals, we can learn about the evolution of symbioses, uncover the structure of photosynthesis, and potentially inspire new optical technologies of our own.

1388 Dakota McCoy, Sönke Johnsen, Stephen Palumbi, Jennifer Dionne

The optics of runaway bleaching in corals (Scleractinia)

Corals worldwide are bleaching at an alarming rate due, primarily, to global warming. An underappreciated driver of coral bleaching is the light environment. Light stress, like heat stress, can also cause coral die-offs. Here, we analyze the skeletal properties of coral across scales (nanomater, micrometer, millimeter, and centimeter). Some species of coral have optical adaptations which make photosynthesis more efficient– increasing rate of growth– but which cause problems during a bleaching event. Put simply, once corals begin to bleach, exposing more and more of the highly scattering coral skeleton, the remaining algae are exposed to greater and greater light stress. This runaway process changes the pace of bleaching and the ability for coral to bounce back from a belaching event. Together, we show that small-scale adaptations have ecosystem-scale consequences for coral health and resilience.

1818 Jamie McCoy, John Spicer, Simon Rundle, Oliver Tills

Measuring the most sensitive stages of life as a spectra of energy

During early development, animals are typically more sensitive to environmental change. Developmental responses to elevated temperatures are hugely multifaceted and encompass changes to form, function and performance at timescales ranging from minutes to days. Manually measuring such responses is therefore inherently limited. ‘Energy proxy traits’ (EPTs) are a new approach, involving the measurement of energy across different temporal frequencies in the fluctuations of mean pixel values from video of developing animals. EPTs can characterise acute and chronic responses to environmental stress, but they remain untested in comparing the sensitivity of different species, a significant precursor to establishing their utility as a scalable and comparative approach to measuring biological responses. Using EPTs we tested the thermal sensitivity of embryos of three freshwater gastropod species with distinct differences in their embryonic development, specifically, in the timings of a number of key physiological and behavioural developmental events. EPT spectra were significantly different between species, temperatures and development stages, with differences corresponding with the onset of multiple developmental events. Furthermore, differences in the relative timings of developmental events between species, individuals and temperatures were reflected in EPT spectra through development. Universality of measurements that extend between species and stages of development will further our understanding of developmental phenotypic responses to environmental change, but also push the boundaries of how we measure responses of animals during dynamic early life stages.

1471 Kyle McCulloch, Leslie Babonis, Kristen Koenig

Exceptional opsin diversity and light behaviors of the sea anemone Nematostella vectensis

In both Bilateria and Cnidaria, the opsin gene family and opsin-expressing cells have diversified and incorporated into a range of visual systems from simple to complex. Within Cnidaria, most work has focused on the Cnidopsin clade of opsins, but anthozoan-specific opsin clades are unexplored. The starlet sea anemone, Nematostella vectensis is a model anthozoan (sea anemones, corals, sea pens) with many opsin genes in its genome, suggesting a potential for evolution of functionally diverse opsin-expressing cell types. This is a result of rampant lineage- and species-specific opsin duplications, however little is known about the function, expression, or even number of opsins in many anthozoans. Despite lacking an eye, N. vectensis exhibits a variety of light mediated behaviors. A baseline characterizing the opsins and behaviors is an important first step. Here I present the number, phylogenetic placement, sequences, and expression patterns of the 29 opsins in N. vectensis, the most of any anthozoan so far investigated. I also characterize the spectral properties of light-mediated behaviors, such as larval swimming, spawning, and scrunching. Current functional genetic work linking specific opsins to signaling pathways and spectral behaviors is also presented. Together this work suggests opsin duplications have led to sequence diversity and possible evolution of novel and diverse receptor functions in the subsequent expanded number of opsin-expressing cell types, in turn leading to increased diversity of sensory behaviors.

392 Victoria McDermott, Lara Roketenetz, Phoebe Jekielek

IDEA+ and OBFS: Using transdisciplinary strategies to create more inclusive spaces

As more students seek to pursue careers in science, technology, engineering, and mathematics (STEM), the calls for creating systems and structures to support students of diverse backgrounds has become increasingly important. Unfortunately, however, personal accounts in popular press articles and STEM-based scholarship highlight deficiencies in much needed support structures, resulting in challenges to retaining people in STEM long-term. Relatedly, due to the unique nature of field work and field-based institutions, people may experience compounded challenges to navigate and succeed because of remote site locations, the strenuous nature of the work, and overall lack of public knowledge regarding the role of field-based institutions. Specifically, field work often highlights vast differences in experiences of people from diverse backgrounds and intersectional identities for surviving and thriving. The proposed manuscript argues for transdisciplinary scholarship and approaches to ways of knowing to support IDEA+ (inclusion, diversity, equity, accessibility, justice, etc.) initiatives by professional societies. We begin by explicating the epistemological and methodological processes of transdisciplinarity. We then explore empirical research that highlights the value of transdisciplinarity in education. Acknowledging the important role of professional societies, like the Organization of Biological Field Stations (OBFS), in setting industry standards, we conclude by providing tangible recommendations for implementing transdisciplinarity approaches in field-based institutions to support IDEA+ initiatives and to guide other field-based professional organizations and associations, as well as users of these institutions.

616 Marisa McDonald, Megan Porter

Feeding Rates of Larval Stomatopods Under Different Light Environments

In this study, feeding rates of two species of larval stomatopods, Gonodactylaceus falcatus and Gonodactylellus n. sp, were tested to determine if light environment and time of day have an effect on prey consumption. Trials were completed on Oahu, Hawaii on the Makai Research Pier. These trials were run at three times of day: noon, twilight, and night, under three light treatments: full spectrum light +UV, full spectrum -UV, and a full dark control. Through this study, we aimed to test (1) if larval prey consumption changes at different times of day and (2) if UV vision is involved in prey capture. We found that light is important for successful feeding, with both species eating significantly more in lighted treatments than the dark control during daytime experiments. Gonodactylellus n. sp. also had a significantly higher feeding rate at twilight in the UV+ treatment than in the dark control. Both species showed a trend of decreased consumption at night and in all dark controls. Our results suggest that light is important for larval stomatopods to feed, but there may be differences between species on daily feeding activity periods. Follow-up studies should incorporate a variety of prey types to test how feeding changes based on food source and density.

704 Christina McDonald

Mechanisms of self-decorating and design of the attachment system in debris-carrying lacewing larva

Several species of lacewing larvae carry debris on their backs. This debris can consist of prey molts, lichen, trichomes, waxes, and other exogenous materials. Research suggests debris packets act as a physical shield and as camouflage to protect larvae from predators and prey symbionts. Although this self-decorating behavior has been described qualitatively, there has not been a thorough investigation into the mechanisms by which debris is applied and attached. The goal of this research is to describe lacewing larvae self-decorating mechanisms as well as to quantitatively detail the design (geometry and distribution) of the attachment setae (hair-like projections). Decorating behavior was induced by removing the debris packet from larvae and allowing the larvae access to the removed debris or other exogenous materials. High speed videos of the self-decorating revealed an undulating body movement that actuated larval attachment setae promoting debris capture and redistribution. Other imaging techniques (Z-stacking and SEM) of the lacewings will reveal overall design of the attachment system. Investigating lacewing debris attachment mechanisms could inform the design of synthetic mimics capable of capturing and retaining debris.

331 Kyle McElroy, Rick Masonbrink, Sivanandan Chudalayandi, Jorge Audino, Andrew Severin, Jeanne Serb

Genomic insights into eye evolution in Pectinidae from the disco clam, Ctenoides ales

Eyes are important sensory structures that have evolved numerous times in mollusks. We know very little about how these morphologically diverse eye types have evolved, including the sets of genes recruited to support their development and function. Pteriomorphia, the subclass of bivalves that includes scallops, oysters, mussels, and arc clams, evolved eyes independently at least five times, making them an excellent setting to explore the molecular basis for convergence of novel traits. We present the first genome assembly from Limida, the disco clam, Ctenoides ales, which is characterized by invaginated eyes. We found that the C. ales genome size has increased dramatically compared to other pteriomorphian lineages, largely driven by transposable element accumulation. We inventoried the genome for known light-related genes, including opsins, and found that, unlike its closest eyed-relatives, the scallops, C. ales lacks duplication of the rhabdomeric Gq-coupled opsin that is typically used for invertebrate vision. In fact, C. ales has uncharacteristically few opsins relative to the other pteriomorphian families, which all have unique expansions of xenopsins, a recently discovered opsin subfamily. Additionally, we performed RNA-seq on light vs. dark treated individuals, sampling eye, mantle, and adductor tissues to characterize the transcriptomic light response to identify genes associated with vision and light-sensing broadly.

1201 Eric McElroy, Joseph Bazzle

Changes in limb function with fatigue in a running lizard

When animals run for extended periods they fatigue. Fatigue is defined as a reduction in locomotor performance and it occurs due to proximate changes in the physiology of the body systems underlying locomotion. This study examines changes in limb and body kinematics as as a small lizard species fatigued due to repeated sprinting locomotion. Phrynosoma cornutum were sprinted down a racetrack repeately in rapid succession to elicit an degration in sprinting performance. Limb and body three-dimensional kinematics were quantified and then compared for the first sprint (fresh, maximum performance) and the final sprint (fatigued, degraded performance).

1317 Liam McGuire

Heterothermic migration strategies in flying vertebrates

Migration is an energetically demanding period of the annual cycle for many species, including thermoregulatory costs. Previous studies of migratory birds generally assumed (implicitly or explicitly) homeothermy, but many migratory bats use daily torpor. In empirical field studies, we have demonstrated that migrating bats extensively use torpor to buffer themselves from variable environmental conditions and greatly reduce energy expenditure during inactive periods. We have since incorporated the idea of torpor-assisted migration into a revised version of optimal migration theory that allows for varied thermoregulatory strategies, and makes wide-ranging predictions about many aspects of migration biology. Subsequent field studies supported model predictions, including effects on body composition, stopover duration, and regional-scale movement patterns. More recently we have been investigating heterothermic migration strategies in birds, and have documented many species using some degree of heterothermy. When studying migration it is important to consider species along a thermoregulatory gradient, from strict homeotherms to daily torpor. Ultimately, heterothermy provides an evolutionary alternative to migration. In a broad phylogenetic analysis of the evolution of migration across mammals, heterothermy emerged as an important factor, alongside body size and mode of locomotion. Taken together, it is now clear from empirical, theoretical, and evolutionary studies that variation in thermoregulatory strategy is an important factor for understanding the ecology and evolution of migration.

1283 Cleo McHenry, Theodora Po, Matt McHenry

Sea stars use their feet for negative geotaxis

Negative geotaxis provides a sea star with the ability to climb reefs when foraging, despite possessing no known organ for sensing gravity. Classic studies have suggested that geotaxis emerges from the mechanics of forces upon the tube feet such that the animals climb along a surface at an oblique angle that is proportional to the slope of the surface. However, we did not find support for this phenomenon in a tropical species (Protoreaster nodosus) from kinematic measurements for climbing at variable slope angles. The sea stars did exhibit a form of geotaxis with a nearly 3-fold greater probability of climbing upwards upon a steep slope than when walking over a shallow slope. We explored a variety of hypotheses for the sensing, mechanics, and control of geotaxis through the development of a mathematical model of the sea star locomotor system.

368 Alora McInnis, Karen Maruska, Christy Wayne

Neural activation associated with repeated social defeat in a cichlid fish

Social defeat is a powerful experience leading to drastic changes in physiology and behavior, many of which are negative. For example, repeated social defeat, or bullying, results in reduced reproductive fitness, sickness, and behavioral abnormalities threatening survival and species persistence. However, little is known about how the brain regulates complex coping behaviors in response to this social stress. In species living in dominance hierarchies, such as the cichlid fish Astatotilapia burtoni, defeated individuals often employ a combination of proactive (aggression, escape attempts) and reactive (fleeing, hiding, no escape) coping behaviors. Over repeated defeat, however, coping behaviors of males can change, often resulting in exclusive use of reactive behaviors. This study tested the hypothesis that repeated social defeat has lasting effects on future behavior and is associated with distinct neural activation patterns in the brain. We demonstrate the emergence of distinct resilient (more proactive behaviors) and susceptible (avoidance behaviors) phenotypes after chronic social defeat, suggesting individual differences in coping behaviors similar to that in other vertebrates. Using immunohistochemistry for the activation marker phospho-S6-ribosomal protein (pS6), we also identify differences in neural activation patterns associated with resilient and susceptible phenotypes in regions of the social decision-making network. These results reveal new insights into the neural mechanisms regulating behavioral responses to repeated social defeat, and towards better understanding the evolutionary mechanisms of stress susceptibility and resilience across taxa.

308 Madison McIntyre, Scott Boback

Rain harvesting behavior in free-ranging Prairie rattlesnakes (Crotalus viridis)

Organisms inhabiting xeric environments face many challenges to obtain dietary water. Numerous species have evolved unique adaptations to collect, harvest, and condense water from infrequent and unpredictable rainfall. Several snake species have been documented collecting and drinking precipitation from their skin, referred to as rain harvesting behavior. Prairie rattlesnakes (Crotalus viridis), in some areas of their range, inhabit environments with soil that has poor water retention properties, and therefore may have evolved and adapted to obtain dietary water through harvesting rain. We designed an experiment to elicit and observe rain harvesting behavior (RHB) in Prairie rattlesnakes in their natural environments. Using a hand-held pump sprayer, we sprayed snakes with short bursts of water to simulate rainfall and recorded their behavior. In a two week period between 25 May and 5 June 2021, we obtained 72 videos of 94 snakes (70 free-ranging snakes). Using these videos, we described and quantified rain harvesting behavior using a six-phase illustrated ethogram. Our observations support previous descriptions of interscalar channels exhibiting capillary action directing water more efficiently to the mouth in Phrynosoma cornutum and Moloch horridus. This research serves as a baseline for further understanding rain harvesting in desert-inhabiting species. Furthermore, we introduce several hypotheses to explain dorsoventral flattening variation, drinking from non-snake surfaces, drinking with the head elevated and no labial contact to a surface, and drinking from neighboring snakes.

1284 Andrew McKamy, Melody Young, Angela Mossor, Jesse Young, Michael Granatosky, Michael Butcher

Going Out on a Limb: locomotor loading patterns in three-toed sloths (Bradypus variegatus)

The limb musculature of tree sloths is specialized for slow velocity, large force contractions that stabilize their body below branches and conserves energy during locomotion. However, it is unknown if two and three-toed sloths converge in their use of limb biomechanics and whether these patterns are comparable to how primates perform arboreal suspensory locomotion. This study addresses this need by collecting limb loading data in three-toed sloths (Bradypus variegatus; N = 5) during suspensory walking. Sloths performed suspensory walking at their preferred speed on a natural beam apparatus instrumented with a force platform. Peak forces and impulses were recorded and analyzed in three dimensions in both limb pairs. The hindlimbs of B. variegatus apply large braking forces comparable in magnitude to forces generated by the forelimbs in propulsion, a pattern consistent with that observed in two-toed sloths. However, B. variegatus exhibits hindlimb-biased bodyweight support in vertical limb loading, with appreciable laterally-directed forces in each limb pair, both of which vary from force distributions in two-toed sloths Moreover, bodyweight distribution between limb pairs is the opposite of that employed by primates during quadrupedal suspension signifying that there are multiple strategies for achieving suspensory locomotion in arboreal mammals. EMG analyses are expected to provide further insight into how specific hindlimb muscle groups contribute to braking/propulsive forces and stabilizing the center of mass of sloths during suspension.

89 Andrew McKechnie, Marc Freeman, Mathome Makola, Matthew Noakes, Mark Brigham

Evolution of avian heterothermy: why no deep torpor in songbirds?

Birds, like mammals, make extensive use of heterothermy to avoid mismatches between energy supply and demand. Among birds, deep torpor is largely restricted to phylogenetically older taxa such as hummingbirds, swifts and nightjars. Among passerines, the most recently-diverged avian order, no Tb values $<$ 20°C have been documented, whereas torpor Tb in groups like hummingbirds and nightjars can be $<$ 5°C. Here, we review the phylogenetic distribution of avian torpor. We also present new data from sunbirds, an Old World nectivorous family ecologically and physiologically convergent with hummingbirds. Two southern African sunbirds, white-bellied (Cinnyris talatala) and lesser double-collared (C. chalybeus) reduced their Tb to minimum values of 24.1°C and 22.9°C, respectively. These data support previous arguments that heterothermy in passerines seems not to involve the same relationships between metabolic rate, Tb and air temperature (Tair) that characterize classic torpor among birds and mammals. It remains unclear why many small passerines that would seemingly benefit from deep heterothermy apparently do not possess the capacity for this response. One possibility yet to be explored concerns the effects of membrane lipid composition on cellular tolerance of hyperthermic Tb. Passerines typically tolerate higher hyperthermic Tb than non-passerines, and the cell membrane requirements for pronounced hyperthermia tolerance may be incompatible with the large reductions in Tb characteristic of deep torpor.

747 Taylor McKibben, Tonia Schwartz, Kaitlyn Murphy

Does Maternal Transfer or Early Life Diet Affect the Gut Microbiome in Brown Anole Lizards

The evolving field of microbiome research has shown the importance of gut microbiota community structure and functionality on the short and long-term health of organisms beginning at birth. Gut microbiome colonization and development is determined by diet and environmental conditions. Altered succession can lead to phenotypic differences such as reduced pathogenic protection and altered metabolic outputs. In this study, we address two pivotal questions in an oviparous lizard (Anolis sagrei): (1) Is there microbial colonization in the embryonic gut in ovo? (2) How does diversity in diet during early life shape the gut microbial community composition at 5 weeks of age? To address these questions, eggs from a breeding colony were assigned to one of three groups: (1) embryo, (2) hatchling on a diverse diet (e.g., consisting of multiple prey types), and (3) hatchling on single-prey diet. Using PCR and qPCR amplification of the 16S microbial gene, we found no evidence of significant in ovo colonization of the gut. Utilizing Nanopore 16S sequencing, we found the most common bacterial genera in the gut of hatchlings to be (in decreasing order) Roseburia, Clostridium, Faecalicatena, Blautia, and Propionispira. Ongoing analyses are testing for differences in OTU abundance and microbial diversity between dietary treatments. We discuss these results of early life diet on the microbiome in contrast to findings in birds and mammals.

1021 Emily McLaughlin, Rowan Batts, Joshua Goble, Christiane Todt, Maria Cobo, Kevin Kocot

A Global DNA Barcode Library for Solenogastres (Mollusca, Aplacophora)

Solenogastres (Mollusca, Aplacophora) is a clade of shell-less vermiform marine molluscs. Though found worldwide, many regions and depths remain unexplored concerning this group and new taxa continue to be discovered from even relatively well-known areas. Therefore, their true diversity is thought to be tenfold higher than currently described. Identification of solenogasters generally requires the work of trained specialists and time-consuming histology. With climate change and the current dearth of taxonomists, advancing new tools is essential to speed up identification before the current diversity is lost. DNA barcoding has been demonstrated to be an effective tool to identify most taxa. However, most solenogasters have been described based only on morphological features, and few solenogaster barcodes are currently available. Here we developed a broadly sampled DNA barcode library for solenogasters using the mitochondrial genes cytochrome c oxidase subunit I (COI), 16S rRNA (16S), and cytochrome b (CytB). To connect morphological and molecular data histology and scanning electron microscopy were performed to identify barcoded specimens. This work provides a DNA barcode library consisting of 474 COI, 313 16S, and 111 CytB sequences from more than 180 lineages. The identification of barcoded species has made this library a useful tool to speed up the identification of solenogasters. These data will be useful for non-experts identifying solenogasters using molecular tools and work as a foundation for future solenogaster research.

523 Jenna McNally, Mark Jankauski

Investigation of the Poricidal Anther Frequency Response through Finite Element Modeling

Approximately 10% of angiosperm species rely on buzz pollination (also called floral buzzing) to reproduce. During buzz pollination, bees apply vibratory force to tube-like poricidal anthers to extract pollen. Some of the pollen is collected on the bee's body and may be transferred to other flowers as the bee continues to forage. The efficiency of pollen extraction relies on the relationship of the bee and the structural dynamics of the floral anther, yet this relationship has not been adequately characterized in most contexts. In this work, we develop a computational model of an idealized poricidal anther using finite element analysis. We use this model to characterize how bee mass, forcing location and forcing direction affect anther deformation, since anther deformation is positively correlated with pollen removal. We found that bee mass decreased deformation by two orders of magnitude, but gave rise to an axial-bending mode that corresponded to a natural frequency within the reported buzz frequency range. This mode is strongly excited when bees apply vibratory forces that are normal and axial to the anther and out of phase by 90 degrees. This optimal force directionality is consistent with the force profile measured in live bees. These results suggest that buzz pollinating bees may exploit the structure of the poricidal anther to maximize anther vibration, and consequently pollen expulsion. Approximately 10% of angiosperm species rely.

865 Emily McParland, Peishu Li, Courtney Orsbon, Callum Ross, Nicholas Gidmark

Of mice and models: XROMM's utility in temporomandibular joint disorder model organisms

The temporomandibular joint (TMJ) has multiple degrees of freedom, with morphology and biomechanics varying across mammals. TMJ disorders (TMD) are common among humans, resulting in limited TMJ range of motion and restricted nutrition due to myofascial pain, internal derangement of soft tissues, and degenerative joint disease. Given the complexity of the TMJ, TMD research often employs a variety of mammalian animal models (i.e., mice, rats, rabbits, pigs, sheep, monkeys) to examine pathology and treatment in more invasive manners than are possible in humans. Several motion analysis protocols are available to study pathological TMD range of motion, yet the precision of measures of complex TMJ motion across model organisms is unclear. We used X-ray Reconstruction of Moving Morphology (XROMM) to quantify precision envelopes for TMJ motion across six common model organisms and humans through 6-degree-of-freedom motion and joint range-of-motion volume. We demonstrate that mouse models are limited by size-related precision of TMJ kinematics using XROMM. However, rats, rabbits, macaques, sheep, and pigs have precision comparable to that of humans for all metrics. Moreover, XROMM-based measurements of most metrics (condylar translation along anteroposterior and mediolateral axes, abduction/adduction, and yaw) outperformed precision of previous studies for evaluating pathological versus healthy motions. This work establishes XROMM as a viable tool in future TMD range-of-motion studies that employ rats, rabbits, pigs, sheep, or monkeys as model organisms.

1482 Alondra Medina-Charriez, Anthony Gelona, Kelsey Reider

Does soil stoichiometry affect leaf litter herpetofauna in a lowland tropical wet forest?

Understanding the mechanisms behind patterns of diversity and abundance is a major goal of ecology. Soil stoichiometry can shape community structure of tropical leaf litter invertebrates, however, few studies have addressed whether organisms in higher trophic levels are also influenced by soil nutrients. In this study, we assessed whether limiting soil nutrients and leaf litter habitat structure affect herpetofauna abundance, biomass, and community structure in lowland tropical wet forests of Costa Rica. We conducted standardized quadrat sampling in relatively higher-nutrient alluvial and lower-nutrient residual soils to compare amphibian and reptile abundance, biomass, and community assemblage across a three-fold gradient in soil N and P. We collected soil samples from each plot and measured soil phosphorus, nitrogen, carbon, magnesium, calcium, and potassium. We found no significant differences in relative abundance of frogs ($t = 0.24398$, $p = 0.8089$) or lizards ($t = -0.4932$, $p = 0.6288$) in alluvial and residual soils, but we found a marginally significant difference in herpetofauna biomass ($t = -1.8495$, $p = 0.06736$). We will expand these preliminary analyses using a multivariate approach, and to determine community differences on residual and alluvial soils we will perform an Analysis of Similarity. Our study will provide additional insight into how bottom-up regulation affects leaf litter amphibians and reptiles, a vulnerable yet ecologically important group, in the lowland tropics.

549 George Meindl, Jessica Hua

Course-based undergraduate research: phytoremediation in Cu-polluted aquatic environments

Creating inclusive, impactful educational experiences for our students requires broadening traditional approaches to undergraduate education. In this talk, we will emphasize our efforts implementing CUREs, in which whole classes of students address a research question or problem with unknown outcomes or solutions. In addition to fostering a strong foundational knowledge, CUREs provide experiential opportunities for students to develop skills in conducting research, communicating about science, and collaborating with other scientists. Recent data collected by our students addresses the phytoremediation potential of several aquatic plants in Cu-polluted environments. Specifically, we first examined the capacity of plants to remove Cu from polluted water. Next, we evaluated the leaching potential of plant tissues following decomposition and how it is affected by a simulated freeze-thaw cycle. Using phytoremediated water and leachates from senesced plants we assessed phytoremediation success and Cu leaching potential by conducting standard toxicity assays using pond snails (Physa acuta), a species with known Cu sensitivity. Our results indicate that in moderately Cu-polluted environments, some aquatic plants can remove contaminants without a long-term risk of leaching. In contrast, phytoremediation in highly polluted environments will likely require removal of plant tissue to prevent leaching of previously accumulated metals. By diversifying the ways in which students are allowed to learn and apply their knowledge (e.g., by implementing CUREs), we can create better trained and more diverse university graduates.

438 Richard Meisel, Alexander Mai, Pablo Delclos

Identifying the regulatory architecture underlying mating behavior using CRISPRa

Mating behaviors are under strong sexual selection, yet species are often not at their fitness optimum for courtship traits. For example, knockdown of a single gene (Obp56h) in Drosophila melanogaster reduces copulation latency (i.e., courtship time), which we show increases fitness by increasing competitive mating performance. This raises the question: why have flies have not evolved to express the gene lower, which would increase their fitness? We answered this question by identifying the regulatory architecture affecting the relationship between Obp56h expression and copulation latency in flies. Using network analysis of gene expression data, we identified a handful of candidate trans regulators that are predicted to reduce the expression of Obp56h. One of those candidates encodes a transcription factor (TF) that binds both up- and down-stream of Obp56h. We used CRISPR activation to induce the expression of the TF in neurons, and we found that it produced the expected reduction in copulation latency predicted by its position in the regulatory network. By analyzing the expression of the TF across tissue types and development stages, we show that it has the capacity to have higher neuronal expression. We hypothesize that the TF has not evolved higher expression in neurons because it has pleiotropic effects that reduce female fitness.

1322 Raquel Mejia-Trujillo, Brendan Pinto, Justin Havird, Sophie Breton, Chase Smith

Genomic signatures of mitonuclear sex determination in a bivalve with doubly uniparental inheritance

Unlike strict maternal inheritance of mitochondria possessed by most animals, some bivalve lineages have a unique mitochondrial biology known as doubly uniparental inheritance (DUI). In this system, females transmit a female-type mitochondrial DNA (mtDNA) to all offspring, while male-type mtDNA is transmitted only from fathers to sons. Because mtDNA inheritance follows a traditional XY inheritance pattern, it has been hypothesized that mtDNA contributes to sex determination or sexual development. However, nuclear genes involved in sex determination or sexual development have yet to be investigated in many DUI lineages using genomic data, including freshwater mussels (Bivalvia: Unionida). In this study, we use multiple sequencing-based approaches to identify potential nuclear genes involved in sex determination in the freshwater mussel Potamilus streckersoni. Genotypic data did not find support for a large, contiguous nuclear sex determining region akin to a sex chromosome. Rather, we identified numerous nuclear genes distributed across the genome that were highly differentiated between the sexes, many of which depicted biased expression in female and male gonadal tissue. Gene ontologies (GO) for these genes were similar to those that would be expected in mitonuclear sex determination rather than strictly nuclear sex determination, including genes that may be involved in the recognition and maintenance of male mtDNA. Our results provide further evidence of a non-respiratory mitochondrial function and an unorthodox sex determining system in freshwater mussels.

200 Prasong Mekdara, Eugene Kim, Ariel Levine

Dynamic sensorimotor interactions in spinal circuits during locomotion

As an animal navigates its environment, its locomotor behavior is far from automatic; somatosensory modalities play pivotal roles in generating corrective and protective reflexes that dynamically adapt ongoing movement and posture. Recent work has also begun to reveal candidate cell types in the deep dorsal horn of mice that are hypothesized to function as integrators, transforming diverse sensory cues into precise motor outputs. To dissect the cellular and circuit logic of adaptive locomotion, we must reveal how spinal neurons function dynamically, how they sculpt sensorimotor network activity, and how they contribute to the execution of coordinated movements. We hypothesize that neurons in the deep dorsal horn of the spinal cord mediate discrete locomotor adjustments, where particular circuits or populations are specialized for a distinct motor task such as pausing locomotor activity to mediate a reflex or selecting the proper motor program for withdrawal based on limb starting position. Here, we established methods for the first high-density electrophysiology recordings, in vivo, of awake spinally fixed mice. Our data demonstrates that: (1) Mice in this preparation can produce consistent and extended bouts of locomotion, withdrawal reflexes, and clear repeatable behaviors. (2) Extracellular recordings from the dorsal and ventral horns revealed stable single unit activity. (3) Neurons in the sperficial dorsal, deep dorsal, and ventral horns display distinct patterns of activity during locomotion.

887 Laura Mendez, Tyson Hedrick

Black skimmers take advantage of wind to power foraging

Black skimmers (Rynchops niger) are named after their unique feeding behavior, skimming, displayed only by the Rynchops genus. Skimming mainly takes place in shallow waters at the coastline and is characterized by low altitude flights (body at 5 to 10 cm) over the water surface and the intermittent introduction of the mandible in the water in search of small fish. Skimming flight has been characterized previously, but not in the context of the environmental conditions. Our field recordings reveal that skimming bouts start with a descending movement and end with increases in altitude and turns toward the starting point. These observations lead us to propose that black skimmers can extract supplemental energy from the coastal winds to help power flight (and foraging) through a strategy that resembles dynamic-soaring. If they are using the energy from the wind, we would expect to see altitude gains against the wind (upwind), skimming crosswind, and descending flights in the direction of the wind (downwind). We characterized the foraging flights of black skimmers from field measurements of wind direction, flight direction, speed, and altitude. The flight direction respect to the wind differs between ascending (upwind), low altitude (perpendicular), and descending (downwind) flights. Changes in flight direction and speed suggest that black skimmers are taking advantage of the wind gradient to help power their foraging behavior.

1412 Elizabeth Mendoza, Marie Schwaner, Monica Daley, Manny Azizi

Quantifying the relative contribution of muscular and elastic energy during a frog jump

Jumping is a powerful movement that requires large amounts of mechanical energy. To meet the power demands of a jump, frogs temporarily store muscular work in surrounding elastic structures and then these elastic structures release the energy at faster rates. Given its significant in series tendon, the plantaris longus muscle-tendon unit (MTU) of frogs is thought to be an important site of energy storage. To date, the pattern of energy flow from the muscle to the tendon and ultimately to the body remains unknown. Unlike other systems using latch-mediated spring actuation (LaMSA), the hindlimb muscles of frogs are thought to contribute energy to the jump even as the elastic structures are recoiling and the hindlimb is extending. To quantify the mechanical energy contribution of the plantaris muscle during a jump, we instrumented the right plantaris longus MTU of bullfrogs with sonomicrometry, electromyography, and a leaf-spring tendon buckle. Then, we jumped the frogs and recorded with 3D high-speed video. We found that of the total mechanical energy output of the muscle, ~70% were stored in the tendon during the loading phase, while ~30% were contributed during the unloading phase supplementing the energy being released from the tendon. Our results are the first to quantify the relative contribution of muscular and elastic energy in vivo in a LaMSA system.

290 Douglas Menke

Anolis Lizards for Studies of Gene Function in Evolution and Development

Studies of gene function in anoles and other squamate reptiles have lagged dramatically behind other amniote groups due to a lack of genome editing and transgenic methods. As a consequence, investigations of gene function have almost completely excluded this diverse and highly successful group of animals. The biggest obstacle for the performance of genome editing in anoles has been delivery of the genome editing reagents into oocytes or early-stage embryos. We have overcome this barrier by establishing a surgical procedure that allows us to inject gene editing solutions into maturing oocytes while they are still physically attached to the ovaries. Using this approach, we have injected Cas9 and Cas12a RNPs to create targeted mutations in several different loci. We have determined that ~10% of injected oocytes yield offspring that carry monoallelic or biallelic mutations, and the analysis of mutant phenotypes can be performed either on G0 offspring or through the establishment stable gene knockout lines. To date, we have applied gene editing to investigate the evolution of limb size, the control of pigmentation, and eye development in Anolis lizards. We anticipate the genome editing methods that we develop in A. sagrei will be transferable to other members of the Anolis genus and will provide a roadmap for the establishment of these technologies in other squamate reptiles.

1192 Anna Merritt, Faith Leri, Laura Stein

Neural and Physiological Responses to Multiple Sensory Cues of Predation Risk in Trinidadian Guppies

Integrating cues from multiple sensory modalities allows individuals to gain information about their environment. Whether and how the brain and body respond differently to different sensory cues, alone or in combination, can help reveal mechanistic decision-making processes in animals. Here, we assessed neural and hormonal responses to different sensory cues of predation risk in Trinidadian guppies (Poecilia reticulata). Adult guppies were assigned to one of four treatment groups: control, visual, olfactory, and both combined. Guppies were exposed to sensory cues from a natural predator, the pike cichlid (Crenicichla alta), for two hours, after which we measured neural activation within different brain regions using pS6 (phosphorylated ribosome marker). We predicted that if cues reinforce each other, neural activation would be higher in combined cues than alone. However, we found that the control treatment had a higher number of activated neurons than the other three treatments, indicating that combined cues do not elicit higher neural activity. Additionally, we found strong sex effects for almost all regions, indicating that male and female brains respond to predator cues differently. Altogether, our results suggest that cues of predation risk, alone or in combination, elicit sex-specific neural responses that may cascade into observed sex differences in anti-predatory behavior.

1839 Conner Mertz

The role of gut microbiota in supplying amino acids to their mammalian hosts

Our understanding of how intestinal bacteria influence mammalian host carbohydrate metabolism is well described, however, the role of the gut microbiome in host protein metabolism is still largely unknown. Sufficient protein is crucial for animal survival. Extraordinarily, wild mammalian herbivores and omnivores often consume diets deficient in the amount of protein required to grow, reproduce, maintain homeostasis, and for proper immune function. Although the underlying mechanism is unknown, there is growing evidence indicating intestinal bacteria can provide amino acids to their eukaryotic hosts. Therefore, it is likely wild herbivorous and omnivorous mammals experiencing seasonal or persistent protein limitation may rely on their gut microbiota to provide missing amino acids. This work aims to uncover the role of the gut microbiome in host protein metabolism in wild omnivorous mammals through a series of controlled feeding experiments on a colony of deer mice (Peromyscus maniculatus) fed "natural" diets containing the quality and quantity of protein and carbohydrates mice would encounter in arid habitats. By combining genetic sequencing with amino acid stable isotope analysis, we can trace the origin of amino acids used by mammalian hosts to build their tissues. Physiological processes that occur in wild herbivorous and omnivorous mammals are often difficult to untangle, this work provides a framework to describe critical interactions between animals and their associated microbiomes furthering our understanding of animal physiology and ecology.

448 Bria Metzger, B. Duygu Özpolat

The cost or payout of regeneration on growth and sexual maturation in Platynereis dumerilii

Regeneration is a costly process which must be balanced with the demands of processes like reproduction. The cost of reproduction is especially dramatic in semelparous organisms where females invest significant body mass into oocytes at the expense of somatic tissues. Here, we test the impact of germline investment on regeneration using the semelparous marine annelid Platynereis dumerilii. We amputated worms of different stages of gametogenesis, removing most segments and gametes, and tracked them to sexual maturation. We hypothesized that worms with greater investment into gametogenesis would be delayed or deficient in germline regeneration and maturation. All amputees regenerated and produced a similar number of gametes, suggesting successful germline regeneration across stages. Surprisingly, older amputated worms grew faster and matured earlier than younger amputees, suggesting that the developmental stage of the remaining segments has a high influence on the fate of the regenerating, growing, and maturing worm. Furthermore, we expected that amputated groups would be delayed in reaching maturation because they had to regenerate over 80% of their body. However, when compared with their unamputated controls, younger amputees recouped all segments and then matured around the same time as their controls. This suggests that amputation itself stimulates changes, including accelerated growth, that persist long after regeneration concludes. Following these results, we will explore hormonal changes in these different groups to identify the source of observed differences.

355 Antonio Meza, Christopher Bell, Patrick Lewis

Inter- and Intraspecific Cranial Variation in the Amphisbaenian genus Zygaspis

Amphisbaenians are an understudied clade of limbless, fossorial reptiles. These reptiles have developed head-first burrowing, an elongated body, and are limbless in almost all species except for the genus Bipes. Here, the inter- and intraspecific cranial variation of seven of the eight currently recognized species of the amphisbaenian genus Zygaspis was assessed and unique morphological features among them were identified. The species examined here are Z. quadrifrons, Z. vandami, Z. nigra, Z. ferox, Z. violacea, Z. dolichomenta, and Z. kafuensis. The cranial anatomy of Z. quadrifrons has been previously described, providing a baseline description that allows for comparison to other specimens of Zygaspis. A total of 15 specimens from the seven species were micro-CT scanned at the University of Texas at Austin CT Lab. The software program Avizo 9.7.0 was used to digitally isolate the individual cranial bones of each specimen. The individual bones were evaluated based on qualitative differences, such as shape and features. Our results demonstrate that cranial variation does exist, including asymmetry, sexual dimorphism in Z. quadrifrons, and species-specific morphological features displayed in a few bones. The cranial element descriptions of the seven species of Zygaspis presented here suggests that inter- and intraspecific variation should be accounted for in functional and phylogenetic studies. These descriptions contribute to the existing literature of amphisbaenian cranial anatomy and provide further comparable material for amphisbaenian studies.

396 Peter Micah, Mark Gunderson

Organic UV Filter Decreases Metallothionein Content in Signal Crayfish (Pacifastacus leniusculus)

Oxybenzone is an organic UV filter commonly present in sunscreens that studies suggest can act as an environmental stressor. In this study, we examined the tissue-specific expression of metallothionein (MT) in signal crayfish (Pacifastacus leniusculus), a keystone species in the Pacific Northwest, exposed to environmentally relevant concentrations of oxybenzone (25, 50, 100, and 400 ng/g). Based on studies reporting adverse effects of oxybenzone on corals, we hypothesized that oxybenzone has the potential to act as a pro-oxidant in crayfish and thus modulate endogenous antioxidants such as metallothionein (MT). Tissue-specific responses to oxybenzone were observed. Results demonstrated a decrease of MT in hepatopancreas at the lowest dose tested (25 ng/g), at the highest dose tested (400 ng/g) in tail muscle, and no change was observed in gill tissue ($p > 0.05$). Decreases in MT could lead to adverse effects due to its significant role in various cellular processes, which include scavenging oxyradicals, binding and sequestering heavy metals, maintaining essential metal homeostasis, and immune functions. While our results indicate that oxybenzone is not acting as a strong pro-oxidant in this crayfish population, future studies are warranted to further investigate the impact of oxybenzone on crayfish physiology.

82 Tanner Mierow, Kate Feller, Alexandra Kingston

The morphology and performance of the Belostomatid visual system

Insects occupy a diverse range of habitats and have consequently evolved diverse eye morphologies that fit each species' ecological needs. A group of insects that represents such a lifestyle is the Belostomatidae, also known as giant water bugs. Belostomatids are semi-aquatic hemipterans that use vision to navigate to new bodies of water, capture prey, and find mates. To better understand how these visual systems are equipped to function in both air and water, we examined the morphology of their compound eyes and tested the visual performance of the belostomatid, Belostoma flumineum. We used scanning electron microscopy (SEM) and light microscopy to describe the ommatidial structure and the external cornea morphology of their compound eyes. We show that the corneas of adult B. flumineum are flat while the corneas of nymphs have greater curvature and appear more convex. Flat corneas are an adaptation known to decrease refractive errors in the vision of amphibious animals. We suspect that the flat corneas of adults improve their visual performance as they transition between water and air when moving to new bodies of water. To assess the performance of the visual system across ontogeny, we are currently using optomotor response assays to quantify visual acuity in each instar of B. flumineum in water and air. Lastly, we are utilizing TEM to assess the cellular morphology of belostomatid eyes across ontogeny.

634 Sam Miess, Andy Dzialowski

Assessing mass effect and ecological drivers in Oklahoma macroinvertebrate metacommunities

Assessing ecological drivers of metacommunity assembly and the influence of mass effect is crucial towards understanding and managing aquatic macroinvertebrates. This study aimed to determine which taxa are sensitive to mass effect, and how ecological drivers' influences change with varying watershed characteristics. Data from 1,363 Oklahoma stream samples were used from 2001 to 2018 as part of Oklahoma Conservation Commission's (OCC) biomonitoring program. Using these data, tolerances ranges, niche breadth, negative co-occurrences, and dispersal propensity values were determined for non-rare taxa (>1% of sites). To determine taxa influenced by mass effect, K-means cluster analysis split taxa into three groups based on niche breadth, dispersal propensity and negative co-occurrences. Taxa sensitive to mass effect were determined to be in the group with narrow niche breadth, high dispersal propensity and few negative co-occurrences. Assessing the change in ecological drivers' effects in varying watersheds used K-means cluster analysis to group sites based on landcover data within the site's respective sub-watershed (HUC-12). Taxa were divided by their niche, dispersal, and co-occurrences values. Beta diversity values were calculated for each site group and each taxa group, and these values were compared to beta diversity values calculated using a null model approach. The findings suggest bio-indices should be cautious of using macroinvertebrates sensitive to mass effect, and stream management should consider how each ecological driver's effect changes with different landcover types.

860 Donald Miles, Pau Carazo, Martin Whiting

Brain size evolution is shaped by reproductive mode and thermal biology

Vertebrates exhibit substantial variation in brain size, even after adjusting for body size. Numerous hypotheses have been proposed to explain diffferences in brain size among species. Most explanations focus on the costs of supporting a large brain and rely on energetic trade-offs among competing life history traits. Limited attention has been paid to ecological explanations favoring larger brains. Here, we address existing hypotheses about brain size evolution in vertebrates by exploring the link between brain size, life history and thermal biology in a sample 232 species of lizards. In contrast to other terrestrial vertebrates, brain size variation was unrelated to longevity or age at maturity, but was correlated with reproductive mode. We also found an effect of thermoregulatory behavior on brain size. Viviparous species had smaller brains than oviparous species, likely because live-bearing tends to evolve in cooler climates. In addition, heliotherms had larger brains than thermoconformers. These results suggest that brain size may be subject to specific selective pressures associated with mode of reproduction, thermal variation and behaviorall regulation.

1107 Brooke Miles, Alex Calli-Wehrman, Rachel Cohen

The effects of steroid hormones on neurogenesis in the green anole lizard (Anolis carolinensis)

Adult neurogenesis, or the addition of new adult-born neurons, has been well characterized, with many studies examining this phenomenon in the hippocampus and olfactory bulb in mammalian species, as well as HVC in avian species. However, less is known regarding neurogenesis in other vertebrate groups or in other brain areas. The present study aims to analyze the overall effects that steroid hormones have on neurogenesis in the amygdala of the seasonally breeding green anole lizard (Anolis carolinensis). Previous work has revealed that the green anole lizard amygdala has more neurons in the non-breeding compared to the breeding season, suggesting a seasonal difference in the regulation of neurogenesis in this region. As anoles have seasonal differences in circulating hormones, we hypothesize that changing hormone levels might play a role. To address this idea, breeding male lizards were treated with testosterone (T), estradiol (E2), dihydrotestosterone (DHT), or blank capsules and injected with bromodeoxyuridine (BrdU), a compound that labels dividing cells. After three-weeks, immunohistochemistry was conducted for BrdU and NeuN (a neuronal maker) on brain sections and double-labeled neurons in the amygdala were counted. We found that neurogenesis is occurring within the anole amygdala and we are continuing to analyze tissue to determine any potential effects of steroid hormones. Examining how steroid hormones impact neurogenesis in anoles will help increase understanding of neural plasticity more generally across species.

1016 Courtney Miller, Ashley Steele, Rex Mitchell, Jason Organ, Rachel Menegaz

Craniomandibular morphological variance decreases with age in mice with a COL1A2 mutation

Early life feeding behaviors contribute to craniomandibular development, shaping the skull to resist biomechanical forces. However, type I collagen (Col1) defects can result in weak bone, altered craniofacial growth, and reduced feeding performance. This study investigates craniofacial growth in a mouse with a genetic mutation affecting Col1 production, with a focus on the role of the hard palate during feeding.We compared the OIM mouse (B6C3FE a/a-Col1a2OIM/OIM) and unaffected wild-type (WT) littermates. Bone mineral density (BMD) and 3D landmarks were collected from micro-CT scans of juvenile (week 4) and adult (week 16) animals. The geomorph package in RStudio was used to conduct geometric morphometric analyses.Juvenile OIM mice demonstrate significantly more morphological variation, yet by adulthood this difference disappears. Cranial size and shape are significantly different between genotypes at both ages, with OIM mice having shorter and broader skulls. The palate is also shorter and broader, except in adults where no difference in anterior palate shape was observed. BMD is significantly decreased in OIM mice than WT mice, except at the adult midpalate region.While OIM and WT mice have significantly different morphologies throughout growth, there is less morphological variance within the OIM genotype as adults. Two explanations for this reduction in variation include functional convergence related to feeding biomechanics and/or the attrition of highly variable OIM individuals. Ongoing work will test these hypotheses in a preweaning sample.

1699 Laura Miller

Multiscale flow between the branches and polyps of gorgonians

Gorgonians, including sea fans, are soft corals well known for their elaborate branching structure and how they sway in the ocean. This branching structure can modify environment flows to be beneficial for feeding in a particular range of velocities and, presumably, for a particular size of prey. As water moves through the elaborate branches, it is slowed, and recirculation zones can form downstream of the colony. At the smaller scale, individual polyps that emerge from the branches expand their tentacles, further slowing the flow. At the smallest scale, the tentacles are covered in tiny pinnules where exchange occurs. In this paper, we quantify the gap to diameter ratios for various gorgonians at the scale of the branches, the polyp tentacles, and the pinnules. We then use computational fluid dynamics to determine the flow patterns at all three levels of branching. We quantify the leakiness between the branches, tentacles, and pinnules over the biologically relevant range of Reynolds numbers and gap-to-diameter ratios. We find that the branches and tentacles can either act as leaky rakes or solid plates depending upon these dimensionless parameters. The pinnules, on the other hand, mostly impede the flow. Using an agent-based modeling framework, we quantify plankton capture as a function of the gap-to-diameter ratio of the branches and the Reynolds number. We find that the capture rate is a complex, nonmonotonic.

936 Isaac Miller-Crews, Hans Hofmann

Single-cell transcriptomics of socially sensitive peptidergic neurons in a highly social fish

Specific neuronal cell types are thought to have evolutionarily conserved functional roles in regulating and maintaining various aspects of social behavior. Peptidergic neurons in the preoptic area (POA) and hypothalamus are integral to regulating social behavior across vertebrates, yet the molecular mechanisms by which these neurons respond to social context remain unknown. Single-nucleus RNA-sequencing (snRNA-seq) provides an opportunity to examine peptidergic regulation of social behavior at cellular resolution on a genomic scale. Here, we use snRNA-seq in the POA and hypothalamus of the highly social cichlid fish, Astatotilapia burtoni, well known for its remarkable social plasticity, to test the hypothesis that the previously demonstrated social regulation of cell size and activity of specific neuron populations is reflected in their single-cell transcriptomes. We generated, from both socially dominant and subordinate males, single nucleus transcriptomes for approximately 28,000 cells, which represent all expected cell classes. We identified populations of arginine vasopressin (AVP), oxytocin (OT), gonadotropin-releasing hormone (GnRH), and somatostatin expressing neurons, including robustly delineated sub-populations likely representative of parvo-, magno-, and gigantocellular neurons. We further find systematic gene expression differences between dominant and subordinate males in specific subtypes of these peptidergic neurons. Finally, we explore the complex interactions of the neuro-peptidome that underlie these dynamic social states. Our results provide novel insights into the molecular lives of socially regulated neuronal cell types at single-cell resolution.

204 Eliza Mills, Dara Orbach, Sarah Piwetz

Theodolite tracking bottlenose dolphin movement and behavior in a busy Texas ship channel

As humans continue to utilize coastal marine habitats, understanding dolphin behavior, habitat use, and vessel interactions in coastal areas is vital to improve conservation and management practices. Port Corpus Christi, Texas is the third largest port in the U.S. and supports high vessel density year-round. Protecting marine mammals in areas of high vessel activity is urgent as past studies indicated that dolphins increased avoidance behavior and altered habitat use in the presence of vessels. A shore-based digital theodolite was used to test the hypothesis that the behavior and movement patterns of free-ranging bottlenose dolphins (Tursiops trunca-

tus) are altered by the presence of vessels in the Corpus Christi Ship Channel. Dolphin movement [swimming speed, linearity, reorientation rate] and behavioral state [forage, travel, mill, social, rest, bow-ride] were analyzed in response to vessel activity [presence, speed, size]. Distances between dolphin positions and habitat features [seagrass, shoreline, sandy/muddy substrate] were calculated in ArcGIS Pro. Dolphins were observed bow-riding on most tankers, suggesting that large, slow moving vessels that produce large pressure waves may elicit social and travel behaviors. Forage and mill behaviors were observed along channel seawalls, suggesting that physical structures are utilized for prey capture. Knowledge of dolphin behavioral associations to diverse habitat features is crucial to improve the preservation of critical environments utilized by dolphins. Understanding dolphin behavioral responses to vessel activity is vital in active seaports.

1056 Mike Misamore, Julianna Martinez, Sophia Pracilio

Factors effecting the survival and reproduction of the invasive zebra mussels in Texas waters.

The zebra mussel (Dreissena polymorpha) is an invasive freshwater mussel infesting many waterways of the eastern, central, and southern United States. They have recently invaded north Texas and have spread through multiple water basins in Texas. Key to their continued invasion into Texas waters is their reproductive ability through broadcast spawning and direct larval development in the water column. As indicated by zebra mussel spread into Texas, zebra mussels have demonstrated the ability to survive and reproduce in environmental conditions beyond predicted values for this cold-water species. This study was looking at various environmental factors which might affect mussel survival, growth, and reproduction as well as possible methods of control. Factors addressed include calcium concentration and pH, as well as the effects of copper as a potential mechanism of control. Impacts on mussel survival and reproductive success including fertilization and larval survival were studied. Zebra mussels showed differing levels of survival under varying calcium concentrations and were negatively impacted by exposure to copper.

921 Geoff Mitchell, Nathan Faulstich

Evidence for phosphorous-dependent control of symbiont cell growth

Reef-building corals depend on symbiosis with photosynthetic algae (Symbiodiniaceae) that reside within their cells. As important as this relationship is for maintaining healthy reefs, it is surprisingly delicate. When ocean temperatures marginally exceed the average summer maximum for even a few days, corals can bleach, expelling their endosymbionts. While the mechanisms underlying bleaching are unknown, several studies implicate the uncoupling of coral and algal cell divisions at high temperatures. Little is known, however, regarding the host control of algal cell divisions that is necessary for maintaining proper symbiont density. Control of nutrient exchange is one likely mechanism. In fact, nitrogen enrichment increases symbiont density in the host and speeds proliferation of Symbiodiniaceae in culture. The consequences of phosphorous enrichment, however, are not as well-established. A meta-analysis of 15 studies across several species of coral found that phosphorous-enrichment alone has no impact on symbiont density but can work synergistically with nitrogen to enhance algal cell division. This suggests that phosphorous only limits Symbiodiniaceae growth in the host when there is excess nitrogen. Still, evidence suggests that symbiont proliferation is limited by phosphorous in the host, indicating that hosts maintain algae in a nitrogen-enriched environment. Here, we examine the effects of phosphorous-depletion on symbiont cell growth in culture and compare the physiology of phosphorous-limited symbionts in culture to symbionts that are freshly isolated from the host.

925 Geoff Mitchell, Chandler Dickert

Making coral endosymbionts more amenable to immunofluorescent labelling

Within the past five decades, tropical coral reefs have declined by more than 50%. To thrive in the nutrient-poor waters of the tropics, reef-building corals depend on a symbiotic relationship with the photosynthetic dinoflagellates (family Symbiodiniaceae) that reside within their gastrodermal cells. As important as this relationship is for maintaining healthy reef ecosystems, it is surprisingly delicate. When sea surface temperatures marginally exceed the average summer maximum for even a few days, corals can bleach, expelling their endosymbionts. These bleached corals fail to reproduce, are more susceptible to disease, and can be readily overgrown by macroalgae. The cellular mechanisms underlying bleaching, however, are poorly understood, and without this understanding, we limit our ability to respond to the threat placed upon coral reefs by climate change. Unfortunately, many of the tools that modern cellular and molecular biologists rely upon are intractable in Symbiodiniaceae, likely due to their thick cell walls. Here, we outline a method that uses cellulase to digest the cell wall and make dinoflagellates more amenable to immunofluorescent labelling.

1319 Tim Mitchell, Alex Shephard, Emiliee Snell-Rood

Pollutant uptake by plants exposes butterflies to elevated toxins loads

Human activities are drastically altering the distribution and availability of toxins in the environment, which can have substantial effects on the health of animal populations. For conservationists to mitigate these effects, they must first have answers to basic questions related to toxin exposure. How do human activities shape the distribution of toxins in the environment? What are routes of toxin exposure for wildlife? How do organisms respond behaviorally and perform when exposed to elevated levels of toxins? Using butterflies and their host-plants as a model system, we address these questions by synthesizing a series of field and laboratory projects. We explore relationships between human activities (e.g. road maintenance and traffic), soil chemistry, plant chemical uptake, and caterpillar nutrition and development. We show how spatial variation in human activities leads to spatial variation in soil toxin loads (e.g. sodium, zinc), which in turn can influence foliar and nectar chemistry in plants. We demonstrate that butterfly behavior influences exposure to such pollutants. Larval nutrition experiments demonstrate that butterflies are generally robust to ecologically relevant levels of common pollutants in many rural sites. Ongoing work is focusing on how pollinator conservation plantings in heavily polluted urban sites influence pollinator health and the movement of toxins through the landscape.

493 Juri Miyamae, Talia Moore

Entails a Closer Look: Comparative muscular morphology and function of the mammalian tail

The diversity of mammalian radiations into the world's terrestrial, aquatic, and aerial environments is fundamentally shaped by modes of locomotion. Much attention has been paid to the role of the limbs, but the fifth appendage – the tail – presents an intricate, challenging anatomy that has been relatively unexplored. We present a preliminary survey of tail muscular anatomy based on both literature review as well as original data collected from dissections and microCT scans in a phylogenetically and functionally diverse sample of mammals. Examination of the muscles and associated tendons reveal considerable variation in the configurations that have evolved to mobilize the tail, including some unexpected muscle architecture and tendon branching patterns. Functionally, the tail is a dynamic element in locomotion capable of storing elastic energy, acting as a stabilizer to maintain balance, acting as a destabilizer to generate body rotations during high-speed turning maneuvers, or utilized as a prehensile source of support during climbing. Within our phylogenetic survey, we focus on the tree kangaroo (Dendrolagus sp.) and jerboa (Jaculus jaculus), bipedal locomotors in arboreal and terrestrial environments, respectively. Through modeling and comparison to previously established form-function relationships, we infer the locomotory role of the tail in these two species. Such foundational anatomical inquiry can provide insights into the evolutionary history of ecological transitions and their relationship to locomotory modes.

494 Juri Miyamae

Probing the proboscis: comparative morphology of the mammalian nasal proboscis and performance

The mammalian proboscis is a soft-tissue extension of the nose that is mobilized by facial muscles. The elephant's trunk is a well-known example of a proboscis, but this distinctive feature can be found convergently in a wide phylogenetic range of extant mammals primarily within the afrothere, eulipotyphlan, and ungulate clades. Relatively little is known about the anatomical structure and functional aspects of the proboscis, particularly in smaller mammals; therefore, I undertook an examination of the soft-tissue facial anatomy using contrast-enhanced microCT scans of different species of sengi (Afrotheria, Macroscelididae) and solenodon (Eulipotyphla, Solenodontidae). Despite superficial similarities of the proboscis across taxa, there is appreciable diversity in their anatomical construction, including differences in the configuration of the nasal cartilages between species of sengi. The complex morphological interplay of muscles, cartilage, bone, and other structures inform insights into the biomechanical properties of the mobile nasal proboscis. Previous work based on behavioral observations reported that each species or group of species displayed characteristic movement patterns of the proboscis such as bending position and angle. Incorporation of the novel anatomical data presented here provides insights into this relationship between the diversity of proboscis form and function.

182 Robert Mobley, Karen Maruska

Effects of rearing temperature on neural development of the cichlid fish Astatotilapia burtoni

The environment experienced by an organism during development can have profound effects on their physiology, brain, and behavior. As temperature is a pervasive part of the environment, capable of influencing many developmental processes and expected to change around the world in years to come, we investigate how temperature alters brain development and neural phenotypes in the African cichlid fish Astatotilapia burtoni. In vertebrates, expression of sonic hedgehog (shh) and associated genes regulates the dorsal-ventral patterning of brain regions. Variable shh in cichlids also drives the organization of brain development in relation to their ecological niche, and it may promote dependence on different types of sensory information. Here we investigate the effects of temperature on cichlid brain development at multiple stages for broods reared at, above, and below normal environmental temperature conditions. In addition to measuring mortality and somatic growth, we compare changes in the size of brain regions involved in sensory processing. We also use in-situ hybridization and qPCR to localize and compare expression of ssh and related genes across temperatures and developmental stages. We predict increased temperatures to upregulate genes involved in elaboration of the ventral telencephalon and resulting neural phenotypes that may be better able to process olfactory information. This work provides insights towards better understanding how traits change in response to temperature and how gene-environment interactions produce phenotypes through development.

656 Brendan Mobley, Suzy Renn, Andrew Anderson

Runaway chromosome evolution in a clade of freshwater fish

Despite being one of the most morphologically and phylogenetically diverse vertebrate groups, freshwater fishes display remarkably conserved chromosome counts; over half of all karyotyped species have either $2N = 48$ or $2N = 50$ chromosomes. Within the subfamily Luciocephalinae, two closely-related species are notable for their low chromosome counts ($2N \leq 20$). Large disparities within a family are extremely rare, and with little information on Luciocephalinae available in the literature, we aimed to determine how, when, and why this shift occurred. We established novel karyotypes for species within Luciocephalinae and the larger family, Osphronemidae, and modeled changes in karyotype over the established phylogeny. We find the subfamily Luciocephalinae has a karyotype evolution pattern characterized by rapid changes in chromosome morphology, and modeling suggests that a large reduction in chromosome number occurred early in the evolutionary history of the clade ($\sim$25 MYA). This chromosome reduction likely was maintained through the creation of semi-isolated populations with different optimal phenotypes. Additionally, the observed low-2N genome arrangement will likely have negative fitness impacts in the face of climate change. Due to the paucity of species in the subfamily and the seemingly repeated rapid losses of chromosome number, models are unable to reliably estimate the when and why of these striking changes, thereby requiring more detailed work to unravel this evolutionary mystery.

691 Kayla Moehn, Isha Gore, Elizabeth Gould

Early Life Adversity Impacts on GABAA Delta Subunits in Ventral Hippocampus and Avoidance Behavior

Early life adversity (ELA) involves unfavorable environmental circumstances during childhood such as abuse, neglect, or exposure to natural disasters. ELA increases the risk of developing a mental illness in adulthood. We examined the ventral CA1 (vCA1) region of the hippocampus which is important for avoidance behavior. The current study aims to explore the mechanisms underlying the influences of ELA on avoidance behavior, including the possibility that GABA-A delta subunits are altered in the vCA1. Maternal separation and early weaning (MSEW) increases avoidance behavior in males and females when they are in diestrus. Avoidance behavior is correlated with increased theta oscillations in the vCA1, and these oscillations are associated with parvalbumin-positive (PV+) interneurons. PV+ interneurons are GABAergic, and GABA-A delta subunits have been linked to certain neuropsychiatric diseases. We investigated whether MSEW affects the expression of GABA-A delta subunits in these neurons in the vCA1. We found that despite differences in avoidance behavior and theta oscillations, there were no differences in the intensity of GABA-A delta subunits between MSEW and control males and diestrus females.

1489 Nina Mohebbi, Matthew Fu, John Dabiri

3D aggregation dynamics of vertically migrating brine shrimp at different swarm densities

Diel vertical migration of plankton is a significant synchronized biomass movement ubiquitous to earth's oceans. The hydrodynamic interactions of swimmers in these swarms may impact the aggregation configuration and the nature of any swarm-scale flow features induced by the migration.Previous work has shown that swimming aggregations can induce aggregation-scale jets significantly larger than individual animals. We use

Artemia salina, known as brine shrimp, to characterize the dynamic 3D configuration of swimmers during induced vertical migrations. A scanning laser sheet and a high-speed camera allow for 3D tracking of swimmers over 13 body lengths of vertical migration. The reconstructed 3D swimmer configurations for swarms of varying number density enable inference and modeling of the hydrodynamic interactions occurring during synchronized vertical migration.

680 Claire Molina

The Anthropogenic Effect on Pigeon Guillemot Nesting Behaviors with a Focus on Provisioning

Pigeon Guillemots (Cepphus columba) are seabirds native to the west coast of North America and forage on the sea floor for benthic fish. The variety in their nesting sites makes them prime subjects for studying the effects that urbanization has on their nesting behavior and provisioning. We asked; how does nesting behavior differ between dock and cliff nesters and how does the presence of humans affect the length of time that it takes adults to deliver fish to chicks? For eight weeks, we surveyed two field sites on San Juan Island, Washington where we observed two cliff nests and one dock nest. To determine how human presence affects length of delivery, we ran two trials: a control in which there was no human presence near the nesting site, and an experimental in which we placed one of the researchers below the nest. We recorded the time that the bird sat in the water with the fish in its mouth before entering the nest. Between the control and experimental of the cliff nesters, we found that the delivery time for the experimental trial was significantly higher than the control ($p < .0001$). The results of this experiment provided an interesting insight into how human activity may influence Pigeon Guillemot behavior and provides a foundation for future studies to expand the sample size and examine other aspects of this influence.

472 James Moloney, Amy Iler, Elsa Godtfredsen

The Effect of Snowmelt Timing on Pollinator Visitation to Subalpine Wildflowers

The plant-pollinator mutualism is under increased stress due to climate change, especially in high elevation ecosystems. In subalpine ecosystems, climate change alters the timing of snowmelt, which changes flowering phenology and can impact plant-pollinator interactions. To better understand the consequences of snowmelt timing on plant-pollinator interactions, an early snowmelt manipulation was performed and pollinator observations were conducted on four species of subalpine wildflowers. The study consists of pollinator observation sessions in control and early snowmelt plots on 4 species of wildflowers: Delphinium nuttallianum (DENU), Geum triflorum (GETR), Linum lewisii (GETR), and Delphinium barbeyi (DEBA). This study aims to better understand future changes to plant-pollinator interactions as climate change advances plant and animal phenology. I found that DENU experienced a significantly lower mean visitation rate in early snowmelt plots whereas LILE experienced significantly higher mean visitation rate. DEBA had a significantly higher probability of receiving a visit in early snowmelt plots compared to controls. As climate change becomes more severe, there will be differential impacts for subalpine plant species and therefore both positive and negative effects on plant and animal interactions. Species that are more resilient to frost and phenological mismatch like LILE may be able to outcompete other more frost and phenologically sensitive species. More years of study as well as further investigation of species' reproductive efficacy is needed to support this hypothesis.

1075 Dillon Monroe, Caitlin Gabor

Geographic variation in multiple stress markers in the Gulf Coast Toad (Incilius nebulifer)

Comparative population studies of physiological processes within a species with a broad climatic niche can give insight into individuals' capacity to cope with rapid environmental change. Natural and anthropogenic environmental variation are common gradients that are conglomerates of biotic and abiotic variables. These integrated measures are often correlated with a species' traits to understand broad patterns in trait geographic variation. The Gulf Coast Toad (Incilius nebulifer) has gradually increased in abundance and distribution in areas where other native amphibians have been struggling to persist due to anthropogenic change. Further, native anuran tadpoles have reduced growth and survival when raised with I. nebulifer tadpoles. The success and potentially detrimental effects on other anurans of I. nebulifer make it an interesting system to study and a conservation concern. We hypothesized that significant geographic variation in measured traits could contribute to the success of I. nebulifer. To test our hypothesis, we collected toads from three areas across Texas and three sites in each area that differed in their level of development. We measured individual glucocorticoid profile (baseline, stress-induced, and one hour after stressor—recovery), hop endurance, and total lipid levels to determine how well I. nebulifer are coping with local environments. Understanding how populations can quickly respond to environmental change will provide insights for amphibian conservation management.

251 Tessa Montague, Daniella Garcia-Rosales, Connor Gibbons, Thomas Barlow, Adriana Nemes, Mycah Simmons, Erica Shook, Larry Abbott, Richard Axel

The neural basis of cuttlefish camouflage

To navigate the visual world, animals create an internal representation of the environment and extract salient features, permitting the generation of appropriate behaviors. Cuttlefish present a unique system for studying the internal representation of visual stimuli. Cuttlefish dynamically change their skin color and texture to camouflage to their surroundings, creating a physical readout of what they see. The skin's "pixels" (chromatophores) are controlled by motor neurons projecting from the brain. Thus, camouflage is a visible representation of neural activity. We are using this system to understand how the physical properties of the visual world are represented by patterns of neural activity in the brain, and how this representation is transformed into an approximation of the physical world on the skin. Specifically, we are generating transgenic cuttlefish that express genetically-encoded calcium indicators and light-activated channels. By recording neural activity in transgenic cuttlefish while they camouflage to a virtual reality environment, we aim to understand how the visual world is internally represented in the brain and then recreated on the skin.

1573 Amanda Montgomery, Allison Welch

Effect of elevated salinity on predator-prey interactions of amphibian tadpoles and dragonfly nymphs

Increased salinity in freshwater habitats is a major ecological concern. Habitat salinization can cause behavioral changes, reduced growth, and even death in various freshwater organisms. However less is known about the impact of elevated salinity on interspecies interactions. Effects of freshwater salinization on ecological interactions are important to understand, as they have the potential to alter community structure and ecosystem function. Elevated salinity has been shown to negatively impact tadpoles from various amphibian species, which play important roles in freshwater ecosystems as herbivores and as prey. We investigated the effects of elevated salinity on predator-prey interactions involving amphibian tadpoles and dragonfly nymphs, a known predator of tadpoles. Salinity tolerance trials with nymphs of the odonates Pachydiplax longipennis and Erythemis simplicicollis indicated greater tolerance to salinity than has been documented for tadpoles of most amphibian species, including green treefrogs (Hyla cinerea). In predation trials, Erythemis simplicicollis nymphs were allowed to prey on green treefrog tadpoles after both species had been exposed to moderate salinity for several days, and predation rates were compared with freshwater controls in which neither species had been exposed to elevated salinity. These findings suggest that tadpoles are less tolerant to elevated salinity than their odonate predators, and may therefore be more vulnerable to predation in elevated salinity conditions, which could impact amphibian populations and their ecological roles.

363 Nicole Moody, Matthew Fuxjager

Network analysis reveals context dependent variability in woodpecker territorial strategy

Territoriality can be broadly defined as a category of social behavior whereby individuals defend resources from competitors. Territorial behavior can take many forms, ranging from widely broadcast signals to close range, proximity-based, physical displays. Importantly, the context of territorial disputes and the type of threat presented by the intruder(s) varies within a system. Therefore, it follows that residents will adjust their territorial strategies to produce a defense tactic tailored to the specific threat they face. ?We assess how territorial strategy varies in response to five different simulated territorial intruders in a population of North American downy woodpeckers (Picoides pubescens). During the spring breeding season, monogamous pairs of P. pubescens jointly defend nesting territories, incorporating an array of acoustic, gestural, and movement based tactics. Previous work in this system indicates that the intensity (i.e. drum speed or length) of an intruder's drum signal can affect the territorial defense employed by resident birds. Here, we use network analysis to quantify the correlative relationships between behaviors performed in different territorial contexts, allowing us to quantify tactical variation. We find that above a certain threat level threshold, residents begin to modularize their aggressive tactics by deploying clustered sets of behavior that are performed at the exclusion of others. Woodpeckers therefore appear to appraise the social context of an aggressive encounter and adjust their territorial defense strategy accordingly.

1033 Katrina Moore, Anahita Sadrossadat, Zhuoyang Zhang, Craig McGowan, Monica Daley

Bold and fast? Does kangaroo rat (Dipodomys deserti) behavior correlate with locomotor performance?

Animal locomotion enhances fitness and survival by enabling individuals to acquire mates, escape predation, and find resources. However, locomotion is only one of many behaviors that are important for animal function and survival. Behavioral plasticity is essential in changing environmental conditions and context as it may enhance an individual's ability to adapt. Here we investigate variance among individuals in behavior expression and locomotor activity levels of desert kangaroo rats (D. deserti). We aim to analyze the potential for correlation in expression of multiple behaviors, hence exploring whether kangaroo rats exhibit "behavioral syndromes" that relate to their locomotor activities. We sampled 9 D. deserti individuals from a population in the Mojave Desert and recorded their behaviors for 15 minutes in a modified novel-environment-test arena in the field. Preliminary results suggest a correlation between expression of exploratory behaviors such as walking, eating, and interacting with novel objects. This indicates a gradient of activity and exploration among individuals in a novel environment, which may be an important measure of boldness (or risk tolerance). Therefore, we predict a correlation between the amount of exploratory behavior and locomotor performance with higher speeds, distance traveled, and jump heights in individuals with higher overall exploratory behavior. We hope this research can lead to greater understanding of animal behavior expression and plasticity, thus enhancing wildlife management and conservation efforts.

1140 Georgia Moore, Richard Blob, Victor Munteanu

How arboreal chameleons and Anolis lizards resist falling from perturbed branches

Animals must contend with unexpected changes in their habitat and environment to thrive. In an arboreal habitat, failure to implement corrective behaviors in response to such changes (e.g., branch perturbations) can result in high risk of injury or death upon falling. However, many arboreal animals exhibit morphologies that facilitate corrective behaviors that help resist falls. To better understand how arboreal animals accommodate perturbations, we evaluated perturbation resistance in two species of arboreal lizard: Cuban knight anoles (Anolis equestris) which grip perches with sprawled limbs that should place the body close to the perch, enhancing stability, and and veiled chameleons (Chamaeleo calyptratus), which use upright limbs that may place the body in an unstable position higher from the perch, but which also have a prehensile tail. Lizards were exposed to simulated perch perturbations on a custom-made apparatus, and three-dimensional kinematic variables were calculated from high-speed videos of trials. Results show that chameleons maintained significantly more extended limbs throughout perturbations but still maintained a grip on the perch, likely aided by the specializations of their hands and feet as well as the prehensile tail. This suggests that potential risks from limb posture and body height in a perturbation event may be reduced via other arboreal specializations.

195 Nia Morales, Darryl Reano

What is The Field? Conceptualizing inclusive undergraduate field experiences

Undergraduate field experiences (UFEs) are key components of many biology, ecology, and geoscience programs and important steps to successful recruitment into careers. However, these experiences can present serious challenges for some students, particularly those from marginalized identities (racial/ethnic minorities, LGBTQ, students with disabilities, etc.). Through semi-structured interviews, this study seeks to understand how primarily BIPoC field program leaders conceptualize their disciplines and the UFE itself. Additionally, this study explores how these program leaders approach desiging inclusive UFEs and the institutional and practical challenges of designing and implementing inclusive UFEs. Building an understanding of these concepts will aid in addressing the underrepresentation of students from marginalized backgrounds in biology, ecology, and the geosciences by creating safe, encouraging field experiences where students can develop their self-identity in the sciences, build peer and professional networks, and develop experiences that lead them towards successful careers.

1352 Tylar Morano, Jennifer Grossman, Chelsea Bennice, Kenddra Buresch, Roger Hanlon

Octopus Arm Flexibility: Characterization of Arm Movements in Freely-Moving Octopus

The extreme flexibility of octopus arms is of significant interest to scientists in the fields of soft robotics and biomechanics. The arm movements used to achieve such a high degree of flexibility have not been comprehensively studied in freely-moving wild octopuses. This study characterized arm flexibility by breaking down fifteen behaviors into arm actions and the deformations which constitute each arm action. Twenty-five videos of Octopus vulgaris from 6 field locations were analyzed using 12 defined arm actions and 4 deformations (bending, torsion, elongation, and shortening) resulting in 3,907 actions and 6,781 deformations recorded. Overall, all arms were capable of performing each action; however, 5 actions comprised 78% of all observations; there was anterior versus posterior arm partitioning for specific actions. Deformations followed a similar trend with all deformations used across all actions;

bending accounted for the majority (70%) of deformations. Aside from bending, actions that performed locomotion (stilt, push, trailing, rolling) used elongation, shortening, and torsion more commonly compared to all other actions. Although bending was the deformation most frequently observed, it specifically occurred in the medial and distal arm regions whereas elongation and shortening occurred mostly in the medial region and torsion only occured in the medial and distal regions. These results were strikingly similar to a laboratory study examining deformations- illustrating the basic mechanics behind octopus arm flexibility.

749 Wave Moretto, Jennifer Taylor

The effect of temperature on the feeding ecology of Brown Box Crabs

Fishing pressures for Brown Box Crab, Lopholithodes foraminatus, are growing in Southern California, and sustainable populations depend on adequate nutrition. The temperature range that brown box crabs experience (8°C - 15°C) across their depth gradient (intertidal zone - 500 m) presents challenges for these ectothermic animals because the rates of their physiological processes vary with temperature. Adult crabs were exposed to one of three temperature treatments (N = 10): 8°C (ambient), 15°C, and 20°C (representative of warm water events). Weekly throughout the exposure period, crabs were given two similar-sized prey items of different crushing strength (clam and mussel). Prey preference, time to consume prey, and claw pinch force were recorded prior to the start of the experiment and each week for the duration of the experiment. We hypothesized that crabs will prefer prey items that require less breaking force at the coldest temperature, consume prey faster at warmer temperatures, and have stronger pinch force at warmer temperatures. Preliminary results confirm that pinch force is stronger in crusher claws versus tearing claws regardless of temperature, and that pinch force increases with body size. Furthermore, crabs have no prey preference at ambient temperature. If box crab feeding behavior exhibits temperature thresholds, then fishery managers can anticipate modifying catch limits to ensure populations remain stable when temperatures fluctuate seasonally or long-term due to climate change.

1824 Itumeleng Moroenyane

The future of Black Lives Matter Legacy: Cultivating an Inclusive and Anti-Racist Environment

In the face of racial and institutionalised injustices occurring all over the world, campaigns have been rising to promote Black persons in science, technology, engineering, and mathematics (STEM). To this end, twelve Black botanists established the internet campaign #BlackBotanistsWeek (https://blackbotanistsweek.weebly.com/) to highlight and promote Black people who love plants in order to bring these issues to the attention of the biological community. The time is right to talk about diversity, equity, and inclusion (DEI) issues within the biological community because they are at the forefront of educational and social transformation. This includes acknowledging the part biology has played in the fabrication of a pseudo-scientific case for racism, as put out by eminent researchers like Carl Linnaeus and Comte de Buffon. By acknowledging this, we may take steps to address the racist attitudes that are still prevalent in academia today. With this awareness, how can we take steps to address the racist attitudes that persist and intrude in academia today? In order to address current injustices in science and foster a brighter future for BIPOC individuals and, ultimately, for all of humanity, this symposium focuses on evidence-based research and pedagogical techniques. Research shows that diversity in work-place promotes creative problem solving, academic performance, and increased productivity. The ultimate goal is to address the three main obstacles faced by BIPOC, that is, 1) lack of representation, 2) recruiting.

333 Omar Morosse, Iris Levin

Assortative mating in the North American Barn Swallow (Hirundo rustica erythrogaster)

While female mate choice is well established, the process of mate selection can be bidirectional, with evidence for assortative mating in many species of birds. Positive assortative mating (PAM) is a pattern in which both individuals within a pair select each other based on similarity in a given trait. Of the possible mechanisms leading to PAM, two are most likely in short-lived animals without long-term pairbonds. During mate choice, individuals may prefer phenotypes resembling their own ("like attracts like"), or in cases of spatial and temporal autocorrelation, similar individuals pair because they are in the same place at the same time ("like meets like"). We asked whether North American Barn Swallows (Hirundo rustica erythrogaster) exhibit PAM when they select their social mate. We collected data on tail streamer length, wing length, mass, age, ventral plumage color, and social interactivity for adult Barn Swallows breeding in Knox County, Ohio. Feather brightness, hue, and chroma were quantified using spectrometry of ventral feathers. Age assignment relied on the assumption that new breeders in our banded populations were second year individuals. Mating pairs were identified through observation of color-banded individuals feeding their nestlings and social interactions were quantified using proximity loggers. Preliminary results suggest that Barn Swallows do not mate assortatively with regards to tail streamer length, wing length, mass, or age.

377 Zachary Morris, Bhart-Anjan Bhullar

Evolutionary origins of amniote secondary palates

Living amniotes display a tremendous disparity in craniofacial form and composition, reflecting over 320 million years of evolutionary divergence. The anatomical and ecological specialization of amniotes makes it relatively trivial to distinguish the skulls of living mammals, birds, turtles, crocodylians, and lepidosaurs. However, mammals, crocodylians, and some lizards and turtles have independently derived "secondary palates" which divide the nasal and oral passages to varying degrees. To assess whether these forms are convergent, we performed 2D and 3D geometric morphometric analyses of the complete palate, maxilla, and palatine across amniotes with and without "secondary palates. These data demonstrate crocodylians and mammals are remarkably similar, particularly the maxillae and palatines. Other reptiles with putative "secondary palates" cluster with other lizards and turtles. Squamates display greater disparity, likely reflecting greater functional and ecological utility of the palate than in other amniote clades. Extant birds occupy a distinct region due to the enlargement of the premaxilla and strut-like palatines. The fossil record of stem-mammals and stem-crocodylians reveals transitional forms that follow remarkably similar evolutionary trajectories and extant species are significantly more convergent than expected. Additional similarities are present across palatal shelf outgrowth of both alligators and mice during morphogenesis. Our study demonstrates the value of quantitative comparisons across highly divergent clades and that a more nuanced language will facilitate a greater understanding of amniote palate evolution.

1335 Catherine Morris, Dave Coughlin, Annika Pfister, Zoe Reynolds, John Parker, Dave Ellerby, Bradley Wood

Electromyography of Bluegill Sunfish at Different Gaits: Steady Versus Intermittent Swimming

Locomotion that is driven by muscle activity dominates the daily energetic expenditure in most animals. In fish, routine propulsion when swimming at low, steady speeds and at various gaits is powered primarily by red, oxidative muscle. In Bluegill Sunfish (Lepomis macrochirus), swimming speed is thought to reflect the most energetically efficient gait type. Since field observations of Bluegill suggest that intermittent swimming is the preferred gait, we hypothesized that intermittent locomotion would be more energetically efficient than steady swimming. To test this hypothesis, we used electromyography to analyze muscle activation intensity of Bluegill swimming steadily in a flume and volitionally intermittently in a pool. In the flume, muscle activation intensity and tailbeat frequency increased as a function of speed. However, when swimming volitionally in the pool, muscle activation intensity varied relative to average velocity and tailbeat frequency was lower than in the flume at the same velocities. Although we expected muscle activation intensity to be higher when steady swimming at a given speed, ~48% of fish ($n = 11$) had higher muscle activation intensities when swimming volitionally when compared at the same speed in the flume. Also, there was a positive relationship between speed and glide duration, but there was no relationship between speed and muscle activation intensity when swimming intermittently. Instead, intermittent swimming may lower fatigue and enhance maneuverability, rather than increase energetic efficiency.

980 Kimberly Moser, Gavin Woodruff

Marvelous Mutants of C. inopinata: Forward Screen Reveals Body Size Mutations

Body size is a fundamental organismal trait varying widely among species. Caenorhabditis inopinata grows to be nearly twice as long as its close relative, C. elegans. Because of its relationship to this model system, C. inopinata is well-positioned to address the causes of body size variation within a comparative molecular genetics context. Here, we report a pilot forward mutagenesis screen to discover genes underlying body size in this species.We screened 493 mutagenized haploid genomes for recessive body size mutations in the F3 generation (as C. inopinata is a gonochoristic species). We established five mutant homozygous lines after backcrossing for five generations to purge background mutations. Three of these lines harbor a short and fat (dumpy) phenotype, whereas two of these lines have a long mutant phenotype.Currently we are characterizing mutants to estimate effects on body size dimensions, rates of growth, and the onset of body size differences. Bulk segregant analyses with mutant and wildtype F2 individuals are also underway to pinpoint the molecular lesions that underlie these mutant phenotypes. Once identified, genes critical for body size regulation in C. inopinata can be compared with homologous genes in C. elegans using molecular and developmental genetic approaches. This, in tandem with further forward screens, will reveal the extent of functional evolution of body size genes in species with exceptional body sizes.

1149 Abilene Mosher, Daniel Papaj, Stephen Buchmann, Thomas Eltz, Avery Russell

Extra, extra, buzz all about it: anther chemical cues signal bees to buzz for pollen.

Plants often provide cues eliciting pollinator behaviors that benefit the plant, but which also may benefit the pollinator. Cues that direct pollinators to floral nectar rewards are common and enhance pollination, yet the function of cues associated with pollen rewards is poorly understood. Here we investigated the function and identity of floral cues stimulating a widespread bee pollen foraging behavior termed floral buzzing, a behavior that >10% of flowering plants require for pollen expulsion. Using crude solvent extracts and gas coupled mass spectrometry (GC-MS), we found that chemical cues specifically associated with the anthers (the male reproductive flower part), mediated floral buzzing. We also found that petal extracts did not mediate buzzing. By allowing extracts to volatize for different amounts of time before testing, we found that the cues eliciting buzzing have low volatility, suggesting anther cues elicit buzzing only at close range. Our results suggest these anther cues thus benefit the plant by stimulating the bee only when close to the reproductive organs (potentially enhancing pollination), but also benefit the bee by eliciting pollen foraging only on the anthers. Finally, we discuss the unusual nature of these anther cues, which seem to serve as a private channel signaling anther presence to bees. In ongoing work, we continue to characterize the specific chemistry involved through via solvent fractionation and GC-MS.

1334 Jeanette Moss, James Tumulty, Eva Fischer

Trophic egg feeding calls of a biparental frog co-opt and modify elements of ancestral signals

The emergence of new social associations is predicted to be an important selective force in the diversification of communication systems. To meet new functional demands, signal repertoires may expand, or existing signals may be co-opted to solicit distinct, context-dependent responses. In anurans, the vocal repertoires of many species have been characterized in detail, including distinct types of calls for advertisement, courtship, and aggression; yet quantitative descriptions are lacking for social contexts such as parental care. Here, we characterized and compared calls of the biparental poison frog, Ranitomeya imitator, across three social contexts: advertisement, courtship, and egg-feeding – a unique parenting behavior in which males call to coordinate the provisioning of trophic eggs by their female partners. We found that egg feeding calls shared properties with both advertisement (i.e., longer in duration) and courtship calls (i.e., broader call bandwidths) but were distinct in other properties (i.e., low dominant frequencies and long pulse intervals). Egg feeding calls contained less identity information than advertisement calls but more than courtship calls. Finally, multivariate analysis revealed relatively high classification success for advertisement (82.9%) and courtship calls (73.5%) but misclassified nearly half of egg feeding calls as either advertisement (21.4%) or courtship calls (21.4%). Taken together, egg feeding calls appear intermediate between the two ancestral call types, and likely borrowed and recombined elements of both to solicit a context-dependent parenting response.

673 Angela Mossor, Andrew McKamy, Melody Young, Michael Granatosky, Michael Butcher, Jesse Young

Comparative three-dimensional limb kinematics during suspensory locomotion in tree sloths

Two-toed and three-toed sloths (i.e., Choloepus spp. and Bradypus spp., respectively) have notable differences in ecology and morphology. Specifically, three-toed sloths have significantly shorter hindlimbs relative to their forelimbs, while two-toed sloths have limbs of equal length, therefore, causing divergence in their adopted choice of substrate angle. Despite this, the two genera potentially show marked evolutionary convergence in limb biomechanical properties. Limb kinematics have been previously described for two-toed sloths (e.g., Choloepus didactylus), but similar data are unavailable for three-toed forms. To better understand locomotor kinematics among tree sloths, we obtained three-dimensional limb kinematic data in brown-throated three-toed sloths (Bradypus variegatus) to test the hypothesis that limb kinematics will not significantly differ between the two species. Individuals were recorded with multiple high-speed cameras while performing naturalistic below-branch suspensory locomotion on an instrumented beam. Preliminary data analysis of 3D limb joint angles show that, although preferred suspensory walking speeds are an order of magnitude slower in Bradypus, average elbow and knee angles during touch down, mid-contact, and lift-off phases of the stride do not differ between these species – in spite of dramatic differences in relative fore- and hindlimb lengths. Based on these initial data, we infer that two- and three-toed sloths will not differ in their use of basic limb kinematics, though ongoing analyses are needed to confirm and explain such a finding.

1091 Andrew Moura, Austin Garner, John McCormack, Carla Narvaez-Diaz, Alyssa Stark, Michael Russell

Stickin' through it: Hyposalinity reduces sea urchin tube foot performance

Precipitation lowers the salinity of coastal waters (hyposalinity events), negatively impacting marine organisms. Global climate change will increase the frequency, intensity, and duration of extreme hyposalinity events (e.g. storms). Sea urchins are dominant herbivores in coastal marine habitats and generally intolerant of salinity fluctuations (stenohaline). Their adhesive tube feet are critical for survival, providing secure attachment in turbulent, shallow, open-coast habitats. However, the impact of hyposalinity on sea urchin tube foot performance, and potential for acclimation to hyposalinity, is unknown. We assessed the effect of repeated hyposalinity exposure on tube foot performance in the green sea urchin, Strongylocentrotus droebachiensis, a species known for some hyposalinity tolerance. Tube foot tenacity (adhesive force per unit area) was unaffected by exposure to 22‰ (ppt) salinity relative to undiluted 32‰ salinity, but significantly decreased in sea urchins exposed to 16‰ salinity. Tube foot breaking force decreased in both hyposalinity treatments. There was no evidence of acclimation after four exposures to hyposalinity. Our results suggest hyposalinity will increase the likelihood of sea urchin dislodgment, either by breakage of tube feet under moderate hyposalinity or by a significant reduction of tenacity under extreme hyposalinity.

938 Bushra Moussaoui, Tim Wright

Effects of aging on adult vocal learning and underlying neural expression

Most vocal learning species exhibit an early critical period during which their vocal control neural circuity can facilitate the acquisition of new vocalizations. Some taxa, most notably humans and parrots, retain this neurobehavioral plasticity throughout adulthood. Downregulation of the transcription factor FoxP2 in both songbird and parrot vocal control nuclei has been identified as a key expression pattern facilitating vocal plasticity. We hypothesize that open-ended vocal learning exhibits senescence, as is typical of complex cognitive traits, and that this deterioration will be reflected in age-related changes in FoxP2 expression. We tested this hypothesis in the budgerigar (Melopsittacus undulatus), a small gregarious parrot in which adults converge on shared call types in response to shifts in group membership. We formed novel flocks of 4 previously unfamiliar males belonging to the same age class, either "young adult" (6 mo-1 yr) or "old adult" ($\geq$ 3 yr), and then collected audio-recordings over a 20-day learning period to measure acoustic overlap between flockmates and individual vocal plasticity over time. Following behavioral recording, whole brains were extracted and immunohistochemistry was performed to measure FoxP2 protein expression in a parrot vocal learning center, magnocellular nucleus of the medial striatum (MMSt), and its adjacent striatum. Preliminary results suggest old adults show higher FoxP2 ratios compared to young adults. Whether this difference leads to diminished vocal learning in older birds is less apparent.

596 Kyle Moxley, Christian Cox, Albert Chung, Myles Davoll, Steph DeHart, Samuel Gerardi, Tony Ly, Preston Nipper, Delaney Novak, Phillip Reeves, Becky Williams, Michael Logan

Determinants of regional heterothermy in a diminutive snake

Temperature is important for physiological rates, and some organisms maintain different temperatures in various body regions (e.g., regional heterothermy) to prioritize or maximize function. However, this regional heterothermy is poorly understood outside of endotherms, and understanding regional heterogeneity in temperature is crucial for understanding how ectotherms regulate body temperature. In particular, little is known about whether small-bodied and elongate organisms maintain different temperatures among body regions. We used a small-bodied ectotherm, the ring-necked snake (Diadophis punctatus), to study regional heterothermy. We tested for the presence of thermal heterogeneity in both field and laboratory settings to investigate links between heterothermy, existing temperature variation in the environment, and the life history and behavioral characteristics of the snakes that might influence the temperatures of different body regions. We found that ring-necked snakes exhibited regional heterothermy that was not clearly linked to temperature variation in the surrounding environment in field or laboratory settings. Furthermore, thermal heterogeneity was maintained even in relatively constant laboratory environments. These results show that even small-bodied ectotherms with high surface area to volume ratios can maintain regional temperature variation that is not linked to environmental variation, consistent with non-behavioral mechanisms to maintain regional heterothermy.

808 Morgan Muell, Kendall Jackson, Ansley Strength, Matt Harrington, Christian Cox, Daniel Warner

Geographic variation in thermal developmental plasticity in the green anole (Anolis carolinensis)

Thermal developmental plasticity occurs when organismal phenotypes change in response to early life temperatures. In lizards, thermal conditions at the embryonic stage affect many fitness-related phenotypes, such as hatchling size and performance. Developmental plasticity in response to temperature is thought to arise in thermally heterogeneous environments. Therefore, populations evolving in environments with high thermal heterogeneity should exhibit larger plastic responses to developmental temperature than those inhabiting environments with low thermal heterogeneity. We examined patterns of developmental plasticity for thermal traits at embryonic and juvenile stages in green anoles (Anolis carolinensis), which make a fitting model system because they have recently evolved from a tropical origin to occupy thermally variable habitats. We bred adults from 5 populations spanning their latitudinal range in the United States, which are representative of climatic variation and genetic subgroups. We incubated eggs under 3 temperature treatments, with fluctuating sine waves to mimic natural conditions. For embryos, we predicted that southern populations would exhibit higher plasticity in heat tolerance because they are more likely to experience lethal temperatures during incubation. For hatchlings, we predicted that northern populations would exhibit greater plasticity in cold tolerance, while there will be no plasticity in heat tolerance in any population. Our study provides insight into the evolution of thermal developmental plasticity across landscapes, and helps predict how these ectotherms may respond to changes in regional temperatures.

1342 Karen Mueller, Yuichiro Suzuki

The role of TGF-β/BMP signaling in development and metabolism in flour beetles

The Transforming growth factor-beta (TGF-β)/bone morphogenetic protein (BMP) signaling pathway has emerged as a major regulator of developmental physiology and lipid homeostasis in insects. In this study, we explored how the BMP and Activin branches of the TGF-β superfamily affect development and lipid homeostasis in the fat body. By knocking down the expression of Mothers against decapentaplegic (Mad) in the flour beetle Tribolium castaneum, we found that Mad mediates the effects of Glass bottom boat (Gbb) and Decapentaplegic (Dpp) in fat metabolism. In contrast, knockdown of Smad on X (Smox) leads to delayed molting. Currently, we are exploring how Activin signaling interacts with the BMP signaling pathway to impact development and metabolism.

97 Chinmayee Mukunda, Sanjay Sane

Position and velocity encoding by Johnston's organs in the hawkmoth, Daphnis nerii

In insects, the antennal mechanosensory Johnston's organs (JO) are crucial for transducing a variety of mechanical stimuli. These include low-frequency stimuli due to gravity and airflow, as well as high-frequency stimuli due to touch, sound and self-generated antennal vibrations signalling aerial turns. JOs are comprised of circumferentially-arranged sensory units called scolopidia, spanning the pedicel-flagellum joint of the antennae. Previous studies have shown that mechanosensory transduction by JO is both extremely fast and highly precise, and hence studying their encoding properties is key to understanding their functional versatility. We performed intracellular recordings from the axons of individual scolopidial units of the JO in Oleander hawkmoth Daphnis nerii. Using a precise servo-motor system, we delivered mechanical step, sinusoidal, chirp and white-noise stimuli to the antennal flagellum relative to the pedicel, and recorded the resulting action potentials in order to test the hypothesis that JO units encode position and velocity of the flagellum relative to the pedicel. Our data show that some neurons preferentially encode stimulus velocity over position with a phasic firing activity, whereas others fire phaso-tonically to encode both velocity and position. These responses are also directionally selective. In agreement with previous measurements, we also find narrow frequency selectivity in individual scolopidial units. Together, these data help address how JO can a wide variety of sensory stimuli by encoding position and velocity.

1592 Ulrike Muller, Rory Telemeco, Alexandria Hansen, Manuel Gonzalez, Fatima Awad

A conference proceedings journal shows changes in the publication process since the start of COVID19

The coronavirus pandemic continues to expose and exacerbate inequality in academia. In this study, we examine trends evident in a proceedings journal. By publishing articles from invited symposium speakers, proceedings journals may be less inclusive than journals publishing contributed papers, first due to bias during the speaker invitation process, and second due to longer lead time, which increases the probability of authors withdrawing in time long time between the invitation to speak and the publication of the invited article, a process that takes almost two years in the case of this journal. We gathered information from conference abstracts and journal articles to test the hypotheses that authors will be negatively impacted by the pandemic, and that authors with a higher probability of substantial caregiver or teaching responsibilities will be more negatively affected. We found that between 2019 and 2022, the number of authors who were unable to submit a manuscript steadily increased, and manuscripts took longer to complete the publication process. Authors from teaching-intensive institutions were more gravely affected. Counter measures, such as extending invitations to submit a manuscript to presenters of a contributed conference presentation that compliments a symposium, might be able to blunt negative impacts. We will continue to collect data to document how the publication process is changing, so that journals can take effective counter measures.

1113 Tasha Mulvena, Manyu Amarasinghe, Amaya DeVore, Isaac Tamez, Steve Morales, Ulrike Muller

Decolonizing a vertebrate collection housed at a minority-serving university

Biological collections have a foundational role in academia and conservation efforts. They also illustrate global inequalities in biological academia. Inequities become apparent in species nomenclature and collection metadata such as collector names. This study expands prior scholarly work relating to scientific inequity by applying analyses developed in these studies to the collections in the Fresno State Biology Department. We found that the majority of the species in our collection are native to California and all 340 species were named by White males. A significant fraction (>10%) of those species are named after a person, compared with less than 5 percent in European mammal species, which are mainly named after geographic locations of morphological characteristics. All but one of those species names (46 of the 47) were honoring White males. Furthermore, female collectors are underrepresented. For the mammal collection, the top 10 collectors who contributed the most specimens are all male, for the bird collection 9 of out 10 are male. The species names of the mammal and bird specimens in the Fresno State Vertebrate Collection reflect colonial ancestry and are consistent practices of the 19th and 20th centuries. Our findings are consistent with previous studies, which found similar dominance of white males who are being honored in the naming of species, who are describing species, and who are collecting specimens.

45 Kathleen Munley, David Sinkiewicz, Sydney Szwed, Gregory Demas

Seasonal variation in neural steroid sensitivity and territorial aggression in Siberian hamsters

Many species display marked changes in physiology and behavior on a seasonal timescale, including non-reproductive social behaviors (e.g., aggression). Previous studies from our lab suggest that melatonin acts via steroid hormones to regulate seasonal aggression in Siberian hamsters (Phodupus sungorus), a species in which both males and females display increased aggression during the non-breeding season. The neural actions of melatonin on steroids and aggressive behavior, however, are relatively understudied. Here, we investigated how melatonin influences neural sensitivity to sex steroids and aggression in male and female hamsters. Hamsters were housed in long-day photoperiods (LDs, characteristic of breeding season) or short-day photoperiods (SDs, characteristic of non-breeding season) and given timed melatonin (M) or control injections. Following 10 weeks of treatment, aggressive behavior was quantified and the relative mRNA expression of steroidogenic enzymes (5α-reductase, aromatase) and estrogen receptor α was measured in four brain regions associated with aggression or reproduction (the medial preoptic area, anterior hypothalamus, arcuate nucleus, and periaqueductal gray) via quantitative PCR. We expect that LD-M and SD hamsters will show higher levels of aggression than LD hamsters, regardless of sex. Conversely, we predict that males and females will exhibit seasonal differences in the expression of steroid-related genes in brain regions associated with aggression, but not reproduction. Collectively, these results will enhance our understanding of how melatonin modulates aggressive behavior in seasonally breeding animals.

963 Catriona Munro, Maciej Manko

Siphonophore genomics, larval development and evolution

Siphonophores are colonial hydrozoans, consisting of asexually budded zooids that are functionally specialized to particular tasks. Siphonophores are delicate, planktonic organisms, and recent studies have focused predominately on genomic aspects of asexual colonial development and budding, rather than on early embryonic and larval forms. Recent culturing advances have opened the possibility to investigate larval development, including the establishment of the first zooid, generating a bilaterally symmetric hydrozoan planula. Here, we discuss siphonophore genomics and larval development across several major clades, and present new immunohistochemical data. We also discuss siphonophore development within the broader context of cnidarian development, including development of the hydrozoan Clytia hemisphaerica.

1590 Victor Munteanu, Richard Blob, Georgia Moore

Keep Holding On: Effect of Perturbation Intensity in Veiled Chameleons (Chamaeleo calyptratus)

Animals must often deal with environmental perturbations that threaten the stability of their locomotion or posture. To avoid potentially fatal falls, arboreal animals might be expected to experience strong selective pressures to maintain purchase on perches and sustain stability over a wide range of perturbation intensities. To evaluate the behavioral and morphological specializations associated with arboreality, we subjected veiled chameleons (Chamaeleo calyptratus, ∼100 g body weight) to a series of increasing intensity perturbations. Animals were perched on a custom-built apparatus that delivered a consistent and repeatable lateral perturbation. The intensity of the perturbation was modulated by employing different weights (500 g, 1 kg, 2 kg) that applied different magnitudes of pulling force. Preliminary results indicate that, despite some kinematic differences, chameleons are able to contend with perturbation intensities with pull forces substantially higher than their body weight. Stability and purchase were further enhanced by wrapping of the prehensile tail around the perch. This suggests that anatomical specializations of chameleons may enable both climbing behaviors that are used on a regular basis and a high capacity to withstand disturbance of their arboreal perches. Supported by Clemson Creative Inquiry (Project #479).

150 Kaitlyn Murphy, Samantha Le, Alan Wilson, Daniel Warner

The microbiome as a maternal effect: A meta-analysis on vertical transmission of microbiota

Most surfaces are colonized by microorganisms that form interactive and fluctuating communities, commonly referred to as the 'microbiome.' Maternal transfer of microbiota to offspring is documented in many taxa, but how life-history traits govern vertical transmission is largely unexplored. The aim of this study was to address the following questions: (1) Is there overlap in microbial community composition and structure between maternal and offspring hosts? (2) What is the effect (if any) of the maternally derived microbiota on the colonization and development of the microbiome in offspring? (3) Do life-history traits (e.g., reproductive mode) influence vertical transmission of microbiota? We used a meta-analytic approach to address these broad and important questions. From the published literature, we extracted Shannon's diversity index values and operational taxonomic unit (OTU) relative abundances from both maternal and offspring hosts. While numerous studies of mammals demonstrate maternal transfer of microbiota to offspring, our preliminary results across a broader range of taxa provide no evidence of a correlation between maternal and offspring Shannon's diversity values. However, offspring tended to have lower values indicating less rich and even microbiomes compared to their mothers. Findings from this study will provide new insight into the prevalence and functional significance of maternal transmission of microbes to offspring in vertebrate animals.

717 Connor Murray

Evolutionary genomics of a complicated crustacean complex

The study of large-scale population genomic datasets has helped reveal how natural selection and demographic history affect the genome across related species. Despite much progress, many species belong to complicated groups to resolve, and efforts to understand the extent of genetic diversity haven't been extensively studied. Here, we investigate the evolutionary genomics of the Daphnia pulex species complex, a group of freshwater crustaceans found throughout the Holarctic. Despite the extensive use of D. pulex in evolutionary biology, there is a fundamental knowledge gap in the timing and extent of divergence across species. Moreover, there has been debate regarding the current species classification across continental D. pulex populations. To address these problems, we have assembled a genomic panel of over 1,100 North American and European clonal lines from the D. pulex species complex. Our results reveal extensive divergence across the genome of continental D. pulex taxa with no evidence for past or present introgression. Additionally, we show that thousands of common trans-specific polymorphisms exist, highlighting the potential for balancing selection to maintain adaptive alleles in genes involved in innate immunity and signaling. This work covers over 30 million years of evolution and reveals the putatively adaptive genes under balancing selection within a difficult-to-resolve species complex.

1667 Annabelle Murray, Thomas Fogle

The effects of Ergosterol on the uptake of Lead in Tetrahymena pyriformis

Lead is a well known heavy metal, having chemical qualities that make it harmful to biological systems. However, its short-term effects are difficult to measure in organisms. Tetrahymena pyriformis is a unicellular model organism that can be used to study the cellular effects of lead. Ergosterol is a fungal cholesterol that alters cell membrane permeability by replacing organismal sterols. Therefore, this molecule may help to better observe the toxicity of lead in Tetrahymena by allowing it to enter the cell more effectively. To evaluate the effects that ergosterol has on lead absorption, a culture of Tetrahymena in log phase was prepared and treated with determined concentrations of lead acetate and ergosterol in solution. Effects were documented after 24, 48, 72, and 96 hour exposures. Living cells were observed to determine physiological changes, and treated with IKI solution to count phagosomes. At 24 and 48 hour exposures, cells treated with both ergosterol and lead had significantly lower phagosome counts than cells treated with lead alone. Microscopic examination of cells revealed membrane and cytological abnormalities. These results suggest that ergosterol is altering the cell membrane structure in shorter time exposures, but is stabilized in longer time intervals. This investigation utilizes ergosterol and lead in Tetrahymena for the first time, as well as introduces ergosterol as a way to better observe the short-term intracellular effects of lead.

988 Mohammed Murtuza, Ethan Lumongsud, Sreevalli Kolli, Christine Prater, James Carr, Breanna Harris

Role of Tectal CRF Administration on Multisensory and Discrete Feeding Behavior

Survival of prey animals depends on balancing feeding and fleeing behavior. To determine this behavior, prey animals rely on multisensory stimuli including visual and lateral line cues, which, in Xenopus laevis, are processed in a brain region called the optic tectum (OT). Although the mechanisms maintaining this balance are not fully understood, research suggests corticotropin releasing factor (CRF) in the optic tectum plays a role in inhibiting feeding behavior in X. laevis. In this study, we investigate whether the injection of CRF into the OT of juvenile X. laevis alters the response to discrete visual or lateral line cues, and to multisensory live prey stimuli. Frogs were assigned to a treatment group (n = 15-18): one of 4 doses of CRF, saline, or left unmanipulated, and a stimulus condition (lateral line or visual). One hour after bilateral tectal injection, frogs were exposed to a visual (iPad worm movie) or lateral line (air puff) stimulus, immediately followed by delivery of a multisensory, live prey stimulus (worm or cricket, respectively); feeding-related behaviors were recorded. Behavioral trials were repeated 72 h later. CRF subtly decreases but does not abolish responses to live worm prey, but CRF does not decrease response to purely visual prey cues. Lateral line data collection is underway. Our data will aid in understanding the neuroendocrine mechanisms determining feeding/fleeing behavior. NSF Funded (Grant No.1656734).

221 Alexander Muth

The effect of habituation on neural activation in the habenula

The habenula is a bilateral brain structure located in the epithalamus of vertebrates. In humans, it has been implicated in mood disorders, motivational learning, anxiety, and addiction. In teleost fishes, the habenula is divided into a dorsal and ventral subregion. The dorsal habenula (dHb) can be further divided into the dorsal lateral habenula (dHbL) and the dorsal medial habenula (dHbM). Fish provide a useful model for investigating the impact of learning in response to fear inducing stimuli. Ablation studies in Danio rerio (zebrafish) have shown the dHbL to be essential for associative learning. Zebrafish with an inactivated dHbL have shown enhanced freezing in response to an aversive conditioned stimuli, and deficits in decision making and memory extinction in operant conditioning paradigms. However, the role of the dHb in nonassociative learning is unclear. In this study, we aim to demonstrate habituation to a fear-invoked startle response in Pelvicachromis pulcher (kribensis cichlid fish), and correlate that response to differential neural activation between the two subregions of the dHb using Phospho-S6 Ribosomal Protein (ps6) staining. Based on the finding that dHbL ablation leads to decreased motor response to an aversive stimulus, we hypothesize that the dHbM will show increased neural activation compared to a control group in response to the habituation procedure, while the dHbL will show greater neural activation in the control group.

1171 Felicity Muth, Claire Hemingway

Reward perception and decision making in bumblebees

When making decisions, animals often compare available options to those that were recently encountered.

Such decisions can be complex, requiring individuals to compare multiple features of each option and their payoffs. Bumblebees are a useful system to address this topic, given that they forage on a wide variety of flowers, and in doing so rapidly integrate information about floral stimuli and rewards to make decisions between flowers. We will present recent work showing how reward perception in bumblebees is affected not only by recent experience with rewards, but also experience with associated stimuli. We will also discuss ongoing work focused on how bees evaluate multiple dimensions of reward quality and how these multi-attribute choices can bias decision making. Our findings shed insight on general processes of reward perception and decision-making in animals.

703 Veronica Muzio-Crego, Yash Sondhi, Elina Barredo, Nicolas Jo, Erickson Francisco, Jamie Theobald

Changes in circadian rhythm activity of moths subjected to simulated light pollution

Continuous exposure to artificial light at night can severely impact natural behaviors. This is especially true for nocturnal species that rely on natural illumination from the moon and night sky to coordinate their movement. Using nocturnal wax moths (Galleria mellonella), we examined the effect of different kinds of light pollution on baseline circadian rhythm. An open-source system, the portable locomotion activity monitor (pLAM) records circadian activity while a controllable light chamber generated different lighting regimes. Moths showed consistent nocturnal activity when exposed to a gradual day-night cycle. This pattern was maintained when exposed to the low intensity of continuous light at night (1% daylight intensity). But increasing the intensity (5%) disrupted activity, and subsequently induced activity during both day and night. In some trials moths dramatically decreased activity but maintained nocturnal activity. Such strong disruptions from even weak artificial light highlights the need to mitigate the effects of artificial nocturnal lighting.

1380 Noah Nadeau

Context Dependant Strike Modulation in Pistol Shrimp

Pistol shrimp have one of the fastest, loudest, and deadliest strikes in the ocean. The rapid snap of their modified claw generates a water jet and cavitation bubble that is used to ward off predators, subdue prey, and settle disputes. It has been suggested that pistol shrimp can control the amount of volume they let into the socket of their snapping claw, thereby affecting the velocity and force of their strikes. The goal of this study is to determine whether pistol shrimp modulate the force and velocity of their water jet strikes in different contexts. Pistol shrimp were presented with a series of stimuli in random order: a predator (shore crab), prey (red rock shrimp), conspecific, and control (paintbrush). Snaps were recorded with a high speed video camera (20,000 fps) and hydrophone. Water jet dimensions and velocity were calculated from video and sound level (db) calculated from sound recordings. Data is currently being collected and analyzed, but I hypothesize that there will be differences in strike force and velocity, with the greatest being exhibited during predator deterrence. Preliminary observations demonstrate the possibility of variability within an individual shrimp under a controlled stimulus. This research will give us deeper insights into the biomechanics of the pistol shrimp strike as well as a better ecological understanding of how they use this potent weapon.

1635 Nadje Najar, Alan Brelsford, Christopher Clark, Brian Myers, David Rankin

Admixture mapping reveals genomic underpinnings of behavioral courtship displays in hummingbirds

How do different courtship behaviors evolve? Identifying the genetic underpinnings of sexual displays is often confounded by sexual selection, which tends to reduce genetic variation in the trait. This limitation can be overcome by comparing admixed with non-admixed individuals in hybridizing species. Rufous and Allen's hummingbirds have courtship behaviors consisting of stereotyped high-speed dive and shuttle displays, and regularly hybridize where their ranges meet in northern California and southern Oregon. Hybrid courtship displays are highly variable compared with parental displays. We recorded 10 courtship displays from each of 377 adult male hummingbirds from two transects spanning the hybrid zone. Each male's courtship displays were decomposed into 14 elements. We categorized each display element based on whether the hybrid phenotypes fall within (non-transgressive) or exceed the parental phenotype range (transgressive). We used whole genomes and an admixture model that accounts for population structure to map each element of the display to the genome. Courtship display elements overwhelmingly map to a small 6 mbp region of the Z chromosome, despite relative homogenization of the autosome. Unlike the rest of the Z, recombination in this region is not homogeneous, with some combinations more favored than others. Overall, the stereotyped, species-typical display behavior of Rufous and Allen's hummingbirds are associated with relatively small genomic differences.

1787 Toshiyuki Nakata, Patricio Simoes, Simon Walker, Ian Russell, Richard Bomphrey

Auditory sensory range in mosquitoes: whence can males hear female flight tones?

Male mosquitoes detect and localise conspecific females by their flight tones using the Johnston's organs (JO), which detect antennal deflection under the influence of local particle motion. Acoustic behaviours of mosquitoes and their JO physiology have been investigated extensively within the frequency domain, yet the auditory sensory range and the behaviour of males at the initiation of phonotactic flights are not well known. In this study, we predict a maximum spatial sensory envelope for flying Culex quinquefasciatus by integrating the physiological tuning response of the male JO with female aeroacoustic signatures derived from numerical simulations. Our sensory envelope predictions were tested with a behavioural assay of free-flying male mosquitoes responding to a female-like artificial pure tone. The minimum detectable particle velocity observed during flight tests was in good agreement with our theoretical prediction formed by the peak JO sensitivity measured in previous studies. The iso-surface describing the minimal detectable particle velocity represents the quantitative auditory sensory range of males and is directional with respect to the female body orientation. Our results illuminate the intricacy of the mating behaviour and point to the importance of observing the body orientation of flying mosquitoes to understand fully the sensory ecology of conspecific communication.

48 Gabrielle Names, Lindsey Chiesl, Victoria Roper, Anuj Ghimire, Heather Mathewson, Jennifer Grindstaff, Britt Heidinger

Variation in house sparrow growth and aging across a latitudinal gradient

Climate change is affecting the behavior, physiology, and morphology of wildlife worldwide. According to Bergmann's Rule, warmer environments favor individuals with a smaller body size because they are more successful at dissipating heat, while larger individuals are favored in cooler environments because they are better at retaining heat. This pattern has been described in diverse taxa, but the related mechanisms and physiological consequences remain poorly understood. In the USA, adult house sparrows (Passer domesticus) are larger at higher latitudes and smaller at lower latitudes. We hypothesized that variation in temperature across latitude has selected upon adult body size via nestling growth rate. We predicted that nestlings in cooler habitats would develop more quickly and be larger at fledging compared to nestlings in warmer environments. Due to trade-offs between growth and longevity, we also predicted that nestlings in cooler environments would experience greater physiological aging compared to those in warmer environments. To test our hypothesis, we collected morphological measurements from house sparrow nestlings across a latitudinal gradient in the central USA extending from North Dakota to Texas during the breeding period (April-August) in 2022. Measurements were collected on days 2, 4, 6, 8, and 10 post-hatching to determine growth rate and size pre-fledging. To examine physiological aging, we collected blood samples from nestlings on day 10 post-hatching to measure telomere length, a cellular metric of aging.

212 Lydia Naughton, Laura Bagge, Sönke Johnsen, Lorian Schweikert

Evidence for a putative photoreceptor cell in the skin of hogfish

Color-changing animals exhibit dermal photoreception, which is the skin's intrinsic sensitivity to light. Previous work has shown that pigment in specialized cells, called chromatophores, can disperse and aggregate directly in response to light when the skin is excised from the body. Additionally, the skin possesses light-sensitive opsin proteins, but the opsin is typically localized to the chromatophores or cells of previously identified function. While examining the dermal photoreceptive system in the hogfish (Lachnolaimus maximus), which is a reef fish that is capable of rapid color change, we demonstrated that the skin contains a single visual opsin known as SWS1, a short-wavelength-light-sensitive protein. Using a combination of fluorescence and electron microscopy techniques, we found that SWS1 protein expression appears beneath chromatophores. There also appears to be a population of cells beneath the chromatophores that exhibit a high degree of membranous structures, resembling the morphology of retinal photoreceptors. We hypothesize that the SWS1 opsin is localized to this population of membranous cells underneath the chromatophores. This would suggest that peripherally-controlled color change may be supported by discrete, specialized photoreceptor cells in the skin previously unseen in other color-changing animal systems. We propose that these putative photoreceptor cells may serve to detect differential light transmission through dispersed and aggregated chromatophores. This could then provide information about the skin's color appearance for sensory feedback to modulate color-change performance.

1614 Lauren Neel, Jacob Youngblood, Dylan Padilla, Zackary Graham, Michael Sears, Michael Angilletta

Thermal landscapes shape life history variation along an altitudinal gradient

The thermal environment shapes an organism's fitness through its effects on thermoregulatory behavior and physiological performance. In environments with high thermal opportunity, ectotherms can be active for longer than ectotherms in environments with low thermal opportunity. However, previous analyses have ignored how the spatial distribution of the thermal environment impacts the costs of thermoregulation. Yarrow's spiny lizards (S. jarrovi) occupy diverse habitat types along a 1500-meter altitudinal gradient in the Sky Islands of southeastern Arizona. We studied five populations along this gradient in multiple mountain ranges. For each population, we used a drone to collect remotely sensed aerial images, enabling us to construct spatially explicit thermal landscapes. In the lab, we collected morphological and physiological data (i.e., thermal preference, thermal tolerance, and metabolic rate) to parameterize a model predicting body temperatures and energetics of lizards. We hypothesized that in environments with high thermal opportunity and low costs of thermoregulation, lizards would have relatively increased energy budgets and fecundity. To better predict how species will fare under future warming scenarios, we need to be able to accurately link environments, and subsequent life history and performance variation under current conditions in nature.

1621 Frederick Nelson, Thomas Hahn

Causes and consequences of Life History Stage overlap: Insights from migratory songbirds

The concept of life-history stages (LHSs) refers to a set of correlated morphological, physiological, and behavioral traits related to a specific process, typically around a particular time of year. LHS present a ubiquitous ability of animals to expand their geographic range and optimize their fitness across different habitats, and/or across temporally changing conditions (e.g., seasonally). One of the main drivers of the evolution of distinct, non-overlapping LHSs is thought to be as a mechanism for avoiding simultaneous expression of multiple highly demanding processes, and related nutritional, energetic, and time conflicts that would lead to reduced fitness. Because transitions between these stages cannot occur instantly, some level of overlap between adjacent stages is inevitable as one stage goes through termination and the next goes through preparation. However, there also is substantial inter-individual and interspecies variation in the extent to which LHSs overlap. As part of my study of LHS coordination in migratory white-crowned sparrows (Zonotrichia leucophrys oriantha and Z. l. gambelii), I present a conceptual framework for understanding both the causes and consequences of LHS overlap, as well as the implications for individuals' and species' responses to timing challenges presented by climate change. I emphasize transitions between reproduction, plumage molt, and preparation for migration in these two long-distance migratory subspecies, and whether individuals overlap stages because they can or because they must.

170 Nandan Nerurkar

Organ-scale buckling morphogenesis of the small intestine from cell-generated forces

Buckling - the tendency of a material to curve under applied compression - has emerged as a core mechanism of morphogenesis, shaping tissues as diverse as the folds of the cerebral cortex and branches of the lung. However, a view of morphogenesis that incoporates the mechanics of buckling with the underlying molecular cues and corresponding cell behaviors is lacking in most contexts. Buckling of the small intestine during embryonic develepent creates compact and highly stereotyped loops that permit proper placement of the lengthy intestinal tube within the body cavity. These loops arise through compressive forces generated by elongation of the intestinal tube against the constraint of its attached mesentery. Here, we will present our recent efforts to understand the biological basis of buckling in the small intestine of the developing chick embryo, tracing organ-scale looping morphogenesis to the molecular control of cell behaviors responsible for differential growht and tissue stiffness in this context.

1093 Dante Nesta, Cristina Ledón-Rettig

Ancestral plasticity in behavior and gene expression precedes the evolution of a larval polyphenism

Genetic accommodation – the process by which the regulation of an ancestrally plastic trait evolves, sometimes resulting in evolutionary novelty – has received wide support for a variety of morphologies. However, although behavior is often assumed to play a critical role in genetic accommodation, less is known about the evolution of novel behaviors, themselves. Here, we focus on the evolution of a novel anuran behavior: larval cannibalism. Members of the genus Spea possess polyphenic larvae that, in response to population density and a shrimp diet, develop as an aggressive carnivore morph that specializes on live macroscopic prey, including other larvae. An important step in understanding whether the evolution of this behavior occurred via genetic accommodation is demonstrating the presence of heritable variation for behavioral plasticity in an "ancestral proxy species". Using behavioral and RNASeq approaches, we ask whether there is heritable variation in cannibalistic behavior and brain gene expression in Scaphiopus holbrookii, a closely related species that does not exhibit polyphenism. Our data demonstrate that S. holbrookii larvae are capable of aggression and cannibalism, despite lacking the polyphenism present in Spea species. Further analyses will reveal whether this ancestral proxy possesses genetic variation at the level of brain gene expression, and which expression patterns are shared with the derived carnivore morph in Spea. Together, our data will evaluate whether behaviors, themselves, can evolve via genetic accommodation.

1435 Kevin Neumann, Alison Bell

Social behavior varies across populations, but not ecological contexts, in stickleback fish

Collective behavior can have significant consequences for ecological and evolutionary dynamics across a wide variety of species. However, it remains an open question how collective behavior might differ across ecological contexts and/or across populations that differ in their environmental conditions. Here, I compared a suite of social and collective behaviors across populations of three-spined stickleback fish (Gasterosteus aculeatus) that occur in lakes that differ in a range of factors including depth, size, and prey communities. Specifically, I quantified collective movement, social network structure, and social roles (leadership) of groups of stickleback across eight populations. I found that there were population level differences in collective movement and social network structure. There were no differences in leadership structure across populations. Rather, all populations exhibited a similar trend whereby a few individuals did a majority of leading. I further measured the social and collective behavior for each of these groups after a predation event (model predator attack) and after a foraging event (bloodworms released into the center of the pool). Interestingly, I found that social behavior was fairly repeatable even after the predation and foraging treatments, suggesting that groups are quick to resume their previous social behavior after a disturbance. This work suggests that variation in stickleback social and collective behavior may be important for adaptation to different types of lake environments.

42 Julia Newcomb

Characterization of Biogenic Amine Receptors in the Y-Organ of G. lateralis and C. maenas

Ecdysis is the shedding of the exoskeleton, a vital process in crustaceans controlled through a complex signaling pathway. Molting is managed by two main organs: the Y-organ (YO) and X-organ/sinus gland complex (XO/SG). The YO is responsible for producing and secreting ecdysteroid molting hormones, which travel peripherally to tissues to ready them for molting. The production of these ecdysteroid hormones in the YO is negatively regulated by molt-inhibiting hormone (MIH) produced and secreted by the XO/SG. Stimulation of ecdysteroid synthesis in the YO can be induced by a number of ligands. Biogenic amine receptors have been identified in the YO transcriptome. Downstream pathways of serotonin (5-HT) have been linked to the protein kinase C (PKC) pathway leading to ecdysteroidogenesis. Six putative biogenic amine receptors have been identified in the YO of the black-backed land crab (Gecarcinus lateralis): 3 serotonin, 2 dopamine, and 1 octopamine. This study aims to characterize the expression of biogenic amine receptors in the G. lateralis and Carcinus maenas YO, and quantify the effects of serotonin, dopamine and octopamine on ecdysteroid synthesis and secretion. Funding is provided by NSF (IOS-1922701).

1622 Ramses Ngachoko, Florence Li, Adam Hardy, Melina Hale

Sensation by free pectoral fin rays of the hawkfish and its role in benthic station holding.

Examination of limb function most often focuses on the limbs' movement; however, standing, perching, and otherwise maintaining posture without movement are also critical roles of the limbs. We investigated the role of proprioception in the function of free pectoral fin rays of dwarf hawkfish (Cirrhiticthys falco), a benthic marine reef fish adept at maintaining stable posture on surfaces, often in flow. To examine the mechanosensory signals that hawkfish receive from their fin rays, we applied ramp-and-hold bend stimulation to individual fin rays while recording from sensory nerves innervating free fin rays. Rapid burst firing of mechanosensory afferents occurs during the ramp on and off periods, while the fin is being bent. Tonic firing of some afferents was observed during the hold period; this activity is different from that previously reported in membrane-connected fin rays used in swimming of other species. To investigate potential roles of sensation in these free fin rays we recorded the ability of hawkfish to maintain position in flow. We compared performance before and after bilateral transection of sensory nerves innervating the free fin rays. Hawkfish with intact nerves are expert at maintaining position even at high flows. Hawkfish with transected nerves could station hold as well, but with more difficulty at high flow rates. These experiments indicate similarities in mechanosensory physiology and function among very different vertebrate taxa and environments.

268 Mercille Nguyen, Catherine McGrath, Caitlin McNamara, Alex Huynh

The effect of host plant species and herbivore-induced plant volatiles on recruiting avian predators

Herbivore-induced plant volatiles (HIPVs) are important signaling compounds released by plants upon wounding. These compounds have been shown to mediate tritrophic interactions in recruiting insect predators and parasitoids. Recent work has begun to show that avian species, which were once thought to have a very limited sense of smell, can cue in on these HIPVs to find insect prey. Here, we test the ability for two general HIPVs, methyl jasmonate and methyl salicylate, to recruit avian predators. We test the recruitment efficacies of these HIPVs across four different host plant species, black walnut (Juglans nigra), red maple (Acer rubum), cattail (Typha latifolia), and wheat (Triticum aestivum), and use clay caterpillars to quantify predation by insectivorous birds. We found no significant differences in predation between treatment groups across any of our host plants. However, there was a nearly significant effect of methyl salicylate in black-walnut trees. Interestingly, our results did show a significant effect of host plant species on predation levels. The two tree species, particularly black walnut, had higher levels of predation than the herbaceous species. We discuss the implications of these results and suggest a number of ideas and suggestions for future studies investigating the role of HIPVs in attracting insectivorous birds.

526 Allyn Nguyen, Natalie Holt

No speed-endurance tradeoff during the "Love Bite" of southern alligator lizards (E. multicarinata).

Some documented instances of the courtship behavior of the southern alligator lizard (Elgaria multicarinata) courtship behavior involves the male grasping the female's head in its jaws for over 48 hours. Previous findings show that a substantial sustained force gradually develops during the fatigue test and persists after max tetanic forces have declined considerably. Molecular analyses revealed that the jaw muscles contain both superfast/masticatory and tonic myosin isoforms. Sustained force may be a characteristic of tonic fibers that allow for the southern alligator lizard (E. multicarinata) to, seemingly, exhibit no speed-endurance tradeoff. Current work involves in situ measurements by stimulating the nerve that's deep to the jaw-adductor complex. We are measuring isometric tetani and twitch, isotonic contractions in order to characterize force-velocity curve of the jaw-adductor complex. Some preliminary twitch data shows the average time to peak twitch force is 0.059 ± 0.008 s (male; $n = 2$) and half relaxation time is 0.062 ± 0.01 s (male; $n = 2$). Vmax for the jaw-adductor muscle measurement is 39.54 ± 4.05 mm/s (male; $n = 2$).

1409 John Nguyen

Diversity and distribution of reed frogs (Hyperolius spp.) on Bioko Island, Equatorial Guine

Reed frogs (Hyperolius spp.) are the most species-rich genus in the Hyperoliidae family, a group of frogs endemic to Africa. However, their diversity and distribution on Bioko—a land bridge island in the Gulf of Guinea archipelago—remain unclear. Two species, H. tuberculatus and H. ocellatus ocellatus, were formally documented on Bioko in the colonial era; however, two additional reed frog species have been detected in recent surveys. In addition, observations of heterospecific amplexus suggest one of the unidentified species and H. o. ocellatus may be hybridizing on the island. In this study, we examined mitochondrial DNA (mtDNA), nuclear DNA (nuDNA), morphological, and acoustic data to confirm the tentative identifications of the reed frogs and determine if there is any evidence of hybridization. Our data confirm that the two unidentified species are H. endjami and H. fusciventris, and that Bioko H. endjami have unique genetic diversity not shared with the mainland population. Additionally, our mitochondrial (16s) and nuclear DNA (CMYC) haplotype networks suggest that H. o. ocellatus and H. endjami are not hybridizing on Bioko. We report color pattern variation in H. endjami and H. o. ocellatus that is unique from reference populations on the continent and describe male advertisement calls of Bioko H. endjami and H. o. ocellatus. Our study sets the stage for future studies of the ecology, evolution, and conservation of this island community.

1779 Alina Nguyen, Jhoselyn Pineda, Tyrone Hayes

Clasping Behavior in the Female African Clawed Frog (Xenopus laevis)

Androgens induce clasping behavior (amplexus) in male African clawed frogs (Xenopus laevis), but the hormonal control of female (receptive) behavior is less understood. To address this question, we paired females with males and examined androgen and estrogen levels in females. Amplexus was not observed in pairs unless females were injected with human choriogonadotropin (hCG). Six out of 44 females unexpectedly displayed reversed-sex roles and clasped males. Clasping females had lower testosterone (T) levels (9.67 ± 3.6 ng/mL) than clasping males (37.11 ± 5.4 ng/mL), non-clasping females (44.1 ± 11.4 ng/mL), and females clasped by other males (36.04 ± 7.7 ng/mL). Estradiol (E2) levels were mostly nondetectable in males, but clasping females had E2 levels (2.73 ± 1.5 ng/mL) that were three times lower than other females (9.78 ± 1.7 ng/mL and 9.18 ± 1.5 ng/mL). These data suggest that, while T induces clasping in males, E2 may inhibit clasping behavior in females. The females in the current study were offspring of animals collected from a site likely contaminated with endocrine disruptors, but the clasping by females was only observed in a single sibship, which suggests genetic influences. Clasping females may provide insights into the complex genetic, hormonal, and environmental interactions that underlie female mating behavior.

1639 Ella Nicklin, Gareth Fraser

A deep dive into elasmobranch denticle diversity and development

Sharks, skates and rays (elasmobranchs) house tooth-like denticles in their skin. These scales function as dermal armor whilst also reducing drag. Owing to this importance, denticle initiation and patterning has been studied independently in embryos of emerging elasmobranch models. However, few studies directly compare this developmental process across different lineages, which show a large variation in denticle morphology and patterning. Using pharmacological treatments that target known and hypothetical genetic networks involved in denticle formation and patterning, we have altered the shape, orientation, polarity and distribution of denticles within the embryonic skin of the Little Skate (Leucoraja erinacea) and the Small-spotted Catshark (Scyliorhinus canicula). Furthermore, we show that wounding and the subsequent healing process in the skin of elasmobranch embryos can greatly affect denticle morphology and patterning. Such morphological shifts include (i) new denticles appearing in regions that are normally "denticle-less", and (ii) routine shifts in size, shape and polarization of away from the standard pattern. This suggests that early patterning might be necessary for correct development during initiation, but lost in later ontogenetic stages. Additionally, this data support the notion that denticle formation is a highly conserved and tightly patterned developmental process that can be readily manipulated. Our findings not only broaden our understanding of how denticles develop, but also highlight the potential impact of skin wounding events (e.g. boat incidents and invasive tagging techniques) on these unique microstructures of elasmobranchs.

1601 Michele Nishiguchi, Brian Pipes

Your genes or mine? Regulation of competence and transformation in the Squid-Vibrio symbiosis

Symbiotic Vibrio fischeri are found in dense populations within a specialized light-emitting organ in Euprymna scolopes, undergoing a daily cycle of expulsion and re-growth of the remaining population. The selective pressure of this cycling can drive horizontal genetic exchange, which plays a role in bacterial adaptation and contributes to widespread heterogeneity in genome sequences and plasticity found in many bacterial species. Additionally, chitin induced natural competence and transformation has been instrumental in gene swapping, particularly in several Vibrio species. Therefore, we examined whether different inducing signals and cues (restricted nutrient availability, high cell density) regulated the induction of V. fischeri natural transformation during the nocturnal cycle within the light-organ. Chitin exposure did not induce natural transformation in V. fischeri, unless the regulatory components of the competence machinery are genetically manipulated for constitutive DNA uptake. Additionally, we show that natural transformation rates in V. fischeri grown in culture are highly variable and strain-dependent, even with the supplementation of chitin oligosaccharides and the presence of quorum-signaling inducers. This suggests that there are different response regulators depending on strain type and host location, as well as induction of transformation due to abiotic stressors (UV, pH). Ongoing research in other environmental and genetic factors controlling the regulation of V. fischeri natural competence will provide further insight in microbial adaptation to environmental cues for symbiosis.

295 Kiisa Nishikawa

What amphibians have taught us about the evolution and neuromuscular control of ballistic movements.

Ballistic movements occur too rapidly for adjustments that depend on sensory feedback. Therefore, anatomy, initial position and muscle mechanics play critical roles in coordinating and powering movement. Inspired by David Wake's extensive studies on the biomechanics and evolution of tongue projection in salamanders, my studies of ballistic tongue projection in frogs, initiated at Berkeley's MVZ, revealed surprising features of muscle function. Tongue projection in frogs is powered by a single pair of jaw depressor muscles. These muscles are never stretched actively, but contract at their rest length until a catch-mechanism is released. Upon release, the muscles shorten by more than 20% of their length in less than 20 ms at a force more than 10 times higher than expected based on the isotonic force-velocity relationship. After accounting for strain in the tendons, the muscles recoil elastically by more than 6 cross-bridge strokes in a time period less than one cross-bridge cycle. Rapid unloading experiments inspired by in vivo studies revealed that the elastic recoil required to reach equilibrium muscle length increased with muscle activation. This unexpected observation motivated development of the "winding filament" hypothesis, which suggests a mechanism for changing muscle equilibrium length via calcium-dependent binding of titin to actin. Accumulating evidence from single molecule studies and muscle mechanics experiments supports a role for titin as a tunable spring in active muscle.

1251 Daniel Nondorf, Matthew Hale, Christopher Robinson, Henry John-Alder, Christian Cox, Robert Cox

Evolutionary implications of sex, age, and tissue differences in fence lizard transcriptomes

Patterns of gene expression can differ dramatically with respect to sex, age, and tissue, but few studies have simultaneously characterized these various sources of expression bias outside of traditional model species. Furthermore, previous work has shown that genes with sex-biased expression tend to evolve more rapidly, but few studies have tested for similar evolutionary implications with respect to age- and tissue-biased expression. We characterized the transcriptome of the Eastern Fence Lizard (Sceloporus undulatus) in each sex across three ages (neonate, pre-reproductive juvenile, adult) and three tissues (brain, liver, muscle). Our study reveals that sex-biased expression is largely restricted to adults and is most pronounced in the liver. Age-biased expression is greatest in the muscle, but pronounced in all tissues, and generally exceeds the magnitude of sex-biased expression. Finally, we developed a workflow to identify variable loci across the transcriptomes of 8 other phrynosomatid species. We are using these data to test the hypothesis that greater specificity of expression facilitates faster molecular evolution of coding sequences. We predict that genes with higher levels of sex-, age-, and tissue-specificity in their expression should exhibit higher rates of genetic divergence across species and fewer polymorphisms within species.

1098 Zachary Nopper, Kaelyn Gamel, Henry Astley

Detecting Hydrodynamic Wake Forces with an Underwater Force Plate

Swimming is primarily achieved by movements of the body or appendages, which impart momentum on the water. Swimming species vary widely in shape and properties of both body and fins, along with differences in swimming kinematics. These lead to differences in flows and consequent forces induced by the animal, which affects performance and ecology. Prior research into the consequences of these morphologies has used particle image velocimetry (PIV) to obtain 2D and, more recently, 3D flow fields, which can be used to infer or calculate forces. However, recent data from our lab shows that wake forces can be directly detected using a custom-built underwater force plate. Preliminary data from a skate (Beringraja bioculata) swimming close to the plate shows an average posterior wake force of 5.5 mN, with a max thrust force of 13 mN corresponding to the skate's fin motions. Further experiments explore the capability of the force plate to measure wake forces from a flapping foil, a swimming robot, and live animal subject. Preliminary data from a small flapping foil in still water show fore-aft forces of +- 1.8 mN, vertical force of 1mN. Although originally designed to collect underwater walking measurements, this force plate could provide a useful complement to other methods such as DPIV to understand the consequences of differing fin morphologies and body forms.

821 Andreas Nord

Thermal adaptation, energy metabolism and thermoregulation over a lifetime

Most organisms are amenable for developmental priming of physiological and morphological phenotypic expression during embryonic and perinatal life. Recently, there has been a spark of interest in how developmental temperature impacts animal form and function, necessitated by the realisation that our future will hold a warmer and more unpredictable climate. Previous work, mostly performed on birds, shows that higher or lower temperature during incubation or for the first period after hatching can influence both body plan and function of the thermoregulatory system in the short term, either predisposing the animal for life in a particular thermal environment or constraining normal development when conditions deviate too far from optimum. It is poorly understood whether any such effects remain over the lifetime of the individual and to which extent they are influenced by subsequent thermal plasticity. In this talk, I will explore these matters across the bird phylogeny to answer questions pertaining to costs, benefits, and constraints in the context of lifelong environmental matching of temperature tolerance. I will exemplify using own data from a range of experiments where we have asked how developmental thermal conditions impact the ability to counter heat- or cold stress from subcellular to organismal levels, spanning fertilisation to adulthood. This is timely as we face a climatically unstable future where drivers and plasticity of animal adaptation is key to survival.

318 Shawn Noren

Building Cetacean Locomotor Muscles Throughout Ontogeny to Support High Performance Swimming

Unlike terrestrial mammals, the locomotor muscles of marine mammals do not support posture (due to water's buoyant force), but rather must sustain locomotion under hypoxic conditions. Despite different demands, all mammals studied to date require postnatal development to attain mature musculature that can impact performance throughout ontogeny. Neonatal cetaceans have a lower proportion of locomotor muscle mass that has lower mitochondrial densities, myoglobin contents and buffering capacities than adults. For example, neonatal bottlenose dolphins have only 10% and 65% of adult myoglobin contents and buffering capacities, respectively. The maturation period required to achieve mature myoglobin contents and buffering capacities varies across cetacean species from 0.75-4 and 1.17-3.4 years, respectively. The truncated nursing interval of harbor porpoises and sub-ice travel of beluga whales drives faster muscle maturation in these species. Interestingly, muscle fiber type remains static throughout ontogeny in dolphins. Regardless underdeveloped aerobic and anaerobic capacities diminish thrusting capabilities and swim performance; size-specific stroke amplitudes (23-26% of body lenght) of 0-3 month-old dolphins are smaller than those of >10 month-olds (29-30% of body length), and 0-1-month-olds only achieve 37% and 52% of the mean and maximum swim speed of adults, respectively. Swimming performance improves with muscle maturation. Limited performance could preclude immature cetaceans from achieving their pod's swim speeds when fleeing anthropogenic disturbances; this could have demographic consequences.

264 Mike Norris, Kaitlyn Murphy, Alexia Alford, Ava Berger, Lincoln Butts, Matt Harrington, Sarah Knuston, John Rogers, Daniel Warner

Experimental test of the environmental matching hypothesis in island populations of the brown anole

Many organisms experience heterogeneity in their environment. How organisms adjust to this heterogeneity can be challenging, especially for embryos of oviparous species that lack parental care because they cannot actively move to different environments if conditions change. Adaptive developmental plasticity is one route by which embryos can cope with environmental heterogeneity. The environmental matching hypothesis (EMH) predicts that organisms will develop phenotypes that are suited to their environment when the developmental environment matches the post-developmental environment. In this study, we test the EMH using the brown anole lizard (Anolis sagrei). We collected eggs (n = 2296) from a wild-caught breeding colony and subjected them to incubation profiles that mimicked the temperature, substrate, and moisture conditions in shaded versus open environments at our field site. After hatching, we measured offspring morphology, desiccation rate, and behavioral responses to a predator. All hatchlings were released on small shaded versus open islands at our field site that either matched or mismatched with their incubation environments. Hatchlings were then recaptured to assess survival and growth. According to the EMH, we predict that offspring growth and survival will be relatively high when the egg-incubation environment matches that of the developmental environment compared to when these environments are mismatched. This experimental test of the EMH will provide important insight into the adaptive significance of developmental plasticity under ecologically-meaningful conditions.

617 Julia Notar, Madeline Go, Sönke Johnsen

No Brain? No Problem! Brittle Stars Are Capable of Associative Learning

There has been a recent growth in interest in the processes governing the coordination and control of loco-

motion in the decentralized nervous systems of echinoderms, yet our understanding of echinoderm behavior and learning remains poor. In this study we tested whether brittle stars (Class Ophiuroidea) were capable of learning to associate two cues: a short period of darkness and the presentation of a food cue. Individually housed Ophiocoma echinata were separated into experimental (trained) and control (untrained) groups. Animals in the experimental group were trained by presenting food during a short period of darkness, while control group animals were fed under regular daytime room lights many hours after the period of darkness. After the training period, the experimental group demonstrated they had learned to associate the two cues by regularly emerging during the dark period even when no food was presented. In comparison, control animals did not spontaneously emerge during the dark period ($p = 0.0007$). This shows that an ophiuroid species is capable of more advanced neural processing tasks than previously appreciated.

1705 Mehrnoush Nourbakhsh-Rey, Michael Markham

Species differences in the leptinergic regulation of electric signals in weakly electric fish

Nocturnal weakly electric fish (WEF) use electric organ discharges (EODs) produced by the coordinated action potentials of electric organ cells (electrocytes) to communicate and sense their environments. The wave-type species Eigenmannia virescens produces EODs at regular uniform intervals with high frequencies (200-600 Hz), while the pulse-type species Brachyhypopomus gauderio generates EODs at 10-120 Hz with long irregular intervals. In both species, melanocortin hormones target electrocyte action potential characteristics to modulate EOD waveform characters on a circadian rhythm and during social encounters. These responses may reveal important information to conspecifics during social interactions, or influence sensory performance. EOD production incurs significant metabolic costs. During food restriction, E. virescens reduces EOD amplitude to reduce metabolic costs. This effect is mediated by leptin, a peptide hormone involved in energy homeostasis. We found that leptin exerts direct effects on the electrical properties of electrocytes to produce corresponding changes in E. virescens EOD waveform while the effect of leptin on EOD characteristics in B. gauderio has not yet been investigated. We focus here on comparing the effect of leptin in regulating electric signaling in E. virescens and B. gauderio, species with different behavioral response to energy shortfalls. These comparisons between pulse and wave fish reveal both common endocrine mechanisms of EOD waveform regulation as well as important differences that are potentially a function of differences in life history.

95 Annaliese Novinger, Katherine Naumer, Dalton McCart, Rachel Wilkins, Haley Muse, Tia-Lynn Ashman, Avery Russell, Maggie Mayberry

Learned bee-haviors of pollen-foraging bees

Learning to forage is ubiquitous among animals, and bees foraging for nectar from flowers have been a model system for the study of learning for over 120 years. While bees often use sophisticated learned motor routines to extract nectar, bees must also forage for pollen. Yet surprisingly, the role of instrumental learning and motor routines in pollen foraging is barely understood. We investigated (1) whether bees learn and remember flower handling and motor routines to extract pollen from flowers, (2) whether the rate of learning differs when foraging on different plant species, and (3) whether learning improves the rate of pollen collection. We assessed learning and memory by allowing each bee to forage on flowers across two consecutive days. Our results demonstrate that pollen extraction from different plant species involves bees learning to perform motor routines specific to a species' flower morphology. Bees learned and retained memory of flower handling and motor routines for at least 24 hours, with some decay. The rate of learning also differed significantly among different plant species. Finally, learning significantly improved pollen collection. Altogether, our results demonstrate that, like nectar foraging, pollen foraging involves learning to optimize handling time and motor routines, and an increase in reward collection.

784 Julia Nowack, Clare Stawski, Danielle Levesque

Rare and opportunistic use of torpor in mammals- a ghost from the past?

Lowering the threshold at which body temperature is regulated during torpor is the most powerful energy-saving option available to heterothermic mammals and birds. With the increasing number of heterotherms that are discovered in non-Holarctic regions (i.e. warm tropical and/or arid habitats), it becomes apparent that torpid states are employed in a wide range of ecological and physiological settings and under various conditions. Since heterothermy is assumed to be an ancestral trait that evolved under conditions similar to climates that we see in today´s tropics, we argue that the recent discoveries can help us to understand the evolution of endothermy. We report data of a macro analysis on all heterothermic species known to date and speculate that torpor patterns reported for temperate and arctic zone species are a highly derived form of heterothermy, while the more opportunistic and variable torpor use that we see in non-Holarctic species may be more similar to ancestral forms of torpor.

52 Steve Nowicki, Alexander Davis, Matthew Zipple, Danae Diaz, Susan Peters, Sönke Johnsen

Influence of visual background on discrimination of signal-relevant colors in zebra finches

Animal color signals are often surrounded by high-contrast achromatic backgrounds, but much remains unknown about the functional significance of this arrangement. In humans and non-human animals, background color can affect the perception of a color stimulus, with high color contrast between a background and two given color stimuli making discrimination more difficult. It remains unclear, however, how achromatic background contrast affects signal discrimination in non-human animals. We asked whether achromatic contrast between signal-relevant colors and an achromatic background affects the ability of zebra finches to discriminate between those colors. Using an odd-one-out paradigm, we found that higher achromatic contrast with the background–positive or negative–decreases the ability of zebra finches to discriminate between target and non-target stimuli. This effect is particularly strong when color distances are small (0.5). We suggest that researchers should consider color patches and their backgrounds as collectively comprising a signal, rather than focusing solely on the focal color patch itself.

672 James Nowotny, Alexandra Bely

Building a blastema: Early cell dynamics in annelid head regeneration

Annelids include some of the most remarkable regenerators of the animal kingdom. Like many other animals, annelids regenerate by forming a blastema, a mass of undifferentiated cells at the wound from which new structures develop. However, how their blastema is initially formed is poorly understood. Some evidence suggests involvement of resident, multipotent stem cells, while other evidence suggests de novo establishment of stem-like cells at the wound site. To better understand where and when blastemal cells arise, we performed a fine-scale time series of cellular and molecular events after head amputation in the freshwater oligochaete Pristina leidyi. The earliest onset of cell proliferation is detected in two waves at the wound site, first within the gut epithelium and subsequently within the muscle layer. Also at the early wound site, we detect mononucleate spindle-shaped cells that bind phalloidin and appear to detach from the epitheliomuscular layer, suggesting muscle cell dedifferentiation. qPCR reveals a sharp upregulation of the stem cell factors nanos and ß-catenin at the wound site within just 3 hours post-amputation. Together, these data support the hypothesis that, like limb regeneration in vertebrates, head regeneration in annelids involves dedifferentiation and proliferation of somatic cells of different tissue layers. This work will contribute to understanding the evolution of regenerative processes and the diversity of mechanisms by which blastemas can be constructed across disparate animals.

1631 Ryan Null, Bria Metzger, Patricia Álvarez-Campos, Helena García-Castro, David Salamanca-Diaz, Elena Emili, Vincent Mason, Nathan Kenny, Jordi Solana, B. Duygu Özpolat

Automating design of fluorescent in situ probes for big data sets

High-throughput solutions for understanding the granular details of cellular differentiation during development have become more readily accessible as technologies such as RNA-seq and single-cell sequencing have matured. Cell clusters predicted by in silico algorithms need to be validated through traditional wet bench means, such as in situ hybridization. However, the design, cloning, and processing associated with traditional ISH is not comparably high throughput, representing a significant bottleneck for a study's workflow. Recent progress has resulted in a multitude of fluorescent ISH methods that reduce the process's length of time and difficulty, while enabling greater multiplexing capability. One of the most prominent techniques is Hybridization Chain Reaction (HCR), which utilizes many small DNA oligomers to hybridize to mRNA. To this end, we have developed an algorithm enabling the automated design of HCR in situ probes. This tool takes in a spreadsheet of genes-of-interest and outputs HCR probe sets in the proper ordering format with a single command. We show the algorithm's utility in validating scRNA-seq-clustered cell populations.

435 Ahmed Nurkovic, Mark Gunderson

Effects of Oxybenzone on Glutathione Concentrations in Signal Crayfish (Pacifastacus leniusculus)???

Sunscreens protect against harmful UV rays by utilizing ingredients that act as UV filters. One of the most common organic UV filters, oxybenzone, is suspected to be an environmental stressor contributing to coral bleaching. Oxybenzone is lipophilic and stable, thus leading to its persistence in the environment and accumulation in food webs. In this study, we tested whether oxybenzone acts as a pro-oxidant in signal crayfish (Pacifastacus leniusculus), a keystone species in the Pacific Northwest, by measuring the endogenous antioxidant glutathione (GSH) in animals exposed to environmentally relevant concentrations of oxybenzone (25-400 ng/g). Based on studies reporting adverse effects of oxybenzone in corals, we hypothesized that oxybenzone has the potential to act as a pro-oxidant and modulate GSH concentrations in signal crayfish. Tissue specific patterns of GSH response to oxybenzone were observed. No significant change in GSH concentrations were recorded in hepatopancreas, gill, or tail. However, GSH significantly increased in response to a low concentration of oxybenzone (50 ng/g) in antennal gland, without significant changes being observed at higher (100 and 400 ng/g) or lower (25 ng/g) oxybenzone concentrations. Our results suggest that oxybenzone is not acting as a strong pro-oxidant in signal crayfish from this population, although further studies examining the non-monotonic dose response observed in antennal gland will provide important information on the potential adverse effects of oxybenzone on aquatic biota.

1597 Amarachi Nwawueze, Frank Smith

Investigating the role of goosecoid in tardigrade foregut patterning

Studies of tardigrade development can help illuminate the evolution of animal biodiversity. Tardigrades are secondarily miniaturized and have lost a mid-trunk region. They have also lost genes that are expressed in the mid-trunk of other animals. While much is known about how the simple body plan of tardigrades develops, little is known about gut development in tardigrades. The gene goosecoid codes for a homeodomain transcription factor. Goosecoid is expressed in the developing foregut of many animals. Here, we used Hybridization Chain Reaction in-situ to elucidate the expression pattern of goosecoid during embryogenesis in the tardigrade Hypsibius exemplaris. To better characterize the expression pattern of goosecoid in H. exemplaris, we compared it to the expression patterns of Hepatocyte Nuclear Factor 4 (HNF4) and forkhead, which label the midgut and the entire gut, respectively, in H. exemplaris and many other animals. Our results demonstrate that goosecoid is expressed in the foregut of H. exemplaris. In addition to the conserved expression patterns of forkhead and HNF4, our goosecoid study indicates that ancient bilaterian gut patterning mechanisms are conserved in Tardigrada. Next, we will elucidate the precise role that goosecoid plays in regulating gut patterning in H. exemplaris with RNA interference targeting this gene.

948 Connor O'Brien, Andrew Schulz

SciComm that reaches millions through livestreaming platforms Twitch & YouTube.

Conservationists and scientists have long struggled to communicate and inspire passion to large audiences effectively. The traditional means of science communication have been through public talks, Twitter threads, and other means, but engagement numbers can be difficult to quantify. The development of live streaming has created a new tool for scientists and conservationists to share their work in real time. Alveus Sanctuary & Window to Wildlife are two organizations that rely heavily on live streaming to communicate their conservation message and fund their work. In this talk, we will discuss the pros and cons of streaming platforms such as Twitch and YouTube and how to effectively manage and grow your science communication community. At Alveus we raised over $700,000 & reached millions of aspiring scientists & conservationists in one year using Twitch's live streaming platform. In Window to Wildlife's first year, we were able to reach 2.2 million views with a single osprey camera on YouTube. This presentation will explore and expand on these two organizations' successes and translate this to how other organizations and scientists can grow their SciComm community through live streaming.

1215 Michael O'Connor, Samantha Giancarli, Arthur Dunham

Clade-based differences in vertebrate metabolic allometries.

Most hypothetical systems meant to explain physiological, and particularly metabolic, allometries posit 'universal' constraints on metabolic physiology and cannot easily accommodate variation in that physiology among groups of organisms. We have systematically investigated variation in metabolic allometry among clades of vertebrates. Here we summarize the emergent trends among those investigations. Consistent patterns include: 1) There is substantial, statistically demonstrable variation among vertebrate clades in the allometry of resting metabolism. 2) Metabolic allometry varies not just among relatively basal clades (e.g., vertebrate classes), but also among more distal clades (orders and families). For example, most orders and families examined differ significantly from some other orders/families within their class. 3) Among-clade variation is most prominent among scaling constants (average metabolism). But significant variation extends to both the mass and thermal dependences of metabolism, producing different metabolic allometries for different clades. 4) When data are available for testing, other physiological variables (diet, predatory mode, seasonal migration, fossoriality) significantly affect metabolic rate and can affect the magnitude of clade-based differences. 5) Classic dichotomies are supported (endotherms vs ectotherms, passerine vs non-passerine birds), but it is often not easy to explain why a clade has higher or lower resting metabolism, steeper or shallower mass dependence of metabolic rate. We speculate on the explanatory importance of these clade-based differences.

886 Johnathan O'Neil, Victor Ortega-Jimenez, Pankaj Rohilla, Xingwan Zhu, Saad Bhamla

Microvelia bugs spin up their own wake while tripod-gait walking on water

Microvelia bugs are some of the smallest semiaquatic insects (2-3 mm) that truly "walk" on both water and land surfaces. In lab experiments, we uncover that these insects use a single-mode alternating tripod gait to achieve similar maximum body speeds on these drastically different terrains. This kinematic performance is paradoxical considering that walking on water incurs hydrodynamic penalties that constrains performance in other tripod walkers such as ants. To understand how these Microvelia can achieve this remarkable terrestrial and aquatic terrain performance, we conduct systematic biomechanical and fluid dynamics experiments. First, we conduct Microvelia-walking experiments on solid substrates of different roughness. Using DeepLabCut tracking, our experiments reveal the role of tripod-gait robustness and leg slippage in walking on different frictional substrates. Second, using particle image velocimetry (PIV), we discover that Microvelia generates a pair of counter-rotating vortices during each leg stroke on the water surface, similar to vortices produced by water striders with rowing gaits such as Gerridae. Notably, we uncover that the vortices created by the middle legs were captured by the hind legs as they initiate their power strokes, thereby strengthening those vortices. Vortex circulation strength and synchronous motion of interacting leg suggest that "vortex recapture" can affect performance and associated energetics. Taken together, our work has the potential to offer insight into the design of amphibious microrobots, that can overcome the constraints imposed.

1680 Todd Oakley, Nicholai Hensley, Yogananda Isukapalli

Waterborne Autonomous Low-Light Electrostereovideograpy to quantify luminous courtship signals

Groups of animals including fireflies and sea fireflies diversified through aesthetic radiations, resulting in a riotous diversity of luminous courtship displays. A challenge to studying these radiations is that quickly and precisely quantifying the patterns of light of their courtship signals is difficult, especially in marine systems. In collaboration with undergraduate engineering students, we designed submersible, low-light video cameras, deployed in tandem. We call this dual camera system WALL-E (Waterborne Autonomous Low Light Electrostereovideography) because of its unintentional, yet uncanny resemblance to the main character of the Pixar movie. We also designed software for analyzing dual-camera videos using an open source computer vision library (OpenCV) and the pipelining software Nextflow. We tested the WALL-E system with simulated bioluminescent pulses, and also successfully deployed WALL-E in multiple locations in the Caribbean to quantify video of courtship displays of Luxorina ostracods. Our results correlate well with signals quantified in aquariums for one species, and provide quantification of signals for multiple previously undescribed species. Setups similar to WALL-E could use any camera pairs that detect luminous signals and our software could be used as a starting point for analyzing marine and terrestrial bioluminescence. By quickly quantifying courtship signals using stereo videography, we will be able to compare newly discovered signals to known ones, assay population-level and inter-specific variation, and produce 3-dimensional models that allow simulated displays for behavioral experiments.

1200 Jimmy Oberlin, John Robertson

Musculature of the Gill Arch of Paddlefish: A Role in Gill Raker-Based Filter Feeding?

Paddlefish (Polyodon spathula) filter feed using long, fine gill rakers that project laterally off the gill arches. While internal gill arch components would seem unlikely to play a role in food acquisition, presence of skeletal muscle could explain how gill rakers may be dynamically oriented to optimize food capture. The goal of this work is thus to identify and describe internal skeletal muscle tissue in paddlefish gill arches. Gill arches isolated from juvenile and adult paddlefish were examined using differential staining and light microscopy, as well as other visualization techniques. Our working hypotheses are that analysis will reveal a consistent internal gill arch skeletal muscle anatomy, and that this musculature will structurally interact with basal gill raker elements in such a way to support a role in positioning gill rakers for optimal food capture. Paddlefish gill raker internal morphology will be compared with that of another non-filter feeding acipenseriform (Atlantic sturgeon), as well as other teleost species. This study could provide novel information about gill structure and feeding biology in paddlefish.

1685 Aurora Oceguera, Carla Narvaez-Diaz

Comparative Study of Sea Urchins S. purpuratus and S. droebachiensis Adhesive Performance

The marine intertidal is a harsh rocky zone with challenging hydrodynamic forces. In the Salish Sea (WA), organisms that reside within these zones; such as purple (Strongylocentrotus purpuratus) and green (Strongylocentrotus droebachiensis) sea urchins, must have strong attachment to prevent dislodgement, ambulate, and feed in intense environmental conditions. Sea urchins attach to the substrate via their podia (tube feet). The disc found in the distal of tube feet has a duo-gland that releases specialized adhesive compounds and de-adhesive enzymes to achieve adhesion. Adhesive performance was evaluated in order to determine if purple sea urchins, that are predominantly found in high wave exposure areas, have better adhesive performance than green sea urchins, which are abundantly found in areas protected from wave action. We evaluated the following adhesive performance variables; stem mechanical properties, tube foot disc tenacity, attachment area, speed of detachment and whole animal adhesive force. We found that purple sea urchins were able to adhere for longer periods of time and put down more tube feet than the green sea urchins when subjected to all testing except for simulated detachment speed. Understanding how morphology, behavior and mechanical properties of tube feet work in conjunction to provide strong attachment, is critical to predict sea urchin fitness in challenging environmental conditions.

1402 Braden Oddo, Reece Jones, Brittany Dobbins, Ruben Tovar, Tom Devitt, David Hillis, Dana García

Pax6 localization in the eyes and neuromasts of sighted and blind salamanders of the genus Eurycea

Salamanders of the Edwards aquifer system of central Texas (genus Eurycea) invaded subterranean environments multiple times from the surface, resulting in parallel evolution of cave phenotypes with reduced eyes. Little is known about the developmental mechanism leading to regressed eyes; however, in cavefish it appears related to reduced levels of Pax6, a highly conserved transcription factor that drives eye development in all animals studied thus far. We hypothesize that Pax6 levels are diminished in the developing retina of salamanders with reduced eyes compared to those from salamanders which fully develop eyes. We used immunohistochemistry to examine Pax6 localization at various developmental stages (one-month post-oviposition to juvenile) in the sighted San Marcos salamander (E. nana) and the Texas Blind salamander (E. rathbuni). Immunolabeling of Pax6 was observed in the retina of both species, and preliminary results suggest more localized labeling in E. rathbuni retina that became more diffuse as E. rathbuni developed. We further corroborate our earlier observations of Pax6 labeling in neuromasts (mechanosensory structures of the lateral line system), notably in the apical region of hair cells. Work is underway quantifying the extent and localization of Pax6 expression in the eyes of sighted and blind populations through development and to determine whether Pax6 levels in neuromasts correlate with the habitat occupied by the species and the extent to which eye reduction has progressed or evolved.

1003 Shauna Odum, Lauren Johnson, Brittney Ivanov, Gerard Beaudoin, Michele Johnson

The Relationship Between Circulating Testosterone and Androgen Receptor Expression in Lizard Muscles

Circulating testosterone (T) modulates social behaviors across vertebrates, causing a cascade of effects that begins when T binds to androgen receptor proteins (AR). Experimentally increasing T levels often results in greater performance of social behaviors, but it is not clear how this manipulation alters the amount and distribution of androgen-bound and unbound AR. In this study, we examined AR in two species of Anolis lizards to determine how differences in T and behavior are associated with AR expression. We established high T, low T, and control treatment groups in 30 A. carolinensis and 39 A. sagrei males, and observed more frequent social displays in high T lizards of both species. We then collected the ceratohyoid muscle in the jaw, which controls dewlap display behaviors, and the retractor penis magnus (RPM) muscle in the tail, which moves the hemipenes, and used immunocytochemistry to measure both bound (i.e., detected in the nucleus) and unbound AR. Preliminary data suggest that in the RPM, both bound and unbound AR may not differ between treatments, but that, in both species, low T lizards have more myonuclei than high T lizards. Furthermore, preliminary analyses suggest that levels of bound and unbound AR within an individual's RPM are highly corre-

lated. Altogether, this study will help us understand the link between T and behavior by examining T bound and unbound AR.

1218 Phillip Oelbaum, Renata Soljmosi, Paul Faure, Louis Lazure, Gheylen Daghfous, Kenneth Welch

Effect of dietary protein on wound healing in Jamaican fruit bats, Artibeus jamaicensis

Fruit and nectar feeding bats can sustain themselves on diets including little to no protein. Bats may encounter periods when they require more protein than their sugar-rich diets typically provide, such as migration, reproduction, and wound healing. For example, many nectar and fruit eating bats like the Jamaican fruit bat (Artibeus jamaicensis) are known to eat insects, and we hypothesize that the consumption of insects may be especially important during these periods. we examined wound healing in two captive populations of Artibeus jamaicensis. We separated populations of intact and castrated males and females into control and protein-enriched diet group, creating a 3mm mechanical injury to the wing membrane of each individual. Wounds were photographically monitored, and we calculated the size of the wound at each timepoint and fitted these data to a non-linear least squares sigmoidal function which estimated the half-point and slope (rate of healing). We found rate of wound healing was significantly higher in the experimental group when only considering castrated males, however we did not find a significant difference in females or intact males. While we failed to detect strong effects in these latter groups, preliminary analysis of our data suggests that dietary protein does impact wound healing in these bats.

1519 Aki Ohdera, Maille Mansbridge, Matthew Wang, Changhua Yu, Goentoro Lea

Modulating the microbiome enhances limb regeneration

The role of the microbiome is increasingly recognized in various aspects of animal physiology, but remains understudied in limb regeneration. In a moon jellyfish, response to loss of appendages is generally marked by wound healing and a remodeling of body symmetry to restore the swimming and feeding functionality. However, some individuals exhibit partial regeneration of the lost oral arms, leading us the use the jellyfish as a model to understand factors that regulate limb regeneration. For cases in which partial limb regeneration is observed, we found natural variation in the microbiome to correlate with limb growth. By modulating the relative abundance of the host associated microbiome through the use of antibiotics, regeneration frequency and quality could be enhanced in an otherwise poorly regenerating stage of the jellyfish. By assembling the genomes of the dominant bacteria and applying genome-scale metabolic network reconstruction, we predicted metabolic pathways underlying the regenerative phenotype. By taking advantage of the metabolic predictions, we tested additional strategies beyond microbiome modulation to further enhance the animal's ability to regenerate lost appendages.

1846 Kaoru Esther Okamoto, Jennifer Kovacs, Erica Harris

The Role of Diet and Density on Adult-Egg Cannibalism in Red Flour Beetles

Bird maneuverability is often cited as a source of inspiration for enhancing the maneuverability of modern non-rotary UAV designs. Maneuverability can be quantified by evaluating a flyer's dynamic response to a perturbation (like a gust). To do this, we require information on a birds' aerodynamic and inertial characteristics across all flight configurations. Obtaining this information is challenging because birds can adopt a wide variety of flight configurations by morphing their wing and shape. In previous work, we developed methods to predict the aerodynamic and inertial properties of a gliding glaucous-winged gull (Larus glaucensces) across its full range of the elbow and wrist extension. Here, we used these tools to analyze the longitudinal dynamic response of a gull in steady gliding flight throughout wing morphing. We assumed the small perturbation form of the governing equations of motion with a quasi-steady aerodynamic response and a rigid, non-porous gull model. Our results showed that gulls can trim if the shoulder joint is allowed to move. Gulls can control the natural frequency and damping ratio of their oscillatory response through morphing their elbow and wrist. In addition, the flying qualities for the majority of gull wing configurations would be adequate for a human pilot albeit with a higher workload. Collectively, our results provide insight into the complete longitudinal stability associated with gull flight and inspiration for future supermaneuverable UAVs.

1193 Logan Oleson, Lucas Kirschman, Dustin Siegel

The effect of latitude and climate change on reproductive strategy

Animals must balance reproduction against survival because they cannot allocate limited resources to both traits simultaneously. For example, cricket frogs appear to live only one year, reproduce, and die in the northern part of their range. Disease and predation cannot fully explain the brevity of their lifespan. However, this evidence is based on mark-recapture studies, size measurements of museum species, and skeletochronology from small samples. There is little data on the age structure of southern populations where a favorable climate, particularly shorter, milder winters, may select for cricket frogs with slower paced life histories, typified by increased longevity and multiple breeding seasons. Anthropogenic climate change may also exert selective pressure on cricket frog life history causing a northward shift in longer-lived, iteroparous life histories. We have assessed the age structure of museum samples, via skeletochronology, across a wide latitudinal gradient from two time periods, 1930-1950 and 2000-present.

1120 Sara Oliveira-Pedro-dos-Santos, Monica Wilhelmus

Leakiness at intermediate Reynolds number in metachronal drag-based swimming

Bio-inspired underwater robots have the potential to start a new era of marine exploration by achieving high maneuverability and efficiency through simplified biological characteristics, including kinematics and morphology. Hair-bearing appendages are present in many metachronal, drag-based swimmers propelling at low-to-intermediate Reynolds number (Re) and act as either paddles or rakes, depending on the induced flow regime and morphology. Studies on leakiness have focused on low Re flows and simplified geometries, and their results are thus not directly applicable to understanding the hydrodynamics of most metachronal swimmers. Here, we use a scaled-up biramous appendage with a fringe of setae to characterize leakiness within a wide range of Re numbers. The morphological and kinematic features of our experimental model emulate those of krill. We perform two-dimensional velocimetry experiments in relevant planes and acquire force transducer measurements. Experiments were done varying the spacing between individual setae to investigate their role in thrust generation, tip vortex shedding, and performance. Our results illustrate the role of setae at the intermediate Re regime for the first time. Going forward, we envision this study will inform the engineering of underwater solutions, from bio-inspired robotics to particle filtering.

670 Maxwell Olson, Philip Bergmann

Different drivers of diversification for body elongation and limb reduction in snake-like lizards

Snake-like or eel-like body forms, characterized by elongation of the body and reduction of the paired appendages, have evolved repeatedly throughout the vertebrates. In the squamate reptiles (lizards and snakes), fully limbless and elongate forms have evolved at least 25 times, along with numerous “intermediate” forms representing possible transitional states between stockier ancestral forms and more derived snake-like forms. It has been suggested that elongation typically occurs first in the evolution of these snake-like forms, facilitating locomotion through the substrate or dense vegetation, followed by limb reduction, but this hypothesis has not been previously tested. We compared the fit of a series of adaptive and non-adaptive Ornstein-Uhlenbeck and Brownian motion models separately for the evolution of limb elements (digits and phalanges) and number of trunk vertebrae in squamates. For both digits and phalanges, the non-adaptive fit best, showing that particular clades had increased rates of limb element evolution. An adaptive model with different rates of evolution by microhabitat preference fit best for vertebrae, with fossorial taxa having elevated rates of vertebral evolution. Our results suggest that limb reduction in snake-like lizards is dictated by differential levels of constraint in different clades. In contrast, fossoriality appears to release a constraint on the evolution of vertebral number in lizards, facilitating body form diversification and supporting elongation as the primary step towards snake-like morphologies, followed by limb reduction.

1694 Chandler Olson, Emily McLaughlin, Maria Cobo, Kevin Kocot

Diversity of Solenogastres (Mollusca, Aplacophora) in Icelandic waters

The biodiversity of the deep sea is generally poorly characterized due to the difficulty of accessing this environment. This is especially true for Solenogasters which generally go unnoticed due to their small size, habitat specificity, and taxonomic difficulty. This project seeks to characterize the diversity of deep sea Solenogastres (Mollusca, Aplacophora). The IceAGE and IceDiva cruises extensively sampled the northern Atlantic with emphasis on the deep sea around Iceland collecting over 3,000 solenogaster specimens. This collection provides exciting insight into the regional diversity of these animals and is being used to prepare a monograph on the diversity of the fauna in the region. Specimens collected from these cruises were divided into four depth classes. Here, the diversity of the two deepest depth classes have been characterized: 2500-3500m and 3500-6000m. Specimens were sorted into morphospecies using features such as body shape and sclerite morphology as observed under light microscopy and scanning

electron microscopy. The mid body of specimens from each morphospecies were then used for DNA barcoding of cytochrome c oxidase subunit I (COI) and 16S rRNA (16S). The posterior and anterior regions are preserved for future histological analysis. Here, we demonstrate that deep water solenogaster diversity surrounding Iceland is higher than currently described. It is important to characterize the diversity of deep-sea animals so that we can understand the ecological importance of these ecosystems.

912 Kameron Orel, Glenna Clifton

Walking kinematics of the purple shore crab over hemispherical obstacles

Over the course of evolution, crabs have transitioned from aquatic to terrestrial locomotion several times. Intertidal crabs are particularly interesting since they locomote in both aquatic and terrestrial environments, as well as over rocky tidal zones. Previous studies on crab locomotion have identified common gaits and limited limb kinematics, however these studies exclusively used flat surfaces. To better understand crab locomotion, we collected purple shore crabs (Hemigrapsus nudus) and tested their ability to walk over non-flat surfaces. We fabricated arrays of hemispherical obstacles with diameters that correspond to approximately 37%, 62%, and 87% of the length of the second pereopod. Crabs were recorded (250fps) walking sideways across the substrates during < 3 0-minute recording sessions. By manually tracking the body, dactyls, and limb joints, we can analyze the three-dimensional kinematics and gait of leading and trailing legs of the crabs. The crabs slipped more on the uneven substrates compared to flat ground, and slowed down as obstacle size increased. On the smallest hemisphere substrate, crabs mostly maintained a normal alternating tetrapod gait. However, frequent slipping of the limbs on the larger hemisphere substrate shifted crabs towards a metachronal gait. These findings contribute to understanding how crabs walk under more naturalistic and ecologically relevant conditions. Not only will this contribute to our understanding of crab evolution, but it can inspire legged robots for movement over uneven, rocky terrain.

111 Andrew Orkney, Brandon Hedrick

Divergent trends in integration with increasing mass in the avian wing and trunk.

Birds are a hyper-diverse and ecologically disparate radiation, whose body masses range over four orders of magnitude, from the tiniest 5 gram hummingbirds to soaring 10 kilogram vultures. High body mass disparity is accompanied by allometric scaling of skeletal proportions, possibly reflecting the rigours of increased mechanical stress at higher body masses. This may result in evolutionary constraints in the wings of more massive birds, possibly leading to greater evolutionary integration within modular anatomical structures. We explore this question in a representative dataset of 149 crown bird species. We account for allometric scaling with phylogenetic regressions and extract the fit residuals, because this derived measure of skeletal proportions is known to exhibit a modular organisation in birds. We then compute the average strength of integration between pairwise combinations of bones within anatomical modules, over a range of body masses. A parallel analysis is run, which excludes the anatomically and ecologically distinctive Apodiformes. We find that integration within the wing increases with body mass, but that this pattern loses significance when Apodiformes are excluded. Significant declines in integration within the trunk module, and between the wing and trunk, are observed whether or not Apodiformes are included. We explore further, assessing whether this complex set of changes in skeletal integration is explained by variation in the flight styles that are available to birds of varying body masses.

1572 Jada Ormsbee, Sara O'Brien, Gabriel Rodrigues, Brian Walker

Getting down and dirty: optimizing microplastics recovery in penguin fecal samples

As microplastics continue to be identified as arguably a ubiquitous source of pollution across the globe, scientists are faced with developing the best methods to collect, recover, visualize, and analyze these pollutants properly to truly understand their impact. While there are a variety of recovery-to-analysis methods out there for relatively "clean" samples, such as those collected from bodies of water, working with other biological samples like tissue, soil, and fecal samples proves much trickier, and often species and/or habitat-specific. Here we discuss tools and techniques utilized to optimize microplastics recovery from dirty biological samples, such as avian fecal samples collected in sandy and rocky substrate. By running a series of trials adjusting sample type, digestion methods, and sample spiking with known amounts of microplastics, we have been able to optimize an efficient and productive method for working with Magellanic penguin fecal samples to recover microplastics.

335 Sarah Orr, Michael Goodisman

Intralocus conflict and the evolution of social phenotypes of wasps

Social insects, like yellow jacket wasps, are characterized by extraordinary social behaviors and thrive in colonies made up of phenotypically distinct castes with unique functional roles. Because each caste is governed by the same genetic architecture, intralocus conflict may inhibit each caste from reaching its specific trait optima. We hypothesized that genetic correlations between castes would differ among traits under different levels of selection. To explore this, we collected multiple colonies of Vespula maculifrons yellow jackets and measured morphological traits in workers and prereproductive queens. We genotyped individuals using microsatellite markers and assigned each to a patriline. We then determined if traits differed as a function of genotype, and whether traits showed correlations between prereproductive queens and workers. We found strong sexual and caste dimorphism for most traits. For example, antenna length varied dramatically among sexes, but was less dimorphic among female castes. Body mass also exhibited strong sexual and caste dimorphism and interestingly, was highly variable among colonies. Additional preliminary data revealed patriline effects on some morphological traits including prestigma length and gaster segment length. Thus, our data provide some evidence for a genetic basis to trait variation among castes. Ultimately, our research will reveal how intralocus conflict may constrain the evolution of morphological traits in social phenotypes of insects.

977 Alexa Ortega, Nicholas Hebdon, Lindsay Waldrop

A Morphological Look at the Many Faces of Man's Best Friend

Dogs have been a companion to humans across the globe for centuries. Over this time breeding efforts by humans have expanded the variation in dog morphology exponentially with the goal of breeding dogs to better serve in certain roles. But while these breeds are certainly different visually its unclear if they're really performing differently. Historically, the evaluation of whether breeds were successfully emphasizing a particular trait is largely qualitative and relied upon imprecise benchmarks of performance. Today these efforts are largely taken at face value with minimal quantitative effort having been invested into learning if breeding has had an impact on performance. However, to best approach this problem we first need to establish a foundational understanding of the ways the breeds differ from each other. One of the most obvious regions of difference is the skull because it has both aesthetic and performance value from a human perspective. We use both geometric and traditional morphometrics to establish a suite of shape parameters relevant to canid skulls and their performance. We use the resulting morphospace to explore the clustering in a small sample group of task-oriented breeds to examine intragroup and intergroup similarity. We find that intergroup similarity is much tighter than was expected with the only major separation occurring between "companion" type breeds and "working" breeds. Additionally, sighthounds were subtly distinct from other "working" breeds.

626 Victor Ortega-Jimenez, Benjamin Seleb, Tien Yee, Pankaj Rohilla, Jake Belair, Joseph Mendelson, Saad Bhamla

Chattering, feet stomping, and skimming induce vortical structures that boost flamingos' feeding

Flamingos are the most sophisticated filter-feeding birds, able to extract single cell organisms from boiling, hyper-saline and murky waters. Previous research on their feeding mechanisms focused on their mandibles (chattering), the unusual head posture, the tongue's pumping action, and the particle filtering by lamellae, as well as their stomping feet. However, the flow signatures flamingos produce are still unknown, which is critical to fully understanding how these birds feed underwater and at the interface (skimming). Here we studied living Chilean flamingos from the Nashville Zoo using Particle Image Velocimetry (PIV). Additionally, 3D-printed physical models, flume experiments, and computational fluid dynamics (CFD) were used to study in detail their hydrodynamics. We discovered that flamingos use three mechanisms to lift sediment particles. First, their chattering beaks act as a unidirectional pump inducing a vertical flow. Second, retracting their heads from the water induces tornado-like vortices that effectively stir sediments. And third, flamingos generate horizontal vortices using their stomping feet that swirl particles towards their beaks. We noticed that flamingos paradoxically skim at the interface with their bill tip oriented downstream. This inverse ram-filtering creates a strong recirculation that helps collecting particles. Thus, flamingos curved beaks and webbed feet seem to be highly effective to induce complex flow-structures that boost food intake. This research can be used to design bio-inspired filtering systems to collect particles in multiphase environments.

499 Emma Ortiz, Kendra Wisenbaker, Donald Powers

Microclimate Characteristics of Perches Used Post-Flight by SE Arizona Hummingbirds

Previous studies suggest that post-flight heat dissipation is important to hummingbirds dissipating extra heat gained during flight due to flight muscles activity. If true, then hummingbirds benefit from selection of perches with microclimates that support rapid passive heat loss. To evaluate this, I studied thermal characteristics of post-flight perches used by blue-throated mountain-gems (Lampornis clemenciae), Rivoli's hummingbirds (Eugenes fulgens), and black-chinned hummingbirds (Archilochus alexandri) in the Chiricahua Mountains, SE Arizona. I used infrared thermography to assess thermal characteristics of perches and for calculation of the aggregation index (AI), a measure of thermal heterogeneity. I also measured wind speed and ambient temperature. Data were fit to two statistical models: a binomial model with perching bird presence as the response and a gaussian model with log perch duration as the response. Log perch duration was used to normalize response due to short perching times, as 76% of all perches (and 90% of the perches when L. clemenciae, a highly territorial species, was excluded) were under a minute in duration. All models suggested that climatic factors had no significant impact on either perch location or duration. Due to the proximity of my study area to the birds' primary food source and the short duration of perch times, it is likely that perch location and duration were influenced more strongly by social interaction than by thermoregulatory considerations.

1049 Andre Ortiz, Joel Sharbrough

Genome-wide patterns of homoeologous gene flow in allotetraploid coffee

Allopolyploid species are the result of hybridization-induced whole-genome duplications, in which the genome of the resulting lineage consists of two distinct subgenomes, one from each progenitor. The extent to which chromosomes pair with their proper homolog vs. with the chromosome descended from the opposing progenitor (i.e., homoeolog), varies across allopolyploid taxa, such that recombination and gene flow between homoeologous chromosomes are also expected to vary across polyploid lineages. The D-statistic, commonly referred to as the ABBA/BABA test, has traditionally been employed as a powerful test of introgression between species. Here we employed it to characterize the extent and direction of gene flow across homoeologs of allotetraploid subgenomes. In particular, we applied the D statistic in reciprocal fashion to genome-wide alignments of coding sequences in the allotetraploid Coffea arabica, using its diploid relatives Coffea eugenioides (maternal progenitor) and Coffea canephora (paternal progenitor), and Gardenia jasminoides (outgroup) to anchor the phylogenetic relationships between homoeologs. Because C. eugenioides also represents the cytoplasmic ancestor, we tested whether nuclear-encoded genes targeted to the mitochondria and chloroplasts exhibited a larger degree of maternally biased homoeologous conversion compared to the rest of the genome. Together, these analyses provide a novel method for testing for homoeologous exchange in polyploids, and provide evidence of whether patterns of homoeologous exchange are affected by selection to ameliorate incompatibilities between subgenomes.

1634 Aaron Ortiz, Cameron Steffensen, Omera Matoo, Danielle Turner, Snezna Rogelj, Kristi Montooth, Maurine Neiman, Joel Sharbrough

Mitochondrial performance in diploid vs. polyploid Potamopyrgus antipodarum

Whole-genome duplications (WGDs), in which the number of nuclear genome copies are doubled or more, represent one of the most profound mutational changes found in nature. WGDs result in global changes to cell size and signaling, gene expression regulation, transposable element activity, and genome rearrangements. WGDs are also expected to alter mitochondrial-nuclear (mito-nuclear) interactions, potentially affecting mito-nuclear stoichiometry, mitochondrial size and biogenesis, mitochondrial gene expression, and ATP production. Potamopyrgus antipodarum, a New Zealand freshwater snail, is ideally suited for understanding the consequences of WGDs for mitochondrial biology, as populations feature closely related and coexisting diploid (2x), triploid (3x), and tetraploid (4x) lineages, all within the same species. Although polyploid P. antipodarum harbor mitochondrial genomes riddled with putatively deleterious mutations, they exhibit no evidence of reduced mitochondrial performance compared to diploids. As such, we hypothesized that polyploids might exhibit some form of physiological compensation that might ameliorate their mitochondrial mutation load. To test this hypothesis, we developed several direct measures of mitochondrial function including assays of organismal oxygen consumption, organismal performance under heat stress, mitochondrial membrane potential, reactive oxygen species production, and citrate synthase activity in P. antipodarum. We applied these newly developed assays to several diploid-triploid and triploid-tetraploid pairs that originated from the same New Zealand lakes to test whether polyploids exhibit cellular compensation for mitochondrial function.

1679 Jennifer Ortiz, Yuriy Bobkov, Melissa DeBiasse, Dorothy Mitchell, Allison Edgar, Mark Martindale, Anthony Moss, Leslie Babonis, Joseph Ryan

Independent innexin radiation shaped signaling in ctenophores

Innexins facilitate cell-cell communication by forming gap junctions or non-junctional hemichannels (innexons), which play important roles in metabolic, chemical, ionic, and electrical coupling. There is a gap in knowledge regarding the evolution and role of these channels in ctenophores (comb jellies), the likely sister group to the rest of animals. Here we identify and phylogenetically characterize the complete set of innexins of four ctenophores: Mnemiopsis leidyi, Hormiphora californensis, Pleurobrachia bachei, and Beroe ovata. Our phylogenetic analyses suggest that ctenophore innexins diversified independently from those of other animals and were established early in the emergence of ctenophores. We identified a four-innexin genomic cluster, which was present in the last common ancestor of these four species and has been largely maintained in these lineages. Evidence from correlated spatial and temporal gene expression of the M. leidyi innexin cluster suggests that this cluster has been maintained due to constraints related to gene regulation. Combined evidence from single-cell RNA-Seq and calcium imaging suggest that innexin gap junctions may have a role in synchronization of coupled muscle cells. Towards understanding the role of innexins in sensory and neuromuscular systems, we have determined basic electrophysiological properties of ctenophore innexons from muscle cells showing substantial overlap with the properties of bilaterian innexin channels. Together, these data provide a foundation from which to understand the role of innexins in ctenophore neuromuscular systems and

560 Trevor Oschenhirt, Jacob DeVries, Eric Domyan

Why does the A23P "Ash-red" TYRP1 mutation cause red pigment in domestic rock pigeon?

In many organisms, color is an important trait for natural and sexual selection, and a variety of colors are displayed to adapt to an environment. Eumelanin (black) and pheomelanin (red) are two pigments shared by mammals and birds, including humans and pigeons. An important step in the production of eumelanin is the modification of DHICA to eumelanin by an enzyme encoded by the Tyrp1 gene. Previous research has found that a mutation in this gene occurring in pigeons known as the ash-red, or A23P mutation, instead causes the production of pheomelanin. This mutation inhibits the removal of the protein's signal peptide. Interestingly, this mutation acts dominantly, suggesting that the presence of the mutant protein, not the absence of the wild-type protein, is driving this phenotypic change. How this simple mutation results in such a large difference in melanin production is unknown. We hypothesize that the A23P mutation may cause TYRP1 to be trafficked differently within the cell, which could contribute to pheomelanin instead of eumelanin synthesis. To investigate this, we have constructed two expression vectors containing tagged versions of the wild-type and ash-red Tyrp1 alleles. Utilizing immunofluorescence we will compare the trafficking and localization of each allele. Through these studies, we expect to uncover a better understanding of how a single amino acid change can generate such a large change in phenotype.

812 Michelle Osovitz, Taegan McMahon, Gretchen Hilt, Bridget Hilgendorff

The effect of Bd fungal metabolites on planarian behavior and developmental regeneration.

The fungus Batrachochytrium dendrobatidis (Bd) is threatening global amphibian biodiversity. This pathogenic microorganism can completely decimate populations to extinction with the spread of swimming zoospores throughout freshwater ecosystems. Even though this issue has been ongoing for decades, attempts to eradicate the infections have been unsuccessful. Our research question focuses on the recent development and use of a prophylactic wildlife vaccine against Bd. This vaccine consists of purified metabolite from the Bd zoospores and has shown promise in reducing infection rates when tested in a laboratory setting. However, the effects of the Bd metabolite vaccine on the ecosystem are not well understood. Our study reports an investigation on the effect of the Bd metabolite on one soft-bodied organism found in the same environment: the planarian worm Dugesia japonica. The planarian worm is a common organism used in developmental research because of their regenerative processes, extensive studies on behavioral responses to the environment and ease of use in the laboratory setting. Here, we present our findings that Bd metabolite exposure has no significant effect on planarian behavior and movement within 24 hrs. and 72 hrs. of exposure. We also explored the effects of Bd metabolite exposure on reproduction and regeneration. The results presented here will expand our understanding of the impacts of Bd metabolite exposure on co-occurring freshwater organisms and of Bd metabolite as a safe wildlife vaccine.

1552 Michelle Osovitz, Taegan McMahon

An interdisciplinary and equitable team based science approach to the undergraduate laboratory class

During the pandemic arose a need for virtual lab activities that were easy, cheap, inclusive and fun. Additionally, we understand that students gain critical thinking skills when challenged with interdisciplinary team science. In the Spring of 2021, we got creative and developed a virtual Course-Based Undergraduate Research Experience (C.U.R.E.) which engaged students from Developmental Biology and Disease Ecology courses. Over the semester, we challenged the students to investigate the effect of Chytrid fungal (Batrachochytrium dendrobatidis) metabolites on planarian (Degusia japonica) behavior, mortality and regeneration. Being that many departments are economically underserved- with equity in mind, we developed and implemented an experimental protocol that allowed students to conduct the entire experiment using minimal lab consumable materials, easily maintained planarians, cell phones for data collection and open access ImageJ for analysis. We will share the basic course organization and implementation, paired with the experimental results of this virtual C.U.R.E. and discuss our experience as interdisciplinary educators in the process. We will also highlight the components that were most successful, areas for improvement and the future of this project as it continues to produce a student generated, reproducible, publication quality data set. The goal of this presentation will be to increase dialog and create new collaborations focused around high impact practice team based research opportunities for students outside the traditional laboratory setting.

589 Kate Otter, Paul Katz

Dopaminergic and octopaminergic neurons in the nudibranch, Berghia stephanieae

Catecholamines play important neuromodulatory roles in decision-making across diverse animal phyla. Specifically, dopamine and octopamine (an invertebrate analog of norepinephrine) have been shown to mediate decision-making in relation to appetitive and aversive cues. The goal of this study was to map the dopaminergic and octopaminergic neurons in the brain of a nudibranch mollusc, Berghia stephanieae. Like other nudibranchs, Berghia has large individually identifiable neurons that can be tracked across individuals and sometimes homologized across species. In this study we used a brain-enriched transcriptome to identify genes coding for tyrosine-hydroxylase and tyramine-beta-hydroxylase, the rate-limiting enzymes in the biosynthesis of dopamine and octopamine, respectively. We then generated custom probes and used in-situ hybridization chain reaction (HCR) in combination with immunohistochemistry (IHC) to label neurons in the brain.The HCR results for tyramine-beta-hydroxylase showed that there are about 10 octopaminergic neurons with consistent positions in the same region, though not in a cluster, across individuals in the cerebropleural ganglia and a pair of bilaterally symmetric neurons in the pedal ganglia located close together. Preliminary results from tyrosine-hydroxylase show a similar number of dopaminergic neurons located close to the octopaminergic neurons. The IHC suggests that these neurons project to multisensory integration regions. This neuronal mapping combined with previous behavioral work lays the groundwork for electrophysiologically and pharmacologically investigating the role of these neurotransmitters in approach-avoidance decision-making.

1728 Grace Ou

Plastic behaviour in shy fish as a result of predation risk exposure

The shy-bold continuum is a well-studied phenomenon of animal personality in fish. Bold fish consistently behave differently from shy fish across different contexts and these differences are suspected to lead to separate survival strategies. Personality studies often focus on the interindividual differences between shy and bold fish, but fewer studies compare the intraindividual differences between shy and bold fish. Shy and bold fish can differ from each other in how their behaviours change across contexts as well. Shy fish tend to show greater plasticity than bold fish. In this study, the plasticity and predictability of shy and bold fish in a context with perceived risk of predation will be compared to determine whether each personality has different coping styles with exposure to predator risk. Fish will be sorted into shy and bold groups and exposed to daily net chasing as a predator cue over several weeks. Their reaction to a slanted tank boldness assay will then be measured at the end of each week. Results will be interpreted using linear mixed models. The predicted result is that shy fish will change their behaviour more than bold fish and the shy control fish in response to the perceived predation risk.

1548 Stephanie Ouderkirk, Mason Ong, Alex Sedley, Nathan Wright, Callie Miller

Developing modeling and image analysis tools to investigate mechanosensing proteins

Many studies have shown that changing the local mechanical environment on a cellular level alters signaling pathways, gene expression, and protein organization. While biologists agree that understanding cellular mechanical environments is useful for elucidating many of these cellular processes, the methods for proving the mechanical link are often highly customized, or too general to draw useful mechanical conclusions. In this paper, we describe a new method where we analyze microscopy videos to quantify parameters describing eukaryotic adherent cell shape (e.g. area, perimeter, curvature), thereby allowing us to draw conclusions about cell mechanics under various conditions. We include an overview of experimental methods to change cell mechanics, different image analysis tools, and a description of measurements which correlate with mechanical impacts. In particular, we use an ImageJ plug-in, WEKA, and custom MATLAB and Python codes to investigate the possibility that the cytoskeletal protein obscurin is mechanosensing in epithelial cells. A mechanosensing protein monitors if the cell mechanical environment is altered and then produces a biochemical signal. In addition to correlating cell properties with obscurin expression level, we describe a simple mathematical model that builds on the image analysis data to predict cell membrane tension. Our goal is to provide microscopists with quantitative tools that are broadly helpful in delineating whether various proteins or conditions alter a cell's mechanosensing capability in an easy, straight forward manner.

309 Jenny Ouyang, Jennifer Heppner, Justin White

Urbanization, heavy metal pollution, and fitness in house sparrows

Understanding the links between environmental characteristics, phenotypes, and fitness enables researchers to predict the impact of changing landscapes on individuals and populations. Although avian reproductive output is typically lower in urban than natural areas, the underlying reasons for this discrepancy may lie at the intersection of abiotic and biotic environmental and individual differences. In this study, we aimed to identify which abiotic stressors are linked to avian reproductive output in urban areas and whether this link is mediated by individual hormone levels. We used fine-scaled estimates (2m2 spatial resolution) of nighttime light, noise, and urban density to assess their impacts on the physiological condition of adult house sparrows (Passer domesticus). We measured circulating levels of lead and glucocorticoid concentrations in breeding pairs of free-living house sparrows and related these physiological traits to reproductive success. Using structural equation modeling, we found that increased urban density levels linked directly to increased plasma corticosterone and lead concentrations that subsequently led to decreased fledgling mass. Although urban areas may be attractive due to decreased natural predators and available nesting sites, they may act as ecological traps that increase physiological damage and decrease fitness. With fine-scale ecological mapping for a species with small home ranges, we demonstrated the presence and impacts of urban stressors in a small city with high human densities.

56 Julia Padro, Tate Linden, Emily Blackwell, Chris Law

Mandibular sexual dimorphism in mongooses (herpestids) and civets (viverrids)

Rensch's rule suggests that sexual dimorphism increases as body size increases in species where males are larger than females. One hypothesis explaining this pattern is that through sexual selection male-male competition for food, mating partners, and territory increases with body size. Here, we examine whether mandibular sexual dimorphism follows Rensch's rule in two families within the order Carnivora: Herpestidae (mongooses) and Viverridae (civets and genets). Although previous work found that these two families exhibit conflicting patterns concerning Rensch's rule, whether a more consistent signal can be found in a trophic morphology such as the mandible has yet to be investigated. To test the hypothesis that viverrid and herpestid mandibles follow Rensch's rule, we 3D scanned 64 mandibles across 10 viverrids and 94 mandibles across 16 herpestids from museum collections and performed geometric morphometrics to quantify shape and size differences between male and female mandibles. We then used ANOVAs to test for mandibular dimorphism in each species, and linear regressions to test for Rensch's rule. We found that mandibular dimorphism does not increase with mandibular size, indicating that herpestid and viverrid mandibles do not follow Rensch's rule. Our results suggest that the effects of sexual selection and niche divergence on sexual dimorphism cannot be captured by Rensch's rule, and additional analyses are needed to investigate how mating system, social system, and diet affect sexual dimorphism.

727 Anchal Padukone, Kimberly Sheldon

Temperature means and fluctuations interact to impact life-history traits in Spodoptera frugiperda

Temperature variability associated with climate change may exacerbate the ecological and economic impacts of insect pests, such as the widespread fall armyworm (Spodoptera frugiperda). However, our current understanding of how temperature changes impact insect performance often comes from studies using a series of constant temperature treatments. These may not

reflect the fluctuating temperatures insects experience in their natural environments. Predictive models of pest populations and impacts may require information on insect performance under chronic exposure to fluctuating temperatures. We used controlled experiments employing a wide range of temperature treatments to study the effects of temperature mean and fluctuations on survival, development rates, and fecundity in Spodoptera frugiperda. The treatments were representative of the breadth of temperatures found in the native and introduced range of S. frugiperda. Our results show interactive effects of mean temperature and the magnitude of daily fluctuations on juvenile survival, growth and development. At the warmest mean temperature, larger fluctuations significantly reduced juvenile survival relative to constant temperature controls, but did not significantly affect adult survival. Our results demonstrate the importance of explicitly considering the biological effects of fluctuating temperatures, especially since these effects may become more salient under climate change. Findings from this project may help evaluate current projections of S. frugiperda populations, particularly in areas where temperature variability is predicted to increase.

1683 Victoria Pagano, Samantha Bock, Josiah Johnson, Benjamin Parrott

Effect of incubation temperature on American alligator (Alligator mississippiensis) telomere length

Telomere length (TL) may be used as a biomarker of oxidative stress and biological age, with potential repercussions for individual survival and population health. As a result, it has become increasingly important to understand the factors influencing telomere dynamics, especially in the context of both environmental contamination and a rapidly changing global climate. To examine the role of contaminant exposure and temperature on telomere dynamics, we analyzed TL in a population of American alligators, a species with temperature-dependent sex determination. We collected alligator eggs from a mercury contaminated site and incubated them at female- and male-promoting temperature groups (29.5 ˚C and 33 ˚C, respectively) until hatch. Blood was drawn 7-10 days post-hatch, and DNA was extracted from erythrocytes to quantify TL using qPCR; total mercury was also quantified from blood samples. We ran linear mixed effects models with AICc model ranking to determine the model that best explained variation in TL. Our top model only incorporated the effects of incubation treatment (log-likelihood = -178.1, AICc = 366.6, Akaike weight = 0.522), wherein there was a positive correlation with individuals incubated at the male-promoting temperature ($\beta = 0.423 \pm 0.123$, $p < 0.001$). Forthcoming data will likewise analyze the relationships between TL and hatchling morphology and early growth.

660 Natalie Page, Alex Gunderson

The effect of urbanization on the temperature dynamics of lizards: an experimental approach

Urbanization leads to heat islands that can increase the risk of overheating for organisms within cities. Nonetheless, we have much left to learn about the ways in which urbanization affects animals and their thermal biology. In this study, we took an experimental field approach to investigate how urbanization affects the thermal landscape experienced by brown anoles (Anolis sagrei) in New Orleans. We tracked the body temperature dynamics of lizards in real time as they were experimentally moved between natural and human-made (e.g. concrete) substrates and differing levels of sun and shade in urban and rural environments. We found that lizards in the urban environment had greater rates of body temperature change when moving between microhabitats, and that rates of change were highest on human-made substrates (i.e., concrete) than on natural substrates (grass, leaf litter, wood). Equilibrium body temperatures were also higher in the urban environment. Our findings demonstrate that urban lizards experience both higher body temperatures and a more dynamic thermal landscape relative to lizards in more natural habitats. Given that rates of temperature change influence physiological responses to heat, differing heating rates of urban and rural organisms requires require more consideration.

1257 Alexandre Palaoro, Akshata Gole, Charles Beard, Peter Adler, Kostya Kostya

How to be a fast nectar drinker – a masterclass by hawkmoths

Drinking is a four-step process. First, the feeding structure needs to reach the fluid. Second, the structure needs to be wetted by the fluid. This step is crucial because absorption and liquid transport (third and fourth steps) can only occur after the structure is wetted. For instance, butterflies have a tongue that can only be wetted near the tip; thus, nectar is only absorbed in the tip. While useful, this method requires long feeding periods. For hawkmoths, however, spending any second more feeding is metabolically expensive because they keep hovering while feeding. The large metabolic demand of hovering flight might thus have selected hawkmoths for feeding strategies that allowed them drink nectar faster. To test that, we analyzed the wettability of 13 species of hawkmoths by measuring the advancing contact angle between a water meniscus and the tongue. We found that all species had an entirely hydrophylic tongue (advancing contact angles below 90 degrees). Further, the advancing contact angles differed significantly between hawkmoth subfamilies. Expanding the areas of hydrophylicity allows hawkmoths to trap nectar around the tongue by simply dipping the tongue. It also allows absorption to occur in more regions, increasing overall drinking rate. The difference between subfamilies further suggests that there is a phylogenetic component to drinking that we have yet to uncover.

801 Daniel Paluh, James Hanken, Gareth Fraser

Probing for the developmental mechanisms underlying repeated tooth loss in frogs

Teeth are present in most living vertebrates, but complete tooth loss (i.e., edentulism) has evolved in several diverse lineages. Recently, we demonstrated that teeth have been lost completely in more than 20 frog lineages, a much higher occurrence of edentulism than in any other vertebrate clade. The mechanisms underlying tooth loss in anurans are unknown, but identifying the developmental, genetic, and environmental factors linked to edentulism in this group will provide insight to the predictability and repeatability of evolutionary processes that generate similar traits. The morphogenesis and regeneration of teeth in vertebrates is mediated by a conserved genetic regulatory network, and the loss of different molecular signals has been shown to arrest dental development and underly independent tooth loss in birds, turtles, and some mammals. Using immunohistochemistry and in situ hybridization experiments, I characterize the developmental genetics of tooth initiation and proliferation in two frog species that possess teeth and then assess if the loss of different signals arrest tooth development among four species that have independently lost teeth. With phylogenetically widespread tooth loss and separate evolutionary losses on upper and lower jaws, frogs offer an unparalleled opportunity to determine if tooth development is repeatedly disrupted by a single conserved or several novel mechanisms.

1626 Lily Palumbo, Ioulia Bespalova, Heather Axen, James Waters

Biodiversity bootcamps and a vision for a regional network of community engagement

We organized a summer workshop to promote interest in biodiversity and to build relationships within Rhode Island. We brought together staff and students from East Providence High School, Providence College, and Salve Regina University for investigations into our local urban ant fauna, building environmental microelectronics sensors, and the use of genetic tools for species identification and experiments with phenotypic plasticity. This experience was a capstone to the summer research program at the universities and hopefully a jumping off point for the high-school student participants. We are exploring ways to expand the program and develop a network of biodiversity monitoring stations at high schools across the state to train, connect, and support interested staff and students, building our biological infrastructure and strengthening ties within and across our communities. This project was supported by funding from the National Science Foundation under grants IOS-1953451 and OIA-1826689.

815 Bole Pan, Young Kwon, Elizabeth Bliss Bagnato-Conlin, Darcy Kelley

Ethology and evolution of courtship vocalization in Xenopus

Effective communication requires coordinated exchanges of socially appropriate signals. Yet, little is understood of how these exchanges have evolved. Xenopus laevis engage in vocal duets during courtship, which is uncommon in anurans. Males produce advertisement calls composed of two trills differing in rate and duration to attract female. Sexually-receptive females respond with rapping, a series of clicks. Males answer by shortening the slower trill whose rate can overlap that of rapping, and intensifying and extending the faster trill. While males across the Xenopus genus produce species-specific advertisement calls, not all are biphasic. Apart from X. laevis South Africa, it is unknown whether other species in the Xenopus genus perform duets. Herein, we investigate the occurrence and structure of courtship duets across four species in the L clade (X. laevis South Africa and Malawi, X. petersii, X. victorianus, X. poweri) of the Xenopus genus. Through acoustic recordings, we quantitatively characterized male-female vocalizations during courtship. We observed that males differentially modify their advertisement calls in response to conspecific rapping. For monophasic callers, calls are faster and intensified. For biphasic callers, the faster trills are intensified and either extended or more frequent. Interestingly, we observe that female conspecifics of biphasic callers preferentially rap during one of the two calls. Results support a model in which sexual selection may have acted through vocal exchanges to promote speciation in Xenopus.

653 Saeid Panahi-Hassan-Barough, Caitlin Gabor, José Jaime Zúñiga-Vega, M Suarez Rodriguez

Consequences of maternal stress on offspring: cognitive, behavioral, and physiological traits in live-bearing fish

Consequences of maternal stress on offspring: cognitive, behavioral, and physiological traits in live-bearing fishSaeid Panahi, Gabor, CRM Suarez Rodriguez, JJ Zúñiga VegaTexas State University, Universidad Nacional Autónoma de MéxicoPrenatal exposure to stressful environmental conditions can alter cognitive, behavioral, physiological, and life history traits in mothers' and their offspring. Both chronic and acute environmental stressors experienced by mothers during gestation can alter offspring phenotype with the degree of change depending on the stage of gestation when stressors occur. Because the HPA axis is evolutionary conserved, live-bearing fish provide an alternative model for studying the consequences of maternal transfer of stress to offspring. First, we examined how cortisol, progesterone and estradiol varied across the reproductive cycle in two species of live-bearing fish that represent low and high matrotrophy index (MI) values: Gambusia affinis and Heterandria formosa. We found no significant relationships between fecundity and reproductive allotment with cortisol for either species despite different MI indicating that either species could provide a useful system to study maternal stress on offspring. Following this we explored the consequences of prenatal exposure to bisphenol A (BPA) for 46 days on embryo traits. Understanding the cost of prenatal exposure to BPA on cognitive skills of offspring in live-bearing fish could provide insights to the role BPA plays on mammals.

1207 Atul Pandey, Delbert Green

Pre-adult stage Juvenile Hormone level regulation affects the immunity-lifespan trade-off in Monarch

The long-distance, illustrious migration of eastern North American monarch butterflies (Danaus plexippus) to overwintering roosts in south-central Mexico is well known. The exceptional longevity and immunity of adult migrants are important aspects of this migration. In addition to controlling morphogenesis and reproduction, juvenile hormone (JH) is critical in the regulation of an immunity and survival trade-off in the insects. In monarchs, JH is known to shorten the lifespan of migrant adults, while blocking the synthesis of juvenile hormone prolongs the lifespan of summer adults. What is less obvious here is how pre-adult JH level changes affect adult immunity and survivability. We hypothesize here that JHs (particularly non-gonadotropic JH-III) levels changes during pre-adult will affect immunity and lifespan in adult Monarch butterflies in summer conditions. Our findings suggest that the JH-III level manipulation at the pre-adult stage increases the chance of infection of parasite Ophryocystis elektroscirrha in emerging adults, affecting immune related genes and reduced life-span. Further, our finding investigates the functional aspect of JH's at pre-adult stages and explains the importance of strong JH level regulation (particularly use of pesticides) in monarch butterflies in order to facilitate their migration and harsh winter with increased immunity, and better survivability. Key words: Juvenile hormone, Monarch Butterflies, Danaus Plexippus, immunity, life-span and Ophryocystis elektroscirrha.

659 Eloise Parish-Mueller, Victor Gonzalez

Acoustic Signatures of Different Bee Taxa in Lesvos, Greece

∗Temporary/ placeholder project description. Corresponded with program Chair on 8/25/22 and obtained approval to submit full abstract via email when complete∗Analysis of differential acoustic features of sounds produced by different animal species can enable new methods of biodiversity and population monitoring. Studies have demonstrated that such distinctions can be applied to the vibration patterns produced by the wingbeats of bees, providing the potential of distinguishing between species based on audio recordings. We gathered recordings of the buzz sounds of different bee species on the island of Lesvos, Greece, and we will perform acoustic and statistical analysis to determine if an association between acoustic signature and taxon can be identified.

1758 Eloise Parish-Mueller, Victor Gonzalez, Charles Abramson

Investigating residents' knowledge and perceptions of bees in Lesvos, Greece

The Greek island of Lesvos in the Aegean Archipelago has long been recognized by the scientific community for its exceptional diversity and abundance of native bees. Communication with inhabitants of Lesvos offers a unique opportunity to complement scientific knowledge on the diversity of flowering plants and bees on the island with analysis of the spiritual, economic, social and recreational value of pollinators to present-day residents, especially in light of the historical significance of bees in Greek culture. To learn more about what people on Lesvos know about local bees, the cultural and economic significance of the insects, and current and potential actions to protect their health and diversity, we conducted semi-structured interviews and distributed print and digital surveys covering these areas of inquiry. We found a wide variety in participant ability to distinguish between species and in the colloquial terms used for different local insects. Most participants greatly underestimated the number of species of bees on the island, but were aware that they lived in an area with greater than average diversity of bees. Almost all participants thought bees were important. Findings from the study so far indicate that residents of Lesvos are likely to be in favor of efforts to protect bees, but many may not be aware of the full spectrum of threats to these pollinators, or the importance of non-Apis bee species.

1554 M. Rockwell Parker, Holly Rucker, Julianna Lincoln, Megan Barlowe

Extragonadal aromatase expression in red-sided garter snakes

Aromatase is a critical enzyme for bioproduction of estrogens from androgens, and multiple vertebrates demonstrate significant, adaptive capacity for extragonadal aromatase activity. Sexual regions of the brain are most well-documented for their tissue-specific aromatase action, but the liver and skin also serve as important sites of local estrogen production. The red-sided garter snake (Thamnophis sirtalis parietalis) exhibits sexual dimorphism in extragonadal aromatase expression in the brain but surprisingly weak sex differences in gonad. Here, we collected tissues from garter snakes in spring (field), summer (lab), and fall (lab) to examine extragonadal aromatase expression in the liver and skin. Liver aromatase expression was female-biased in spring but not the rest of the year, and skin showed no sex differences but increased from spring to fall. Given that red-sided garter snakes have limited production of circulating sex steroids during their truncated activity window in any given year, tissue-specific aromatase expression may allow both sexes to circumvent these systemic limitations.

507 Benjamin Parrott, Ethan Shealy, Emily Bertucci

Age-dependent disorder of DNA methylation in epigenetic aging, development, and rejuvenation

Changes in DNA methylation (DNAm) with age, or "epigenetic aging" is widely observed across the tree of life. Age-associated DNAm patterns manifest as two general phenomena; one leading to stereotypical shifts in mean methylation levels that can be modeled to predict individual age with high accuracy (e.g., epigenetic clocks) and the other leading to increased variability or "disorder" in DNAm states due to the erosion of the epigenetic landscape. These phenomena are hypothesized to be linked; however, the extent to which they reflect distinct or similar underlying processes remains unresolved. Here, we develop a novel approach for measuring regional disorder in DNAm patterns, and then construct an epigenetic clock based on DNAm disorder. We find that regional DNAm disorder is highly correlated with age and enriched in gene promoters and Polycomb Repressive Complex 2 binding sites. Cytosines included in conventional epigenetic clocks are enriched in regions experiencing age-dependent changes in DNAm disorder, suggesting a direct link between DNAm disorder and epigenetic clock signals. However, upon exploring the influences of development, lifespan interventions, and cellular dedifferentiation, we identify clear divergence between epigenetic clock signals based on either mean DNAm or regional DNAm disorder, suggesting a fundamental decoupling of disorder dynamics from canonical epigenetic aging. These findings will be discussed along with potential contributions of age-related DNAm disorder to the diversity of maximum lifespan across vertebrates.

521 Rachel Parsons, Robyn Crook

Neural control of quadrupedal walking in the flamboyant cuttlefish, Metasepia pfefferi

The flamboyant cuttlefish (Metasepia pfefferi) is notable for its method of locomotion, using lateral arms and a pair of extensible, posterior papillae to perform coordinated, alternating stepping. How these walking movements are controlled is unknown. Cephalopod nervous systems are independently evolved from those of vertebrates and the degree to which similar circuit architectures generate oscillatory locomotion has never been explored. In most cephalopods, the left and right sides of the mantle are not connected directly, only via central projections into the brain; whereas in vertebrates, oscillatory locomotion is achieved via spinal networks that excite and inhibit muscle contraction across the midline, independent of central brain control. Some cephalopods, including cuttlefish, have a central commissure between the two stellate ganglia in the mantle, which we hypothesize permits peripherally mediated, reciprocal inhibition and excitation of the paired ventral papillae. Using DeepLabCut, video recordings of M. pfefferi walking were analyzed to map the precise relationships of the four limbs. In ongoing work, we will immobilize and anesthetize either one lateral arm or one ventral papilla to investigate how the gait changes in response to perturbation of one component, or we will surgically manipulate the central commissure to identify its involvement in left-right coordination of the ventral papillae. Our overall goal is to identify convergent circuit properties of walking in cephalopods and quadrupedal vertebrates.

877 RANNYELE PASSOS-RIBEIRO, Jamie MacKinnon, B. Duygu Özpolat

Comparative transcriptomics reveals sex-specific differences in Platynereis dumerilii

Sex determination is a critical component of sexual reproduction, which is necessary for conferring genetic variability over generations and allowing species to propagate. In animals, sex is often determined by chromosomal and environmental mechanisms (e.g. temperature). In the segmented worm Platynereis dumerilii, the mechanism of sex determination has been largely elusive. P. dumerilii lacks sexual chromosomes, and is morphologically distinguishable only at maturation, which makes it difficult to determine sex as a biological variable in experiments that focus on the juvenile phases of development. Because lab cultures produce a 1:1 male to female ratio in controlled environmental conditions, it has been suggested that genetic regulation may play a larger role in sex determination. Hypothesizing that genetic components of sex determination can be detected before initiation of gametogenesis, this study aimed at comparing the transcriptomic profiles of male and female juveniles. We collected gonial clusters from different developmental stages and carried out bulk RNAseq. We found upregulation of 549 transcripts in juveniles that became males, and 977 transcripts in those that became females. Transcriptomic profiles of older juveniles (>50 segments, meiotic stage) showed pronounced differences between males and females. Interestingly, young juveniles (40-49 segments, pre-meiotic stage) had similar transcriptomic profiles with each other but still showed sex-specific differences in gene expression. We conclude that sex can be distinguished in juveniles via differential expression of marker genes.

1230 Sheila Patek, Sophie Hanson, Kim Manturuk, Mark Ilton, Jeffrey Blanchard, Theo Cai, Donovan Hardy

Muser: a platform for enhancing equity in and access to interdisciplinary academic research

Three critical issues underlie the recruitment and retention of diverse participants in research: (1) make research opportunities accessible and visible to everyone, (2) evaluate applicants equitably, and (3) establish quality, mentored research experiences. To address these needs through an efficient, data-driven mechanism, Muser serves as an open-source, Drupal software application. Muser software runs at Duke, Harvey Mudd College, and UMass Amherst as single-department or university-wide programs. We present the principles of the software application as well as examples of and the capacity for collecting and analyzing data. We assess the effectiveness of specific interventions in the student-research interface, such as encouraging diverse participation and rewarding excellence in mentor behavior. Muser is an example of effective educational technology that makes equity and access both measurable and feasible to achieve - even for a single faculty member to run university-wide programs across disciplines and diverse stakeholders. To create truly accessible research experience means creating and measuring structural change to enable equitable, transparent, and multidisciplinary access to diverse research mentors and students at all levels.

1298 Sheila Patek, Suzanne Cox, Mark Ilton, Megan Porter

Exquisite energetics of spring-propelled, latch-mediated movements

Ultrafast organisms exemplify how biological systems manipulate and control energy to generate spectacularly diverse movements. Across the tree of life, repeated-use, ultrafast movements are driven by springs and controlled by opposing, latch-like forces. We focus on the biomechanical processes that sequentially reduce the duration of each energetic event to yield intense mechanical power density - often external to the organism to reduce self-damage. We leverage a new model system of young, transparent mantis shrimp (Stomatopoda) to quantify the timing and dynamics of muscle contraction, storage of elastic potential energy, latch engagement and release, and the levers and linkages that transform elastic potential to kinetic energy of their ultrafast strikes. We examine how the convergence of physical limits and inherent evolutionary integration of biomechanical structures yield generalizable features of energy storage and energy delivery, such that these mechanisms occur exclusively in small systems. While ultrafast organisms have historically been invisibly fast to science, today's technology and new model systems have unveiled effective experimental approaches to quantifying energetic control and manipulation in these intriguing biomechanical systems.

1266 Subhasmita Patro, Thejaswini Saravanan, Ayush Parag, Maria Thaker

Integration of signaling traits during social interaction in a color-changing lizard

During social interactions, animals display various static and dynamic signaling traits that are mediated by the neuroendocrine system. For an animal to respond appropriately to a social context, all the traits involved in generating an optimal response should be suitably coordinated. The extent to which these trait components are correlated determines the direction and outcome of social interaction. Males of the agamid lizard, Psammophilus dorsalis, have elaborate social behaviors that involve dynamic changes in body color and behavior, along with increase in steroid hormone levels. Using wild-caught lizards, we staged male-male interactions and recorded their responses using digital cameras to quantify behavior and color. Males displayed a suite of behaviors, along with dynamic color change in both visible and UV spectrum. Blood samples were taken to measure baseline and social interaction-induced hormone levels. In this study we show that, some aspects of body color i.e. maximum chromatic contrast of dorsal yellow and the size of UV patch, predict behavior displayed during an interaction. Individuals that had larger UV patches and displayed higher chromatic contrast on their dorsal body region, were also behaviorally more active during social interactions. Testosterone and corticosterone levels also change due to social interaction and are potential mediators for components of the complex signaling suite. Identifying relationships among these traits is essential to understand the spectrum of social strategies in animals.

1647 Edward Patterson, David Grossnickle, Nashaly Cortes-Viruet, Stephanie Jimenez-Rivera, Sharlene Santana

Mandible strength profiles reflect dietary adaptations in bats

The diversification of many vertebrate groups was spurred by the use of novel food resources, and jaw functional morphology provides clues about the adaptations associated with dietary diversification. The external dimensions along the mandible reflect strength to resist bite forces, which are in turn associated with physical properties of the diet. Variation in these dimensions along the jaw and between different species therefore may reflect adaptations of the jaw to specific diets. We applied this biomechanical framework to investigate the relationship between jaw robustness and diverse diet types in bats. Using mandibles of 90 species, we quantified the external dimensions at interdental gaps to generate mandibular strength profiles. The strength profiles of frugivorous, insectivorous, and omnivorous bats showed similar patterns, with a trend of increasing jaw depth toward posterior teeth. All diet types showed a high level of variation in jaw shape along the toothrow, suggesting differences in the functional roles of different teeth. Insectivores showed the greatest within-guild variation in jaw shape, while nectarivores had noticeably gracile symphyses. Further, insectivorous bats showed relatively deep jaws at the canine and premolars, which may be associated with the use for prey capture, while frugivores have relatively deep jaws at the posterior molars, possibly linked to adaptations for crushing seeds and pulp. These results suggest that mandible strength profiles reflect dietary adaptations in bats.

614 Tessa Patton, Sara Lipshutz-(she/her), Kimberly Rosvall

Neurogenomics of competition and parental care in a socially polyandrous shorebird

The division of reproductive labor between sexes often involves competing males and caring females. However, in socially polyandrous species like the northern jacana (Jacana spinosa), females compete for multiple mates, and males care for offspring. We hypothesized that sex differences in reproductive behavior are explained by neural transcriptomic profiles. We conducted RNA-Seq in the nucleus taeniae and preoptic area of the hypothalamus, two brain regions within the social behavior network. We compared competing females to males in two breeding stages – courtship and incubation. We found sex and stage-specific differences in the expression of genes that regulate competition and parental care. Compared to females and courting males, incubating males had higher expression of genes encoding prolactin receptor, and lower expression of androgen receptor in the preoptic area of the hypothalamus, suggesting that male parental care is reflected in neurogenomic profiles. In the nucleus taeniae, females had higher expression of genes encoding vasoactive intestinal peptide receptor as well as progesterone receptor – mechanisms that have previously been implicated in aggression. These findings suggest that differential selection on reproductive behaviors in females and males may also shape differences in the neuroendocrine phenotypes that facilitate those behaviors.

1260 Gustav Paulay

Collecting and collections are critical for recording vanishing biodiversity in the Anthropocene

The biosphere is undergoing enormous, accelerating and often irreversible perturbations that is resulting in the sixth mass extinction. Most biodiversity remains unknown and undocumented. Humanities knowledge of biodiversity will hinge in large part on the record our generation leaves behind. Yet at this critical time documenting the biosphere through collecting and collections is declining. Field collecting has waned and few field efforts are to scale given what is undocumented. Collection staffing at natural history museums has declined, exacerbated by mission drift away from collections as archives of biodiversity. While collections and collecting have declined, our ability to efficiently and deeply document biodiversity has made great strides. Modern large-scale biodiversity survey methods, field to collection pipelines, developments in informatics from born digital specimens to extended specimen applications, together with advances in genomics to phenomics allow documenting the biosphere at unprecedented levels. I will discuss these and present an agenda for capturing biodiversity economically at scale, based on ongoing efforts in marine biodiversity.

305 Sara Paull, Cory Ritz

Enabling PI Research at NEON – Assignable Asset Program Explained

The National Ecological Observatory Network (NEON) offers long-term ecological data, archival samples and resources to scientists and other users to study the environment and ecological responses to ecosystem changes. NEON gathers data from across the continental United States. The Observatory monitors 81 field sites (47 terrestrial sites and 34 aquatic sites) with a large suite of observational protocols and instrumentation at multiple spatial and temporal scales. In addition to providing data and samples, NEON also serves the scientific community for PI research by providing access to the observatory infrastructure and resources through NEON's Assignable Asset program. Primarily a cost reimbursable program, PI requests to access NEON for research typically fall into several categories: Sensor Infrastructure, Observational Sampling, Airborne Observation Platform, Mobile Deployment Platform, Field Site Coordination and Excess Samples. NEON program staff can assist researchers with planning and executing field campaigns across the Observatory. Projects may entail low-level assistance such as site host introduction, field escort or a letter outlining our support for the research. Complex projects may combine activity from multiple NEON teams for sensor deployment or collecting field samples and data. Research support from NEON's Assignable Asset program can harness the power of NEON and tap into the support of professional scientists, project managers and technical experts that work daily on delivering high-quality ecological data.

445 Jake Pawley, Scott Nichols

Investigating antibacterial immune responses in a sponge

Sponges are filter-feeding invertebrates that continuously encounter bacteria, directly attach to bacteria-covered substrates, host rich bacterial communities living within their tissues, and feed (in part) by direct phagocytosis of bacteria. We are interested in whether and, if so, how the sponge immune system disentangles and regulates these complex bacterial interactions. Challenges include that 1) most sponges and their symbionts are not readily cultivable, 2) prior environmental exposure to bacteria, combined with differences in the density and diversity of sponge-associated microbial communities can confound experimental design. Here, we overcome these challenges using use the freshwater sponge Ephydatia muelleri, grown under gnotobiotic culture conditions, to examine the immune response to the bacterially derived immunostimulatory ligand, lipopolysaccharides (LPS). We show that the tolerance of sponges to LPS from a prey species is more than 3 orders of magnitude greater than tolerance to LPS from a possible pathogen. Low doses of pathogen-derived LPS caused widespread cell death/tissue collapse, and induced the expression of a host of candidate innate immune pathway genes. High doses of prey-derived LPS had no effect on cell survival and tissue integrity, and induced the expression of >20 genes without any evident role in immunity. Our data support that sponges may have an elaborate innate immune system capable of distinguishing between, and responding differently to, different species of bacteria.

1567 Stephanie Peak, Tingting Xiang, Karl Castillo, Christopher Willett

The Role of Histone Acetylation in Thermal Tolerance of Exaiptasia diaphana, a Coral Model Organism

Tropical hermatypic corals have an obligate symbiotic relationship with algae of the family Symbiodiniaceae. This relationship is threatened by ocean warming through a process known as bleaching, whereby corals expel their algal symbionts. Exaiptasia diaphana, or Aiptasia, is a sea anemone that can also exist in symbiosis with Symbiodiniaceae; however, they can exist aposymbiotically as well. This makes Aiptasia a great model system for studying the coral-algal symbiosis. Epigenetic mechanisms likely play a role in maintenance of this symbiosis. Here, we focus on histone acetylation, which is linked to transcriptional activation. In Aiptasia, H3K9ac is associated with apoptotic genes and immune-related genes that may be involved in symbiosis regulation. We will use H2 and CC7 Aiptasia genotypes infected with either thermally tolerant Symbiodinium linucheae strain SSA01, thermally sensitive Brevolium minutum strain SSB01, or kept aposymbiotic. Anemones will be exposed to histone deacetylase inhibitor Trichostatin A (TSA) and kept at 32oC (thermally stressful) or 27oC (control) for 72 hours. For all host-symbiont combinations, survivorship, oxygen consumption, symbiont density, and photosynthetic efficiency will be measured. In addition to these physiological parameters, chromatin immunoprecipitation- and RNA-sequencing will be performed in order to determine which genes are regulated by TSA-affected histone acetylation sites and to assess differential gene expression. These methods will provide insight on the role of histone acetylation in the thermal tolerance of each host-symbiont combination.

1109 Bradley Pedro, L. Michael Romero, Mimi Kao

Repeated social isolation during song learning alters perineuronal nets in motor nuclei of songbirds

Neural circuits are shaped by experience during critical periods of development. In songbirds, the percentage of parvalbumin-positive (PV) inhibitory neurons with perineuronal nets (PNNs) increases in song motor nuclei over development and correlates with song maturity. Factors that modulate the timing of PNN development, however, are poorly understood. Here, we induced stress in juvenile zebra finches during the critical period for song learning via repeated social isolation. For 14 consecutive days, juveniles were placed in individual cages for 3 hours and then returned to their home cage. Corticosterone (CORT) was measured on day 1 before (baseline) and after isolation. CORT and testosterone were measured on day 14 after isolation. PV and PNN co-expression were quantified via immunohistochemistry following the social isolation protocol. All isolated birds exhibited acute increases in CORT levels on day 1, but CORT levels in socially-isolated juveniles were similar to baseline levels by day 14. The percentage of PV+ cells with PNNs was greater in the song motor nuclei of isolated juveniles compared to age-matched controls that were not socially isolated. This change does not appear to be driven by androgens. Testosterone levels were not significantly different between isolation and control juveniles. Thus, while juvenile zebra finches may hormonally acclimate to social isolation, repeated social isolation has lasting effects on the brain, driving premature maturation of motor circuits for song production.

1041 Mary Pena, Quinny Cao, Omid Shayegh, Adrien Arias, Manny Azizi

Proximo-distal gradient in limb muscle architecture and in vivo mechanical function in alligators

The musculotendon anatomy of most legged terrestrial vertebrates follows a clear proximo-distal gradient where proximal muscles tend to have longer muscle fibers and shorter tendons, whereas distal muscles tend to have short, pennate fibers and often operate in series with elastic structures. This trend has resulted in the prediction that proximal muscle will undergo larger strains and generate or dissipate significant mechanical work, while distal muscles operate largely isometrically by cycling energy through tendons. Here we examine the proximo-distal gradient in function in walking alligators. We use sonomicrometry and EMG electrodes to measure in vivo fascicle length and activation in a distal muscle the lateral gastrocnemius (LG) and a proximal muscle the iliotibialis (IT2) during level, steady state walking. Our preliminary results show that the LG mostly contracts isometrically, whereas IT2 contracts almost exclusively eccentrically. These results are consistent with predictions that distal muscles function isometrically while proximal muscles undergo larger changes in length.

1424 Valentina Peña, Joseph Heras

Wining and Dining Gut Microbiomes: Uncovering Dietary Diversity in Elongated Fishes

Host phylogeny, habitat, and diet are recognized for their role in shaping the gastrointestinal microbial community, however the extent of their influence on the taxonomic composition of the gut microbiome remains poorly understood within marine ecosystems. We investigated how these factors can be altered by working with nine species of elongated fishes Anoplarchus insignisC, Anoplarchus purpurescensC, Apodicthys flavidusC, Lumpenus sagittaC, Phytichthys chirusO, Pholis laetaC, Pholis ornataC, Xiphister atropurpureusO, and Xiphister mucosusH (superscript letters indicates their natural diet: C = Carnivore, H = Herbivore, and O = Omnivore) across two families (Stichadae and Pholidae). A four week high-protein feeding trial was conducted in order to replace the natural diets of lab-reared individuals while simultaneously controlling for host habitat. Intestinal microbiota were identified with high-throughput DNA sequencing of 16s rRNA V3-V4 gene amplicons pooled from lab-reared individuals (n = 28) and wild-caught individuals (n = 44) that maintained their natural diets. Fish gut microbiome studies offer the opportunity to improve aquaculture operations worldwide with the enhancement of probiotics tailored for the health and survival of reared fishes.

1285 Lucinda Peng, Christopher Pierce, Xuefei Lu, Daniel Goldman, Hang Lu

Feedforward and feedback mechanisms interact to control environment-dependent gait adaptation

Animals that encounter a wide range of terrains must be able to adapt their locomotion strategy to their environment. We hypothesize that gaits change based on feedforward control modulated by a combination of passive mechanics and mechanosensory feedback. Caenorhabditis elegans provides a great opportunity to study the interplay of these different feedback mechanisms with its compact nervous system and ability to modulate its undulatory gait in many environments. We use genetic mutations to perturb mechanosensation in two classes of putative proprioceptive neurons in a range of environments. In low viscosity fluids, where passive mechanical effects are minimized, we find that proprioceptive defective mutants adapt their gait in opposite ways. We hypothesize the divergence of gaits is due to opposing signals each of these neuron classes sends to downstream circuits. In contrast, gait properties converge in higher viscosity environments, regardless of genetic perturbations of the proprioceptor. We attribute this convergence of gaits to the dominance of passive mechanical effects in more resistive environments. To further test this hypothesis, we performed ratiometric calcium imaging across a range of environments, finding that the importance of passive mechanical modulation of commanded gaits increases with external viscosity. Taken together, our results suggest that environment dependent gait modulation in C. elegans is achieved through competition between proprioceptive feedback and feedforward control with passive mechanics dominating in more resistive environments.

356 Kiley Penwell, Cheyenne Coppinger, Jennifer Grindstaff

Maternal compensation after paternal removal and consequences for offspring growth

Biparental care is widespread in birds, but the consequences for mothers and offspring of a loss of care by fathers at distinct stages of the nesting cycle are less well known. After a loss of paternal care, mothers may compensate in whole or in part for the reduction in nest attendance, brooding, feeding, and allopreening. Offspring may differ in growth patterns between nests with and without male care. Additionally, a loss of male care may have greater effects on mothers and offspring if males are removed at the beginning of the nestling period rather than at the beginning of the fledgling period. In this experiment, we tested the effects of a loss of paternal care on female and offspring zebra finches (Taeniopygia guttata) by removing males at one of two time points. In the early removal group, males were removed at the beginning of the nestling period. In the late removal group, males were removed at the beginning of the fledgling period. Control males remained with females and offspring. From parental care videos, we recorded nest attendance, brooding, feeding, and allopreening. We also measured offspring growth. We predict that mothers rearing larger broods may not be able to fully compensate for the loss of paternal care, especially in the early paternal removal group. We also predict that these nestlings may have reduced growth rates.

643 Nick Peoples, Peter Wainwright

Patterns of tooth diversity in the cichlid fishes of Lake Tanganyika

The teeth of cichlid fishes are highly diverse and range from slender canines with a single cusp to complex multi-cusped teeth fit for herbivory. The shape, size, and arrangement of teeth impacts feeding efficiency and ecological specialization. Because teeth are direct points of contact with the environment, they are thought to be constantly subjected to strong evolutionary forces. Prior descriptions of cichlid tooth diversity are largely qualitative or limited in taxonomic scope. My research identified patterns of tooth diversity across the Lake Tanganyika cichlid radiation. Tooth diversity can be described in two ways: the size, number, and arrangement of all teeth in the jaw (hereafter tooth traits) and the shape of individual tooth cusps (hereafter cusp shape). I extracted 710 teeth from 106 specimens representing 35 species, using counts and 5 linear measurements of individual teeth to characterize tooth trait diversity and geometric morphometric analysis to quantify cusp shape. The major axis of tooth trait diversity was tooth height and number, while the number of inner rows and tooth curvature dominated PC2. The major axis of cusp shape diversity was cusp width and tip pointedness. While multicuspid species are more diverse in cusp shape than unicuspid species, they have a limited occupation of the tooth trait morphospace. Additionally, evolutionary convergence in tooth traits is prevalent within the twelve cichlid tribes.

930 Katherine Pereira, Cindy Rodriguez, Nicholas Sayegh, Noah Weik, Anabela Maia

Ubiquitous Sensory Innervation in the Membrane of Bluegill's Spiny Dorsal Fin

This study explores how the spiny dorsal fin, a main stabilizer of bluegill, is innervated to respond to perturbations. We hypothesize that the spiny dorsal fin and surrounding membrane may be equipped with nerve endings and/or encapsulated mechanoreceptors that can detect flow perturbations. We also predict that afferent nerves have a smaller diameter and be more prevalent within the fin membrane than efferens. Three spine pairs from the spiny dorsal fin were isolated from four previously fixed bluegill. Dorsal spine pairs were incubated in either anti-acetylated tubulin (AAT, binds to all neurons), calcitonin gene-related peptide (CGRP, binds to only sensory neurons), or both, followed by a corresponding secondary antibody. Nerve diameter was measured within four different regions of the sample with NIS-Elements D and ImageJ. AAT-stained specimens revealed sensory cells and innervations within the fin membrane, in addition to neuromuscular junctions in the muscle. In CGRP-stained specimens, bundles of sensory cells and free nerve endings were found primarily in the fin tip, but throughout the fin membrane, which were connected to the fin base via CGRP-stained fibers. Neurons in the fin membrane were found to be smaller in diameter and more abundant within the fin membrane than those found in the muscle. Understanding how the dorsal fin is innervated allows us to model sensorimotor integration.

768 Tal Perevolotsky, Jacob Brotman-Krass, Adam Summers, Matthew Kolmann, Cassandra Donatelli, Roi Holzman

A snap to the left, a swing to the right - head and body shape affect biting kinematics in fishes

Fishes use various control surfaces to propel and stabilize themselves. These surfaces include paired, median, and caudal fins as well as the body itself. The contribution of these control surfaces has been established in fish swimming, and for feeding on suspended prey, but is unclear for substrate feeders. Across teleosts, biting surface-attached prey is associated with convergent morphologies that include a deep body and an elongated, tapered head. However, the functional role of these morphologies is not established. In this study, we used simplified models of various substrate-biting fish to examine the role of head and body morphology in facilitating the removal of substrate-attached prey. Models simulated the swift lateral movement of the head, previously documented in two Acanthurid species biting substrate-attached algae. We found that increased lateral surface area of the body and median fins resulted in decreased body lateral displacement, producing more stable bites. Additionally, a decrease in head surface area resulted in faster lateral head movement, known to facilitate removal of attached prey in Acanthurids. Overall, our results suggest that the laterally compressed bodies and elongated median fins function as control surfaces during feeding in substrate-biting fish. We propose that a selective pressure to extend the lateral surface area underlies the prevailing morphological convergence of biting reef fishes.

1470 Pedro Antonio Perez, Michele Nishiguchi

Crossing communication barriers: Autoinducer production between symbiotic Vibrio from Sepiola

Two species of bacteria, Vibrio fischeri and Vibrio logei, can occur within the light organs of squids in the genus Sepiola (Cephalopoda: Sepiolidae). The ability to produce light by these bacteria is necessary for the squid to camouflage due to a phenomena termed counterillumination. Light production depends on the accumulation of small chemicals called autoinducers, which trigger this response at high concentrations. Interestingly, it is still unknown whether both species can communicate with one another to coordinate bioluminescence during symbiosis. We therefore measured the production of the acyl-homoserine lactones C6 and oxo-C10, and the autoinducer-2 (AI-2) in symbiont isolates from Sepiola atlantica and S. affinis using the biosensors Pseudomonas putida F117, Escherichia coli MT102 and Vibrio harveyi MM32. Our findings yielded a different pattern among and within the isolates from the two locations. These differences were also observed using High Performance Liquid Chromatography-Mass Spectrometry (HPLC-MS) analysis, which can detect each autoinducer molecule and their concentration. Validation of these AHLs was through the Global Natural Products Social Molecular Networking (GNPS). Our analysis gives a first approximation about how these two species of bacteria could communication within the

light organs of two allopatric Sepiola species, and how they govern the patterns of counterillumination behavior in this beneficial symbiosis.

1795 Christian Perez-Martinez, Marissa LaMartina, Juan Daza, Manuel Leal

Comparative anatomy of vibration-sensitive and chemoreceptive structures in Amphisbaenia

Fossorial animals exhibit sensory adaptations that allow them to operate in habitats devoid of light. Their reduction in visual capacity is often accompanied by a greater dependence on chemoreception and perception of substrate-borne vibrations. Due to the high metabolic demand of sensory tissues, we hypothesize there is a tradeoff between sensory modes that is reflected in neuroanatomy and skeletal morphology. Amphisbaenians are a suitable clade to examine this question because the distinct anatomical structures that underlie sensory functions are well described. Chemoreception is achieved by a transfer of particles from the tongue to the vomeronasal organs and processing in the accessory olfactory bulbs. Vibrations are conducted through the cartilaginous extracolumella to the inner ear, and such stimuli are processed in hindbrain nuclei and the torus semicircularis. Using diceCT scans of seven species from six families, we characterized the skeletal elements and brain regions responsible for chemoreception and vibration perception. The extracolumella reveals remarkable diversity in shape, e.g., antenniform, arbuscular, bulbous, and triangular. Preliminary geometric analyses suggest extracolumellar type corresponds with brain morphology, and subsequent models will uncover whether a more developed extracolumella is associated with a reduced vomeronasal system. Our work provides insight into how vibration and chemoreceptive mechanisms covary in a fossorial group of squamates, and the comparative framework we use for investment in sensory systems is broadly applicable to studies of sensory biology.

1247 Jorge Pérez-Moreno, Mihika Kozma, Danielle DeLeo, Heather Bracken-Grissom, David Durica, Donald Mykles

CrusTome: A transcriptome database resource for large-scale analyses across Crustacea

Transcriptomes from non-traditional model organisms often harbor a wealth of unexplored data. Examining these datasets can lead to clarity and novel insights in traditional systems, as well as to discoveries across a multitude of fields. Despite significant advances in DNA sequencing technologies, access to genomic and transcriptomic resources for non-traditional model organisms remains limited. Crustaceans, for example, being amongst the most numerous, diverse, and widely distributed taxa on the planet, often serve as excellent systems to address ecological, evolutionary, and organismal questions. While they are ubiquitously present across environments, and of economic and food security importance, they remain severely underrepresented in publicly available sequence databases. Here, we present CrusTome, a multi-species, multi-tissue, transcriptome database of 201 assembled mRNA transcriptomes (189 crustaceans, 30 of which were previously unpublished, and 12 ecdysozoan outgroups) as an evolving, and publicly available resource. This database is suitable for evolutionary, ecological, and functional studies that employ genomic/transcriptomic techniques and datasets. CrusTome is presented in BLAST and DIAMOND formats, providing robust datasets for sequence similarity searches, orthology assignments, phylogenetic inference, etc., and thus allowing for straightforward incorporation into existing custom pipelines for high-throughput analyses. In addition, to illustrate the use and potential of CrusTome, we conducted phylogenetic analyses elucidating the identity and evolution of proteins involved in the regulation of crustacean molting and limb-regeneration. Supported by NSF (DEB-10556059, IOS-1922701, IOS-192275).

1575 Craig Perl, James Haas, Jon Harrison

Causal mechanisms for variation in resting metabolic rates

The physiological and morphological mechanisms responsible for variation in resting metabolic rates among animals remain poorly understood and a major focus of research. Across nearly all taxa, metabolic rate scales hypometrically, with larger animals exhibiting lower mass-specific metabolic rates than smaller animals. One hypothesis to explain this pattern posits that high mass-specific resting metabolic rates are associated with having a greater proportion of "expensive tissues" such as livers, kidneys and brains. However, tests of these hypotheses have proved difficult due to a limited capacity to measure tissue-specific metabolic rates within individuals. We solve this technical limitation by using an Agilent Seahorse to record oxygen consumption rates of different, costly tissues.To untangle the impacts of tissue proportion on resting metabolic rate, we compared whole body and tissues specific metabolic rates of queens and workers of the seed-harvesting ant Veromessor pergandei. This enabled us to examine the energetic cost of various tissues for closely-related animals that differ in size. We found significant differences in mass-specific metabolic rate among castes, as well as differences among metabolic rates of specific tissues. Our data support the hypothesis that variation in resting metabolic rates are, in part, driven by proportions of expensive tissues. This research is partially supported by NSF IOS 1953419.

1362 Kristin Perrin, Talia Moore, Deanna Gates

Dynamic locomotion of legged robot using biomimetic articulated feet

Both vertebrates and invertebrates have compliant structures in their limbs that dampen the impact of collisions associated with each step and provide some mechanical feedback aiding in recovery from perturbation. In legged robots, either series elastic actuators or fully compliant limbs function similarly to provide a smoother gait pattern, but some robots have legs made of entirely rigid structures. In this study, we developed bioinspired passive mechanical feet for a rigid-legged quadrupedal robot using 3D printed parts paired with off-the-shelf supplies. The goal of the study was to replace spherical squash balls with bioinspired designed feet. The foot designs needed to mitigate lateral roll from the robot during ambulation and while standing from a resting position. One solution, based on the cloven hoof of mountain goats, splays laterally under load to increase surface area in contact with the ground, conferring lateral stability. Printed with flexible materials, two independent compliant structures mimic hoof splay under loading and retraction with unloading. The other foot design solution was based on human anatomy, in which invertor and evertor musculature provide control at the ankle to support mediolateral stability and limit lateral motion. Combining rigid filament 3D printing with springs and pins, this design withstands lateral loading and rebounds to neutral when unloaded. Future experiments will mechanically compare stabilization to neutral after lateral perturbations across all three feet.

1264 Weston Perrine, Sarah DuRant, Erin Sauer, Ashley Love, Ashley Morris

Diet composition affects on Serinus canaria infected with Mycoplasma gallisepticum.

Individual dietary macronutrients possess unique roles within immune processes, which could have a profound effect on disease response and host recovery. Using an avian host-pathogen system and isocaloric diets, we first explored the effects of dietary macronutrient composition, specifically lipid and protein content, on disease pathology and behavior of canaries (Serinus canaria) infected with Mycoplasma gallisepticum (MG). We then tested whether infection caused macronutrient-specific shifts in feeding behavior. In experiment one, canaries provided a protein-rich diet consumed more calories per week than birds fed a lipid-rich diet. All infected canaries exhibited illness-induced anorexia in the first week post infection and a significant decline in body mass. Infected birds fed the lipid-rich diet maintained fat stores during infection, whereas birds fed the protein rich diet did not. However, these birds experienced clinical signs of infection (swollen eye conjunctiva) for longer than birds fed the protein diet, although diet did not affect pathogen load or MG-specific antibody concentrations. In experiment two, providing both diets during infection reduced loss of fat stores and prolonged conjunctiva inflation. Birds maintained intake of the lipid rich diet, but decreased intake of the protein rich diet immediately following inoculation. These data indicate that diet macronutrients could play an important role in individual variation in disease severity among hosts infected with a pathogen.

334 Constant Perry, Eric Gangloff, Fabien Aubret, Capucine Pierrel, Emma Depreter, Alyssa Head, Ethan Livingston, Maxime Stanislawek

Impact of increased daytime and nighttime temperature on the phenotype of a vertebrate ectotherm

Climate warming is happening asymmetrically, with nocturnal temperatures increasing at a faster pace than diurnal temperatures. Still, most studies focusing on global warming consider temperature increments as constant over a 24h cycle or as a purely diurnal factor, leaving the effects of nocturnal warming largely unknown. Warmer nights may expand diurnal ectotherms' species thermal niche and open new opportunities for prolonged activities and improve foraging efficiency. However, increased activity may also have deleterious effects on energy balance if exposure to warmer nights reduces resting periods and elevates resting metabolic rate and energy expenditure. We exposed common wall lizards, an actively-thermoregulating and diurnal lizard species to a full-factorial combination of elevated temperatures at day and night. Before the treatments began and then after six and twelve weeks of treatment, we measured a suite of relevant traits representing energetic status including food consumption, metabolic rates and thermal preferences that were measured during the day and the night. This design allowed us to assess the energetic consequences of warming at different times of the diel cycle as well as the potential behavioural and physiological plasticity in the complex multivariate thermal-metabolic phenotypes of lizards.

The aim of this study is to enrich our fundamental knowledge of the future impacts of increasing temperatures on ectotherm populations, so that we can better predict and mitigate the outcomes of continued warming.

1835 Elin Persson, Andreas Nord

Physiological consequences of growing up during a heatwave

Climate change has caused an increase in global temperature and an increase in the frequency and intensity of heatwaves. In birds, changes in environmental temperature during the developmental period can directly affect growth, metabolism, and temperature tolerance of the offspring. However, we know little about whether these changes remain in adulthood. This is important to fully understand the fitness effects caused by climate change. For example, if birds adapt non-reversibly to extreme weather conditions experienced in the juvenile stage, they may be maladapted to the prevailing environmental context of their adult ranges. We investigated if any phenotypic consequences of the thermal environment in early life manifested as legacy effects in adulthood. This was achieved by raising Japanese quail under simulated heatwave conditions and in a common garden afterwards until adult. We then measured thermophysiological responses to variation in environmental temperature, both at the end of the heatwave period at halfway to adult size and again in adulthood. Here, we detail the short and long-term effects of heatwaves on morphology and on the physiological machinery responsible for keeping the birds warm or cool under normal conditions and at the extremes of temperature tolerance. This study gives new insights into how developmental priming and plasticity allow birds to cope with increasing temperatures, if phenotypic effects are long-lasting and under which circumstances such responses are adaptive or maladaptive.

169 Sierra Pete, Alexander Kitaysky, Scott Hatch, Z Morgan Benowitz-Fredericks

Baseline corticosterone levels neither reflect nor predict behavior, stress-induced levels do

We asked why young nest-bound seabird chicks dramatically increase corticosterone secretion in response to acute stressors. We tested the long-standing hypothesis that increased corticosterone redirects behavior to increase survival. We recorded an hour of behavior in two-chick Black-legged kittiwake (Rissa tridactyla) nests when the oldest chick was 5 days old, bled chicks in < 3 min, restrained the oldest chick for 15min to induce corticosterone elevation, bled again, then recorded for a second hour. If elevations in corticosterone drive changes in behavior, stress-induced corticosterone should be most strongly correlated with behaviors in the second hour. Alternatively, if behaviors drive corticosterone, baseline corticosterone should be most strongly correlated with behaviors prior to the acute stress. 15min restraint increased corticosterone levels five-fold but did not affect mean behavior rates. Baseline corticosterone neither reflected prior behavior nor predicted subsequent behavior, but stress-induced corticosterone did both. Chicks with higher stress-induced corticosterone had been aggressive more recently and received fewer feeds in the previous hour, and were more aggressive and received more feeds in the subsequent hour. Their siblings also died younger, abolishing intra-brood competition. Experimental food supplementation reduced baseline corticosterone and eliminated relationships between corticosterone and behaviors. These results support the hypothesis that elevations in corticosterone quickly redirect behavior, but also reveal a strong relationship between behavior and underlying endocrine responsiveness that may not be apparent when considering baseline corticosterone alone.

1359 Jarrod Petersen, Alexander Wilde, John Capano, Thomas Roberts

Costocutaneous muscle function following large prey ingestion in Boa constrictor

Large prey ingestion in snakes produces extreme distention of the body wall as some snakes consume prey up to 100% of their own body mass. After transporting prey into the body, large snakes like Boa constrictor may use rectilinear locomotion to crawl forward on their ventral scales to safety. The costocutaneous inferior (CCI) muscle, a muscle required for rectilinear locomotion, attaches between the skeleton and the highly mobile ventral skin. The body wall distention caused by ingesting large prey may be at odds with the fundamental mechanics of vertebrate skeletal muscle by acting to lengthen the CCI muscle beyond lengths where active force production should be possible. We fed Boa constrictor large prey ranging from 30-40% body mass and used X-ray Reconstruction of Moving Morphology (XROMM) to determine in-vivo CCI muscle operating lengths. We found that Boa constrictor anatomy allows for $\sim 35°$ rotation of the CCI muscle line of action (relative to the snake long axis) following large prey ingestion which acts to reduce the strain placed on the CCI muscle. Yet, the CCI muscle still undergoes extensions greater than 200% resting length prior to feeding. The unique ability for the CCI muscle to operate at two extreme strain regimes over a dynamic line of action may be necessary mechanisms for the evolution of large prey ingestion in certain snake species such as Boa constrictor.

473 Ashley Peterson, Matt McHenry

Vigilance is more important than speed for the survival of prey fish

It is commonly assumed that faster locomotion will aid in the survival of prey. Experimental tests of this idea are challenged by the uncontrolled and stochastic nature of predator-prey interactions. We therefore evaluated the effects of prey behavior on survival by developing a 2D agent-based mathematical model parameterized by kinematic measurements of red lionfish (Pterois volitans) as they pursued a prey fish (Chromis viridis) in a cylindrical arena. This model successfully replicated the duration of experimental interactions and batches of numerical simulations varied both fixed parameters and random model variables to test their effects on prey survival. We found that the duration of prey survival was most influenced by changes in arena size, and by small differences in predator speed. Varying the prey metrics of vigilance and evasion had a greater effect on survival than maximal measures of their locomotor performance.

1389 Christopher Peterson, Mikhail Matz

Inheritance of DNA methylation in hybridized Acropora corals

The potential for multigenerational epigenetic inheritance to drive non-genetic adaptation remains an open question. In invertebrates and plants, gene body methylation (GBM) is elevated in genes that are consistently expressed, while unmethylated genes tend to be induced. In this study, we quantified gene expression and allele-specific GBM throught the genomes of a pair of two reef-building coral species (Acropora millepora and A. selago) and their hybrid. Our results on the heritability of methylation and its effects on gene expression could provided insight into mechanisms for coral adaptation to changing environments.

486 Madison Pfau, Daniel Blumstein, Conner Philson, Gina Johnson, Sam Degregori

The social microbiome: the relationship between the microbiome and sociality in a wild mammal

The microbiome has a well-documented relationship with host behavior. Greater microbial diversity and specific microbes have been associated with improved fitness, though these associations have been studied almost exclusively in captive animals with implications for human health. In wild populations, the microbiome has important fitness consequences, such as being associated with mass gain and body condition, and specifically, microbial diversity and composition have been associated with increased individual stability. An individual's social behavior also has important fitness consequences for acquiring food resources and avoiding predation. While both factors individually influence fitness, the relationship between the microbiome and sociality is understudied. Here we use social network analysis to quantify the relationship between microbial diversity and composition and a variety of attributes of social relationships in a wild, free-living population of yellow-bellied marmots (Marmota flaviventer). Our preliminary results found no significant correlations between microbial diversity and social network measures, corroborating previous studies that in facultatively social mammals, microbial diversity is not a driving factor in the propensity towards particular social behaviors. However, future analysis of microbial composition and abundance is currently underway to understand the extent of the relationship between these two key fitness correlates.

433 Kevin Pham, Madeline Choi, Haruka Wada

Nighttime light exposure decreases blood glucose levels independent of the adrenocortical response

Organisms across taxa rely on external light-dark cues to entrain biological processes to a 24-hour cycle. As nighttime light exposure (NLE) increases throughout the natural light-dark environment, whether organisms can mount adaptive responses to maintain homeostasis and cope with an altered circadian rhythm is not well understood. Here, we exposed diurnal zebra finches (Taeniopygia guttata) to continuous light (24L:0D) for 23 days followed by a recovery period of 12 days where the light stressor regime ceased, and the light-dark cycle returned to 14L:10D with controls undergoing a consistent light-dark cycle (14L:10D). We measured plasma corticosterone, blood glucose levels, and body mass pre, during, and post treatment. We found that individuals exposed to continuous NLE had significantly increased body mass. However, after recovery, body mass returned to the pre-treatment level. Additionally, blood glucose levels secreted after 30 minutes of restraint stress significantly decreased in the continuous light group, with no alteration to the baseline blood glucose levels. After recovery, stress-induced blood glucose levels returned to pre-treatment levels. Lastly, we found no statistically significant effect of treatment on the adrenocortical response. Taken in sum, these results demonstrate that continuous NLE can lead to phenotypic adjustments of physiological traits; however, does not cause long-lasting effects on the same traits after recovery, suggesting that avian species are able to adjust and recover from to this stressor.

441 Kevin Pham, KayLene Yamada, Emma M. Rhodes, Agata Rudolf, Wendy Hood

The effects of continuous light and darkness on mitochondrial physiology and body condition

The presence of external light-dark cues entrains an organism's circadian clock to maintain patterns of physiology and behavior that vary over a 24h period. As light at night increases due to urbanization, unnatural light-dark cues can alter the entrainment of circadian rhythms. One outcome of abnormal circadian rhythms is the emergence of metabolic disorders and increased stress. Stress has been shown to cause biphasic effects on mitochondrial performance, and metabolic disorders often arise from altered mitochondrial function. Yet, the interaction between light-dark exposure and mitochondrial respiration has not been explored in depth. Thus, we sought to understand the impact of constant light and darkness on metabolic rate, mitochondrial physiology, and body condition. We divided 36, 3-to-6-month-old male and female wild-derived house mice (Mus musculus) into three groups, constant light, constant darkness, or a consistent light-dark cycle of (14L:10D) for 6 weeks. Throughout the experiment, we measured body mass, nesting behavior, and resting metabolic rate. After 6 weeks of treatment, we euthanized all animals and collected liver and skeletal muscle to measure state 3 maximum and state 4 basal mitochondrial respiration. We found sex-specific and tissue-specific effects of treatment on mitochondrial respiration in addition to differences in organ mass and oxygen consumption. In conclusion, unnatural circadian rhythms due to abnormal light-dark cues can lead to tissue-specific and sex-specific effects on mitochondrial physiology and body condition.

1190 Katherine Philipp, Catherine Harvell, Olivia Graham

Understanding the mechanistic relationship between herbivore grazing and seagrass wasting disease

Eelgrass (Zostera marina) is a marine foundation species forming critical habitats in coastal areas but is at-risk from eelgrass wasting disease (EWD). Increased disease is associated with invertebrate herbivore grazing, though the mechanism underlying this relationship is unknown. Here, we evaluated two possible explanations: different grazing patterns and simulated versus actual herbivory. First, we examined whether leaves with more, smaller grazing scars would have higher disease severity (proportion of tissue covered in disease) compared to leaves with fewer, bigger grazing scars but with the same amount of tissue loss. This was done to understand if eelgrass with a larger perimeter of simulated herbivory (more grazing scars) is at higher risk of more serve EWD. Next, we compared the severity of eelgrass exposed to isopod (Idotea resecata) grazing or simulated grazing. This was done to understand if grazing scars physically create entry points for pathogen entry into eelgrass leaves, or if isopod herbivory induces an eelgrass stress response, compromising eelgrass and making it more susceptible to infection. Little is known about the transmission of marine diseases—including eelgrass wasting disease—and this work furthers our understanding of disease dynamics in natural eelgrass meadows. Doing so, we can gain a better understanding of potential risk factors for natural meadows.

965 Jennifer Phillips, Todd Jones, Clinton Francis

Nesting near noise and light-filled nights: The fitness consequences of combined sensory pollutants

Natural rhythms are entrained by the sensory world, and 'zeitgebers' such as light and natural sounds have been encroached upon by anthropogenic light and noise as the human footprint expands. For songbirds, seasonal breeding decisions such as where to nest and when to feed are cued by light, and attracting a mate typically includes acoustic signals, making light and noise pollution evolutionarily novel stimuli in which they must adjust their behaviors, with potential fitness consequences. Here, we use a large-scale manipulative experiment that isolates light and noise from urban environments to examine how nesting decisions, daily activity of adult cavity nesting birds, body condition, and survival of offspring is affected by four sensory pollution treatments and gradients of sensory pollution: Control, Noise, Light, and Light+Noise. To test various hypotheses, we monitored a community of birds for three years. Overall, birds do not avoid sensory pollution across species, yet Light+Noise has additive negative effects on sleep, resulting in lower body condition for sensitive species like Mountain Bluebird. These changes align with patterns in nest outcomes, where nests are more likely to be abandoned in Light+Noise conditions, and Noise increases nest survival. Open-cup nesters have a significant decrease in survival with exposure to light. These results are the first to show the nuanced effects of combined sensory pollutants, which could contribute to population declines for some species.

1463 Magdalena Phillips, Jesse Granger, Sönke Johnsen

Collective Navigation by Talitrid Amphipods

Collective navigation is a common behavior in many animals. It has previously been shown that the presence of other conspecifics may improve navigational accuracy; however, research on the effectiveness of this navigational method has largely been focused on pigeons. The goal of this research is to assess how collective navigation may assist in the orientation of Megalorchestia columbiana, a talitrid amphipod native to the eastern North Pacific. Talitrid amphipods are ideal candidates for an invertebrate model system because they orient strongly towards the wrack line of coastal beaches. Their navigational abilities are based on a robust set of cue types, including visual, celestial, and magnetic. Additionally, talitrid amphipods are plentiful and easy to access in the intertidal zone. For this study, we conducted a behavioral orientation assay to test how well M. columbiana orient towards the beach in three different group sizes: individually, in groups of five, and in groups of ten.

218 Conner Philson, Daniel Blumstein

Survival consequences of group social structure in a wild free-living mammal

Engaging in social interactions has important implications for an individual's fitness in group-living species. Survival, a primary fitness correlate, is differentially influenced by the degree, rate, and context of social relationships across species, as measured by social network analysis. While many studies explore the survival consequences of the social interactions an individual partakes in directly, the role of social structure – specific attributes of the pattern of all social interactions in a group – of an individual's group has been overlooked. Social structure has been associated with fitness correlates such as reproductive success and mass gain in captive and wild animals. However, how group social structure relates to patterns of survival in animal populations is less understood. Here we explore this relationship for both summer and winter in wild yellow-bellied marmots (Marmota flaviventer), a hibernating species. On the individual social level, females who engage in more social interactions have enhanced summer survival. By contrast, more social marmots are less likely to survive hibernation. We hypothesized that marmots residing in more connected social groups would experience increased summer and decreased winter survival. Using generalized linear mixed models, preliminary results suggest individuals in more connected groups experience decreased over-winter survival. No relationship was observed for summer survival. Overall, these results suggest social structure has important survival consequences across social scales.

787 Emily Pierce, Markus Frederich

Squishy versus crunchy: physical characteristics affect invasive species detection using environment

Environmental DNA (eDNA) is commonly being used to detect cryptic or low density species, but interpreting a respective eDNA signal in detail is challenging. Previous work has shown that for some species, the eDNA signal is comparable to biomass or abundance of the target species, whereas for other species there is no correlation. Physical characteristics (such as having an exoskeleton or soft body) and metabolic rate are two likely candidates for this discrepancy. In this study, we used eDNA detection in field and laboratory samples to detect invasive invertebrate species in the Gulf of Maine. Monthly field water samples from a tide pool in southern Maine were compared to visual surveys for invasive species. Laboratory experiments used mesocosms with varying amounts of target organisms in sterile seawater. Our results suggest that for soft bodied animals such as ascidians and bryozoans, eDNA copy number is correlated with abundance in laboratory and field studies. For organisms with a hard exoskeleton such as crabs or oysters, no patterns between abundance and detectability were found. Preliminary results of a metabarcoding analysis suggest no correlation between biomass and DNA sequencing reads, but high likelihood of detection and potentially relevant insights into community dynamics. We suggest that eDNA techniques can be used for presence/absence detection, but advise caution in abundance estimates for some invasive invertebrates.

1158 Christopher Pierce, Lucinda Peng, Hang Lu, Daniel Goldman

Aperiodic Undulation in High Resistance Environments

Undulation is a common locomotor strategy found in organisms that dwell in many aquatic and terrestrial environments. In homogeneous terrain, undulators typically move via periodic waves of body bending that pass smoothly from head to tail approximating a traveling sinusoidal wave of curvature. This behavior is thought to be controlled by a combination of open-loop, neural feedback, and passive mechanical processes. Environmental obstacles or highly resistive media (e.g. highly packed soil) can perturb this process, resulting in more complex wave-like behavior. We study this phenomenon using the nematode C.

elegans in a series of synthetic, optically transparent environments inspired by the dense vegetative and soil environments where C. elegans are found in the wild. We find that viscoelastic gels of increasing bulk modulus ($\sim$1-50 nN/μm2) lead to a transition from periodic undulation to more complex behaviors, including multi-frequency undulation, interference of forward and backward waves, novel three-dimensional modes, and overall aperiodicity. To understand how these complex behaviors are controlled, we exploit C. elegans' genetic mutability to perform ratiometric calcium imaging and behavior recording for mutants with defective mechanosensation and proprioception. Our results suggest that competing feedforward commands from the mechanosensory circuit, local feedback in the motor circuit, and passive mechanical processes lead to the observed behavioral complexity.

359 Smruti Pimplikar, Felicity Muth, Jessica Buelow

A comparative test of reversal learning in queen and worker bumblebees

Many animals use learning to gain information about their environments. Learning is particularly beneficial when an environment is predictable within the individual's lifetime. However, learning capabilities vary between and within species. This may be because while information may be predictable in the short-term, longer-term environmental variability means individuals need to forget learned information that is no longer useful. This may lead to a trade-off, where individuals that learn better have greater difficulty reversing learned associations. Bumblebees are a useful system for studying this topic since individuals forage in a dynamic environment where floral resources are often predictable within a day but vary across a season. In addition, queens are better at learning rewarding stimuli than workers, allowing for an intraspecific comparison in cognition. Using a free-moving protocol in the field, we measured reversal learning in wild-caught queen ($n = 44$) and worker ($n = 24$) bumblebees. Data analyses are currently underway to ask: 1) Is there a trade-off in learning and reversing an association? 2) How does this differ between queens and workers? We expect our results will lend insight into more broadly why animals vary in their learning ability.

1532 Dakota Piorkowski, Andrew Lowe, Doug Fudge

Micro-scale mechanics of hagfish defensive slime deployment

Hagfish deploy a defensive slime when threatened that quickly and effectively clogs the gills of predatory fishes. Hagfish slime forms rapidly in natural conditions (0.1–0.4s) while undergoing a mass increase of 25,000 times from seawater uptake. This occurs as slime exudate, a combination of mucin-containing vesicles and tightly bundled protein threads (known as skeins), is ejected from specialized glands along the hagfish body and mixes with water. The mucus vesicles swell and deploy upon contact with seawater and skeins fully unravel with an expansion ratio of 1000:1 through an enigmatic mechanism that does not rely upon stored strain energy. Unravelling of skeins does not happen in isolation, and depends, in part, on the presence of deployed mucins and hydrodynamic mixing. We investigated the role of mucus in skein unravelling by probing its mechanical properties, adhesive interaction with skeins, and the forces required to peel threads from skeins. Hagfish slime mucus demonstrated high extensibility ($\sim$3000% strain), and Young's modulus (390 Pa), with a stress relaxation response typical of a viscoelastic material. Hagfish mucus is also capable of transferring sufficient forces (5–25 nN to initiate unravelling) required to unravel skein threads. These results indicate that hagfish mucus serves a vital role in the rapid formation of slime by assisting in unraveling skeins through the formation of an expansive, elastic network.

1376 Jacob Pithan, Joseph Rinehart, Kendra Greenlee, Giancarlo López-Martinez

Oxidative damage and age-related declines in locomotion

Aging is a progressive deterioration of physiological functions which impairs an organism's ability to maintain homeostasis, and leads to function senescence and death. The oxidative damage theory of aging postulates that an imbalance between the production of reactive oxygen species (ROS) and the body's antioxidant defense, leads to age-dependent accumulation of damage in macromolecules (lipids, proteins, and DNA), which progressive deteriorates physiological functions and advance aging. Most of our current knowledge about aging mechanisms stems from model organisms, however, focusing on a few species ignores aging mechanisms regulators, and plasticity. Insects offer a needed insight into aging due to phenotypic plasticity, high-levels of activity, and aging intervention. In this study we aim to further understand the role of oxidative damage on aging and locomotion senescence using the solitary bee, Megachile rotundata. We hypothesized that M. rotundata experience age-related performance declines, due to increasing oxidative damage and reduced antioxidant capacity. Adult M. rotunda were reared from emergence and tested at day 0, 7, 14, or 21. For each age group walking performance was assessed using a locomotion activity monitor (LAM) and flight performance was measured using a cylinder drop assay. Oxidative damage was measured for lipids (TBARS), proteins (protein carbonyls), and DNA (ELISA) using whole individuals. Antioxidant capacity was estimated using a TEAC assay.

436 Amanda Platt, Kristen Whalen, Marta Wilbrink

Designing a bacterial biosensor to detect chemical signals within the phycosphere

Bacteria and phytoplankton participate in nutrient and chemical exchanges that impact both species at the cellular level and have broader impacts on marine ecology. We focus on interactions between Pseudoalteromonas and the globally-relevant coccolithophore Emiliania huxleyi which plays a central role in nutrient cycling and marine food web stability. Co-culture imaging shows that Pseudoalteromonas and E. huxleyi form close associations and recent studies have started to detangle the complex chemical interplay between these species. This work focuses on the role of bacterial quorum sensing molecule 2-heptyl-4-quinolone (HHQ) within bacteria-phytoplankton interactions. HHQ has primarily been studied in Pseudomonas aeruginosa where it modulates expression of genes involved in biofilm formation and virulence factor production. However, recent work shows that Pseudoalteromonas is capable of producing HHQ and that this bacterial quorum sensing molecule induces cellular stasis in E. huxleyi, conferring protection from viral induced mortality. While these effects have implications for cellular fitness, and in turn flow of nutrients within marine systems, the amount of HHQ present within the phycosphere (the nutrient-rich environment surrounding phytoplankton cells) and the conditions that induce its production are not known. To answer these questions, we constructed a bacterial biosensor to monitor microscale changes in HHQ concentration within Pseudoalteromonas and E. huxleyi co-cultures. Developing technology to probe the chemical landscape of the phycosphere is an important step toward linking cell-cell interactions with their larger ecological consequences.

1689 Theodora Po, Matt McHenry

The collective and central control of locomotion in sea stars

Locomotion in sea stars is achieved through the coordination of hundreds of tube feet by a nervous system that lacks a brain. We tested how this behavior was generated by local reflexes and centralized control through experimental manipulation and mathematical modeling of one species (Protoreaster nodosus). In response to an experimental increase in submerged weight, these animals elevated the number of tube feet recruited per powerstroke. We successfully replicated this result with an agent-based mathematical model that lacks centralized control, suggesting that tube-foot recruitment emerges from the collective dynamics of the tube feet. In other experiments, sea stars exhibiting negative phototaxis changed their heading by altering the power-stroke direction of all tube feet. These directional changes were exhibited in an experimental preparation where the feet were not coupled to the substrate. These findings suggest that central control is unnecessary to respond to variable loading, but plays an essential role in the directional control of locomotion.

628 Katya Podkovyroff-Lewis, Kaedan O'Brien

Bulk vs Serial Sampling in 13C, 18O, and 87Sr/86Sr Isotopic Analysis of Fossil Herbivore Teeth

Reconstructions of paleoclimate and paleoecology using stable isotopes of carbon, oxygen and strontium have become fairly common around the world. However, due to cost and effort, the vast majority of studies analyzing these elements utilize cross-sectional (bulk) sampling, rather than incremental (serial) sampling. Previous studies have shown that there are systematic offsets in values between the two methods, and quantifying these differences across different taxa within an ecosystem adds valuable information for future stable isotope research. In this study, we determine the extent to which information is lost about an individual's diet, water intake, and movement when bulk, rather than serially, sampling along the growth axis of mammalian molars. We do this through the evaluation of samples taken from bovid and equid fossils dating to the Late Pleistocene of southern and western Kenya as a part of a larger project tracking seasonality and migration in eastern Africa from 100-12 ka. Our results for carbon, oxygen, and strontium isotopic analyses indicate that caution is needed when evaluating bulk sampled isotopic samples, as the majority of information stored in each tooth either remains unsampled or is averaged into a single neutral value, erasing information about seasonality and intra-year movements. This has strong implications for both how new research should best be conducted and how paleoecologists should interpret previous studies utilizing bulk sampling.

192 Delyle Polet, Jim Usherwood

Mass distribution effects on optimal gait in quadrupedal rimless wheels

Passive dynamic walkers use no motors and instead are powered by a shallow slope. They have illuminated mechanisms of economical locomotion in bipeds, but have been underutilized to understand quadrupedal locomotion. Here we use 2D and 3D simulations of passive dynamic quadrupedal rimless wheels to examine the effect of moment of inertia about the center of mass on gait choice. We compare the optimal gait (minimizing slope, or maximizing speed for a given slope) to those of mammals with similar mass distribution. We confirm that a phase offset between hind and forelimbs is optimal for low pitch moments of inertia, while in-phase gaits (e.g. trotting) are optimal for high pitch moments of inertia. We search for similar effects by varying moment of inertia in other dimensions, and explore whether these explain variation in limb phase among mammals.

1715 Sydney Popsuj, Alberto Stolfi

Examining the Role of Dkk3 in Wnt Regulation during Ascidian Neurodegenerative Events

The Wnt pathway is a driver of evolutionary change as well as disease onset and progression in humans, however it can be very difficult to contextualize and study given its many regulatory genes. One such gene is Dkk3, the most divergent member of the Dickkopf family of Wnt inhibitors. Dkk3 is tied to Alzheimer's and dementia disease progress yet it also plays significant neuroprotective and apoptotic roles in cancers and strokes. Understanding the contexts through which Dkk3 regulates the Wnt pathway in neurodevelopmental and neurodegenerative events could provide insights into the nuances of the wnt pathway that have eluded researchers.Work in ascidian model systems has shown promise for further understanding the regulatory role of Dkk3 within the Wnt pathway. As biphasic lifestyle animals, ascidians have a stereotyped and programmed neurodegenerative event during metamorphosis. Therefore, they are ideal candidates to study regulation of neural remodeling events. Comparative work between Ciona robusta and tailless Molgula occulta, has identified sets of differentially expressed genes within the Wnt pathway which may contribute to evolutionary differences in life history, tailed phenotype, and neurodegeneration during metamorphosis. Through creation of fluorescent reporters specific to Dkk3 and other Wnt-associated genes, CRISPR-Cas9 mediated knockouts, and analysis of binding competencies between candidate genes, we can assess the contexts through which Dkk3 influences major neurodevelopmental, neurodegenerative, and neuro remodeling events through regulation of Wnt.

652 Landon Porter, Scott Juntti, Cheng-Yu Li, Hans Hofmann

Does knocking out the V1a2 vasopressin receptor impair social dominance in a highly social cichlid?

Most animals navigate dynamic social environments that require context-appropriate decision-making to ensure survival and maximize fitness. The neuromolecular mechanisms underlying these processes have been studied in detail. For example, across vertebrates, the nonapeptide arginine vasopressin (AVP) and its receptors regulate diverse social behaviors such as aggression and affiliation, yet a general framework of AVP's role in social decision-making is lacking. The AVP V1a2 receptor subtype has been implicated in transforming socially salient experiences into long-lasting changes in brain function and behavior. In Burton's Mouthbrooder cichlid fish, Astatotilapia burtoni, AVP is differentially regulated in socially dominant and subordinate males, and affects the ability of an animal to ascend in social status. Similarly, the teleost V1a2 receptor subtype is widely expressed throughout the evolutionarily conserved Social Decision-Making Network (SDMN), further indicating this pathway in regulating social behavior. Here, we first used immunohistochemistry to test the hypothesis that V1a2 expression throughout the SDMN is dependent on social status. We then employed CRISPR-Cas9 mediated knock-out of the V1a2 gene to test the hypothesis that V1a2 mediates social dominance behavior. While analyses are ongoing, our results suggest that the V1a2 AVP receptor subtype is critical for regulating social behavior in this species. By examining the role of specific receptors within these ancient nonapeptide systems, this work furthers our understanding of how social behavior is modulated within the brain.

254 Kelsie Pos, Patricia Hernandez

Characterization of the muscle architecture of the zebrafish palatal organ and pharyngeal jaw

Zebrafish, used as a popular model system for studying conserved vertebrate morphogenesis, are also exceptional for examining the origin of trophic novelty. The palatal organ, a muscular pad found along the roof of the pharynx, is composed of an entangled mesh of fibers of varying diameters and lengths. While the function of this structure is unknown in zebrafish, in goldfish contractions of these muscles form protrusions that assist with food selection. Muscle fiber orientation within the palatal organ is strikingly different from parallel-fibered skeletal muscle found elsewhere in the body. Although likely derived from the same progenitor population, pharyngeal jaw and palatal musculature is very different. Preliminary data collected using a new type of transmission electron microscopy (which facilitates examining a broader region of interest) suggest that the palatal organ has an entirely unique ultrastructure, yet to be fully described. Two types of muscle fibers have been previously distinguished where the presence of triads is at either the Z-lines or A-I bands, resembling cardiac or skeletal muscle respectively. Indeed, the single nuclei that characterize these muscle fibers are most like smooth and cardiac muscle, while the thinnest fibers most closely resemble extraocular muscles. Here, we present a multi-level characterization of muscle ultrastructure of the novel palatal organ, where characteristics of all three basic types of vertebrate muscle appear in this single muscle type.

59 Caroline Potter, Shannon Gerry, Will Robinson

Relating variation in morphology and maneuverability of juvenile bluegills

Bluegill sunfish (Lepomis macrochirus) are typical freshwater fish found in lakes and ponds.Previous research has shown that adult bluegills diverge in their body shape andswimming ability based on habitat. Littoral fish have deeper bodies with larger fins to aidin maneuverability, while pelagic fish have more streamlined bodies for steady swimming.Adults of each ecomorph nest in the littoral zone, but it is not known what causes somejuveniles to move to the pelagic habitat. The goal of this study was to induce morphologicaldivergence by rearing fish in two habitats, simulated littoral and simulated pelagic, and testfor differences in their morphology and maneuverability performance. We hypothesizedthat juveniles raised in a littoral habitat would be comparable to adults: they would havedeeper bodies and broader fins to better navigate through an obstacle course, as comparedto pelagic fish. The snout and center of mass of each fish were tracked to quantify velocitiesand accelerations. Individuals were photographed for morphological analysis. Neithermorphology nor performance differed between ecomorphs ($P > 0.05$). Therefore,morphological divergence and performance were not induced by rearing juvenile bluegillsin two different habitats.

121 Emily Poulin, Jonathan Huie, Jules Chabain, Karly Cohen, Matthew Kolmann, Christopher Martinez

Making a point: exploring the form and function of stingray spines

Defensive spines are widespread across the animal kingdom – examples include thorns, sea urchins' spikes, and porcupine quills. Spines are an especially important adaptation for stingrays (Suborder: Myliobatoidei). Stingrays have spines on their tail that are adapted to inflict mechanical and molecular damage to tissues during both puncture and removal through laceration, envenomation, and infection. Spines are highly diverse in their morphology among stingrays, suggesting a trade-off in defensive performance against different casts of predators in different environments, for which puncture and removal may play a role. The spines of marine rays are often found broken-off and embedded in the tissues of predators, while this is not observed among predators of freshwater rays. To compare dynamic withdrawal performance among habitats, we micro-CT scanned, 3D printed, and set in ballistics gelatin spines from freshwater (Potamotrygoninae) and saltwater (Urotrygonidae, Dasyatidae) stingrays. We built a pendulum to replicate the ballistic withdrawal likely exhibited in life, measuring the force and work required to remove each embedded spine. We compared force measurements to spine morphology in marine and freshwater taxa including the moment of inertia which accounts for spine deflection. Our analysis of the 2nd moment of area found that spines of freshwater stingrays were significantly stiffer than spines of saltwater rays. Additionally, each of the three stingray orders examined produced distinct patterns of damage that were consistent across genera.

1618 David Pounders, Kayla Fast, Michael Sandel

Population genomic structure of the Everglades Pygmy Sunfish yields evidence of vicariant speciation

The Everglades Pygmy Sunfish (Elassoma evergladei) ranks among the smallest and least-understood freshwater fishes with a wide distribution in North America. This species has potential to have pockets of overlooked populations with high Fst values. To date, no study has systematically assessed morphological or molecular genetic variation across the species geographic range, which includes minor coastal watersheds from Alabama to North Carolina. Sampling was completed so nearly all populations can be analyzed, including different ecoregions within the coastal plain. We used mitochondrial cytochrome b (CYTB) DNA sequences and double-digest Restriction-site Associ-

ated DNA sequencing (ddRADseq) to characterize genomic variation among 100 populations across the species range. We also used trypsin-cleared and stained specimens to examine osteological variation among populations. Our analyses reveal strong population-genetic structure across even locally isolated watersheds, and yield evidence for vicariant speciation across the northern Gulf Coastal Plain. This work highlights the need for continued investigation of intraspecific genetic variation among North American freshwater fishes. Results of this work will aid in the development of conservation plans for this wetland adapted species with strong population genetic structure, which are rapidly threatened by anthropogenic habitat disturbance.

1440 Maya Powell, Verena Schoepf, Sarah Solomon, Chris Lippens, Anastasia Dulskiy, Karl Castillo

Coral algal and microbial communities in extreme environments provide insights into reef resilience

Coral reefs are crucial to global biodiversity, cultural heritage and local economies. The fragility of coral reefs makes them vulnerable to climate change and a high research priority. Corals that reside in extreme, high-temperature environments will provide insights into how corals will cope under future ocean conditions. Inland bays in Curaçao exemplify these conditions and show uniquely elevated and variable levels of temperature and other local stressors. Microbiome restructuring is one of corals' quickest defenses against these environmental stressors, and it has yet to be explored in these extreme environments. This study aims to understand coral-microbial and symbiont interactions and their role in mediating coral stress tolerance and acclimatization across environmental gradients in Curaçao. Holobiont samples of Siderastrea siderea and Porites furcata were collected from inland bays and fringing reefs in Curaçao. Although sample analyses are ongoing, a previous study showed that symbiont composition in S. siderea was variable across three thermal regimes. We hypothesize that: 1) corals from inland bays will have higher proportions of stress-resistant microbial taxa compared to conspecifics from fringing reefs, and 2) corals will have a core composition of essential bacteria and a broad diversity of species- and symbiont-specific microbes. Results will provide a framework for assessing and predicting future Caribbean coral health, microbiome and symbiont correlation, and acclimatization capacity, furthering global knowledge of coral-associated microbial genetics.

1001 Megan Powers, Billie Swalla

Assessing Ascidian Invasion in the Salish Sea

Ascidians, or "sea squirts", are tunicates with a sessile adult stage and a swimming tadpole-like larval stage. Ascidians are dominant competitors for space and able to travel long distances on ship or barge hulls, in ballast water, or as epibiota on imported bivalves and aquaculture gear, and they can often tolerate wide fluctuations in temperature, salinity, and pollution. These qualities make them incredibly successful invasive species worldwide and have the potential to make them better competitors as the climate rapidly changes. Nineteen nonnative ascidian species inhabit the US Pacific coast, and six species had been reported as invasive within the Puget Sound by the year 1998. We hypothesize that climate change and human activities like shipping and aquaculture have caused the spread of invasive ascidian species to new locations throughout the Salish Sea in the past 20 years. We surveyed marinas in Washington, USA to assess the current distribution of native and invasive ascidians within the Salish Sea and to determine how many new nonnative species have arrived in the Salish Sea and how far invasive populations have extended within the Salish Sea in the past two decades. Current survey results will be reported for the Salish Sea.

535 Vivek Prakash

Tissue mechanics govern plastic shape changes and asexual reproduction in a simple animal

In animals, epithelial tissues mainly provide a barrier function, but these tissues are also subjected to extreme strains during daily activities such as locomotion. From a materials science perspective, how the properties of living cells and their small-scale interactions determine larger-scale tissue rheology in dynamic force landscapes is an area of active study. We complement this research by carrying out a multi-modal study of the locomotion in a simple yet highly dynamic marine animal, Trichoplax adhaerens, that lacks both muscles and neurons. We report the discovery of abrupt, bulk epithelial tissue fractures and healing induced by the organism's own motility that cause dramatic plastic shape changes and physiological asexual division. By developing a suite of quantitative experimental and numerical techniques, we demonstrate a force-driven 'ductile-to-brittle' transition in these tissues.

495 Archana Prakash-Kalpana, Pete Hurd

Stress effect on sex ratio, and transgenerational stress effects on a West African Cichlid fish

Environmental sex determination (ESD) is a phenomenon in which the sex of an individual is determined after conception, in response to environmental influences. Though sex allocation theory predicts an even allocation of sex, i.e. a 1:1 ratio, ESD is often related to biased sex ratios. ESD is thus one of the distinctive examples of phenotypic plasticity, the potential of an individual genotype to generate different phenotypes depending on the environmental conditions. Previous studies have identified fish species with ESD in response to environmental factors including salinity, dissolved oxygen, and temperature. In our model system, Pelvicachromis pulcher, previous research has found that pH exposure during the early stage of development influences both the sex ratio and proportions of alternative male morphs. Here we investigate the influence of early-life stress exposure on the sex ratio and male morphs. Exposure to stress in early life can have lifelong influence on morphology and behavior. This phenotypic plasticity may be, which can significantly affect the activities crucial for survival. Here, we are also interested in assessing the transgenerational effects of stress on the behavioral syndrome in adult P.Pulcher.

840 Samantha Price

Are evolutionary regression slopes shallower at lower taxonomic levels? A study using teleost fishes

It is commonly reported that taxonomic level influences evolutionary regressions, with slopes found to be shallower at lower taxonomic levels. This taxonomic scale-dependency has been attributed to a variety of causes, including selective forces acting differently on the two traits over evolutionary time as well as artifacts, such as measurement error, evolutionary lag or maladaptation. However, there is surprisingly little empirical evidence to support the expectation that regression slopes vary predictably with taxonomic level. The pattern appears to have been primarily derived from studies of brain-body size allometry in clades of mammals. An investigation of life history allometry found shallower slopes at lower taxonomic levels in mammals but the opposite pattern in lizards. I investigate how allometric slopes vary within and between teleost genera, families and orders using body shape data on approximately 6,000 species. Using phylogenetic regressions my preliminary analyses reveal that the allometric slopes between standard length (a measure of size) and body shape traits do not change predictably with taxonomic level. Like previous analyses I find that many taxa exhibit an isometric relationship, although this varies considerably across the phylogeny. These results suggest that taxonomic scale-dependency of regression slopes is not universal and should be empirically tested rather than assumed.

917 Amanda Price, Jonathan Perez

The behavioral response of Eastern Bluebirds (Sialia sialis) to simulated nest predation

Avoidance of predation is critical for survival. In species where the young are largely helpless, anti-predator behaviors exhibited by parents may play an important role in the protection and survival of offspring. For altricial songbird nestlings, the threat of predation peaks in adolescence, making them dependent on parental care for survival. Parental behaviors that effectively reduce predation rates on young and increase reproductive success are expected to be strongly selected for, leading to specialized adaptations to commonly encountered predators. Conversely, such adaptations may be sub-optimal or non-existent in the face of invasive or non-historical threats. In this study we used Eastern Bluebirds to explore how anti-predator behavior in response to historic and a more evolutionarily recent nest predator may vary and how these differences may change across the nestling period. We assess anti-predator behavior of parents in response to four simulated predator stimuli: control (no threat), House Sparrow with song, House Sparrow without song, and a dummy snake. Preliminary analysis of our data suggests that the visual cue of a predator alone is insufficient to elicit a strong anti-predator response from parents, however the addition of an auditory stimulus to the novel House Sparrow predator resulted in increased incidence of anti-predator behaviors. This suggests that multiple factors contribute to how passerine birds recognize threats and modify their behavioral responses.

1462 Bennett Price, T. Erin Cox, Kelly Boyle, Amanda Kirkland, Dakota Brunetti

Red Drum calling behavior interactions with vessel noise at Panama City beach, FL, U.S.A.

Red Drum (Sciaenops ocellatus) exist along North America's east coast and northern Gulf of Mexico and produce sound in spawning aggregations in coastal waters. These coastal regions can also experience frequent commercial and recreational vessel traffic and resulting noise pollution is predicted to negatively impact sound producing fishes like Red Drum. Noise pollution can increase hearing thresholds, damage sensory epithelia, and alter behavior. We aimed to determine if vessel noise changes Red Drum calling behavior, masks calls, or both. During 2021 and 2022, we obtained vessel noise and fish sounds via passive acoustic recorders in Saint Andrews Bay, Panama City Beach, Florida. Red Drum sounds occurred frequently at this site [ec2] during spawning season (June - November). Red Drum calling peaks immediately after sunset and we found significant overlap between chorusing and vessel noise during this calling period (0-2 hours post-sunset). Preliminary data shows intense vessel noise ($>$130 dB re: 1μPa) occurred during calling periods on 54% of evenings and, when present, persisted for 20+16% (mean+SD) of calling periods. We are testing the contribution of call pulse number, vessel noise, and sound pressure level with a linear model. Results (in progress) indicate Red Drum decrease call rate when intense boat noise occurs and calls are masked ($p = 0.013$, $r^2 = 0.3$). This suspected behavior modification and subsequent call masking could decrease spawning success and impact fitness.

434 Paul Proctor, Nerida Wilson, Andrew Hosie, Ana Hara, Greg Rouse

Phylogenetics of Swimming Acrocirridae (Cirratuliformia, Annelida)

The discovery of deep-sea swimming worms within the primarily benthic Acrocirridae represents one of three origins of pelagicism within Cirratuliformia. This study represents the first use of mitogenomic data to construct an acrocirrid phylogeny. In 2020, expeditions using the R/V Falkor and ROV SuBastian collected fourteen specimens of swimming acrocirrids at around 2000 meters depth from the Perth, Hood, and Ningaloo Canyons of Western Australia. We used morphology and new sequence data from the whole mitochondrial genome; mitochondrial cytochrome c oxidase subunit I, cytochrome b, 16S rRNA; and nuclear 18S rRNA and 28S rRNA to conduct phylogenetic analyses. Phylogenetic analyses revealed a new record of Swima tawitawiensis and four previously undescribed species. We describe a new species of Swima and a new species of Teuthidodrilus. Also, we identify a need to either expand Swima to include the other two novel species or restrict Swima to preclude their addition into Swima. Our results align with previous analyses on the phylogeny of Cirratuliformia that found a single evolutionary origin of pelagicism in Acrocirridae. Further, this study represents the first phylogenetic evaluation of Acrocirridae using mitogenomic data, improving our understanding of the evolutionary transition from benthic to pelagic within Cirratuliformia.

1217 Melissa (Misty) Proffitt, Tara Empson, Rachel Evans, Kayci Messerly, Susanna Tsueda, Kimberly Rosvall, Elizabeth Derryberry

Early Postnatal Heat and the Potential for Carryover Effects: an Experimental Approach in Wild Birds

High temperatures are the new norm as heat waves increase in number, intensity, and duration. Experimental approaches demonstrate that acute heat engages behavioral and physiological thermoregulatory mechanisms in songbirds. What is not known is the extent to which these heat events have carryover effects. Here, using free-living songbird nestlings (tree swallows, Tachycineta bicolor), we tested the extent to which a prior acute heat challenge had a lasting effect on gene expression of heat shock proteins (HSP). We also evaluated whether there are key developmental windows for any carry-over effects. We focus on two key time points in the nestling period, including postnatal day 6, when chicks are at their peak of growth, and day 12, when chicks reach their asymptotic mass. We also quantified behavioral thermoregulatory responses at the individual-level, and we explored how these behavioral mechanisms interacted with any HSP responses. Understanding the temporal scope and internal mechanisms by which birds respond to heat challenges will generate important insights into how populations may respond to our warming world.

1208 Richard Prum

The Performative Phenotype: A Queer-Feminist Model of the Genotype-Phenotype Relationship

The genotype-phenotype distinction was established to facilitate experimental research in genetics, but contributed to sidelining developmental biology from evolution in the 20th century. Developmental evolutionary biology has contributed greatly to understanding novelty, modularity, robustness, etc., but the field has not yet displaced/replaced the problematic traditional model of the genotype-phenotype relationship. The queer feminist theory of gender performativity provides a detailed intellectual model of individual development that is precisely and productively applicable to molecular, developmental, and evolutionary biology. Performative refers simultaneously to the individual self as an historically contingent, context dependent performance, and to the linguistic category of non-representational speech acts– e.g. I promise you…– expressions that are doings in the world rather than descriptions of it. Both senses of performative have precise applications to gene expression and organismal development. Occupying a queer intellectual space between Butler, Barad, Waddington, and Nüsslein-Vohlard, a performative theory of the phenotype proposes that the organismal body is the material enactment of the organismal self, realized through molecular/physical discourses among a hierarchy of molecular, cellular, tissue, and anatomical agents. Many elements of performative theory– including agency, discourse, citationality, constraint and innovation, distributed power relations, and hierarchy– provide a predictive framework for the analysis of with molecular genetics, developmental biology, and evolution. Biological performativity will be presented using examples from human and vertebrate sexual and genital development. Phenotypic performativity implies that there is no fact of individual organismal sex indepedent of, or prior to, its material becoming in the world. (Prum 2023. Performance All the Way Down. Univ. Chicago Press, Forthcoming).

173 Agnish Prusty, Payel Chatterjee, Sanjay Sane

The sensorimotor apparatus for head stabilization in the Oleander hawkmoth Daphnis nerii

In walking or flying insects, compensatory head movements are essential to ensure gaze stabilization. These head movements are carried out by an elaborate sensorimotor system that senses and integrates multisensory stimuli from the ambient world, and generates appropriate motor responses to actuate the neck muscles spanning their head and prothoracic segments. Along with vision, vestibular feedback from the mechanosensory system is essential for generating compensatory head movements. In Diptera, mechanosensory feedback is derived from halteres which sense body rotations during flight and the prosternal organ which senses rapid head movements. However, we know relatively little about how multisensory inputs are obtained and integrated in non-Dipteran insects which lack halteres. Specifically, in nocturnal insects such as moths, the long latency for visual transduction means that the mechanosensory feedback system is essential for guiding rapid compensatory head movements. We conducted a detailed study in the nocturnal hawkmoth Daphnis nerii to determine the sensorimotor apparatus underlying the neck motor system. Our anatomical study shows that the neck motot apparatus comprises of at least 11 pairs of neck muscles. Systematic backfills of neck motor neurons revealed that their soma are located in the sub-esophageal zone and prothoracic ganglia.Additionally, we describe the putative neck prosternal organ and its projection patterns. These data provide a detailed picture of the neck sensorimotor apparatus and its role in generating compensatory head movements.

1536 Adam Puchalski, Alexandre Palaoro, Kostya Kostya

Insect antennae: coupling morphology with mechanics

Insect antennae are hollow, blood-filled fibers with complex shape. Muscles in the two basal segments, pedicel and scape, control antennal movement, but the rest (flagellum) is muscle-free. Modified chordotonal organs called Johnston's organs are embedded in the pedicel-flagellar joint and are extremely sensitive to small flagellar deformations. To probe its environment, the insect can controllably flex, twist, and maneuver its antennae laterally by coupling mechanical deformations with sensory input from Johnston's organ. We question how small deformations at the distal part of antenna could be transferred to the pedicel-flagellar joint. A comparative study was conducted to understand the mechanical performance differences among the Manduca sexta, Ceratomia catalpae hawkmoths, and Periplaneta americana cockroach. We discovered anisotropy in bending properties of the antennae when bent dorsally and ventrally. We further studied these phenomena to reveal that in hawkmoths, which antennae are pectinated and complex-shaped, insignificant antennal bending in the dorsoventral plane results in antennal twist. Dynamically, this transition from inplane bending to out of plane twisting significantly amplifies antennal deformations as demonstrated by the high-speed videography. These observations of unique instability question the current use of the rigid rod model of antennae and the textbook explanation of its mechano-sensory coupling.

1438 Joshua Pulliam, Giovanni Morris, Sydney Haywood, Zoe King, Jeffery Anderson-Jr, Jerry Wong, Beckett Socha, Ulmar Grafe, Salwa Khalid, Jake Socha

Reach for the skies: Effects of perch diameter on vertical gap crossing of snakes

Arboreal animals must move and maintain balance in environments with substrates that vary in diameter, surface texture, and compliance, as well as distance between supports. As limbless animals, snakes must grip the substrate with one part of the body while reaching with the remainder. Although previous studies have examined how snakes navigate horizontal gaps, few have explored the challenges associated with vertical gaps. Here, we investigated how perch diameter affects vertical gap-crossing ability in two species of snake, Dendralephis pictus and Ahaetulla prasina. In 174 trials, snakes were recorded crossing vertical gaps between two horizontal perches using 4 synchronized cameras. The radius of curvature of the origin perch was varied from small to infinite, modeled using three PVC pipes and a wooden plane. The target was a pipe wrapped in plastic foliage to provide visual incentive for crossing. Based on preliminary analyses, the average maximum vertical height attained was similar between small, medium and flat substrates across both species, ranging from 53-60% and 36-41% SVL in A. prasina and D. pictus, respectively. By contrast, snakes reached much lower heights on the largest-diameter pipe, 23 and 31% SVL, respectively. Future work will incorporate motion-capture recording to analyze the dynamics of balance of a semi-rigid flexible rod. This research was supported in part by the National Science Foundation under grant numbers 1922516 and 2027523.

87 Judit Pungor, Angelique Allen, Jeremea Songco, Cristopher Niell

Visual response properties and functional organization of the octopus optic lobe

Cephalopods have remarkable eyes that instruct a rich repertoire of visually guided behaviors, from hunting prey and avoiding predators, to finding mates and communicating with conspecifics. Although superficially similar, the camera-type eyes of cephalopods and vertebrates emerged independently, resulting in one of the most stunning examples of convergent evolution. Despite the enticing complexity and tremendous capability of this visual system, relatively little is known about visual coding in cephalopods, as there has been no direct measurement of the visual response properties of neurons in the central visual system. In this study, we aimed to identify the visual features extracted by the octopus visual system using calcium imaging. We presented an array of visual stimuli and recorded the response dynamics of hundreds of cells across multiple layers of the optic lobe. We found that cells have spatially localized receptive fields, and many are selective for distinct features of the stimuli, including luminance polarity. Furthermore, we found a retinotopic organization of response to stimuli across the optic lobe and patchy organization for On/Off preference. These data are the first measurements of functional circuit organization in the central visual system of cephalopods and provide a foundation to study how the octopus brain performs the computations necessary to guide visual behavior.

1789 Laksh Kumar Punith, Emily Abbott, Gregory Sawicki

Dynamic Muscle Properties Enable Rapid Recovery From Terrain Perturbations Without Neural Control

Legged animals traverse complex terrestrial environments with incredible stability. They do this despite having large neural delays in their controllers that render high-bandwidth closed loop control impossible. Instead, they embed self-correcting properties in the emergent mechanics of their limbs. Ultimately the adaptive behaviour of the limbs needs to arise from their muscle-tendon units. To test this hypothesis directly, we attached the plantaris longus muscle-tendon unit from 5 American Bullfrogs (Lithobates catesbeianus) to a novel biorobotic interface that emulates hopping in gravity through a single joint/muscle. We cyclically stimulated the muscle to generate hopping. Once the hopping settled to a steady state, we suddenly raised/dropped the height of the ground by one of four heights (+0.5H, -0.5H, -1H and -1.5H, where H is the apex height of the mass in steady state). We measured the amount of work done in the 3 steps after the perturbation. We compare the behaviour of muscle-tendon units with an 'ideal' actuator that stabilizes the system in one hop and the estimated Hill-model of the muscle. In this study, we found that biological muscle-tendon units in vitro can rapidly reject perturbations across a broad range of terrain perturbations without neural control. Since the Hill model grossly underestimates the forces of real muscles, we also show that dynamic muscle properties enable self-stability. Future studies need to mechanistically model dynamic muscle properties to determine the source of self-stability.

1065 Jain Pushpalatha-Krishnan, Manjari Jain, Richa Singh

Sound perception in a field cricket (Acanthogryllus asiaticus) and the effect of traffic noise.

Crickets are nocturnal insects known for their loud and conspicuous calls.The response of female crickets in the form of movement towards the sound is called phonotaxis. Duringphonotaxis, females may consider various temporal and, or spectral parameters of calls and its loudness for choosing their potential mate. One major factor that determines the detection of call is its loudness, while recognition typically involves a combination of temporal and spectral features of the call. The minimum sound pressure level at which the receiver behaviourally responds to the calls of a sender is called the behavioural hearing threshold.In this study, I have examined the Behavioural Hearing threshold of the females of Acanthogryllus asiaticus, a field cricket, in ambient and traffic noise conditions to examine whether and by how much traffic noise could alter detection thresholds of mating signals in the insect. The study also examined effective signal transmission, female preferance based on the loudness parameters. The findings suggest that, there is a significant shift in female cricket's behavioural hearing threshold in precence of traffic noise. The study has important implications on the signalling system in this field cricket species from both the sender and receiver perspective.

707 Ruchao Qian, Jamie Theobald

The visual influence of swaying behavior of praying mantises

Among Mantodea, the majority of the species have magnificent body camouflage to help hide from predators and ambush prey. These mantises usually resemble structures of plants in their habitats, such as leaves, grasses, branches, flowers or tree trunks. Praying mantises mimicking leaves, grasses and branches sometimes display a rhythmic pendulous movement sway, their body from side to side, especially in response to wind, while this behavior has never been observed in the species that mimic tree trunks or other stationary elements. We hypothesized that this swaying behavior functions as motion camouflage to the moving background environment. We used visual moving backgrounds to trigger swaying, and compared the swaying pattern among 4 mantis species with different types of mimicry. Our findings show that the visual cue is sufficient to stimulate the swaying behavior in mantises, and the species with different types of mimicry exhibit distinct swaying frequencies.□

1166 Adam Quade, Guillaume Rieucau

Fluctuations in floodplain hydrology and connectivity elicit topological shifts in fish schools

Anthropogenic modifications such as levee construction and flood control structures have decoupled the floodplain from the Mississippi River, disrupting biogeochemical cycles and trophic stability. Numerous freshwater fish species rely on the timing, magnitude, and duration of the Mississippi River flood pulse to trigger key aspects of their life history. Variation in schooling tendency commonly observed in response to environmental factors, predation risk or anthropogenic disturbance strengthens the idea that fish schools display a high degree of behavioural and structural plasticity. School-level modifications are thought to reflect changes in the way shoaling fish balance their fitness tradeoffs; school structural flexibility considered an adaptation improving information transfer among school members. Recent research has demonstrated shifts in school area, speed, and polarization in response to turbidity, temperature, and habitat complexity, even under low to no predation risk. In complex and highly dynamic environments such as floodplains, it is important to assess how schooling fish assess and respond to the rapid and unpredictable variations in environmental conditions (e.g., pulse of floodwater) they are exposed to. Combining non-invasive high-resolution imaging sonar and advanced tracking technology we quantified how floodplain-associated schooling fish adjust their schooling tendency across a latitudinal gradient of hydrologic connectivity in the Mississippi River floodplain. Our preliminary results indicate that the degree of floodplain inundation strongly affects school topology even under limited predation pressure.

1468 Zachary Quigley, Jonathan Huie, R. Pyron, Sandy Kawano

Kinematic variation in ecologically diverse Desmognathus salamanders during terrestrial locomotion.

Salamanders are ecologically diverse and range from aquatic to terrestrial. Most have a generalized tetrapod Bauplan but can exhibit morphological differences due to ecology. We hypothesize that differences in locomotor performance vary with microhabitat use. Dusky Salamanders (Desmognathus) are noteworthy in this context because the degree of terrestriality often differs between closely related sympatric species. Locomotor kinetics from other genera indicate that semi-aquatic salamanders have more laterally spread (‘hyper sprawled’) limbs with limited ability to protract compared to terrestrial salamanders. We predict that species with more aquatic lifestyles will exhibit more sprawled postures with limbs that are more abducted and retracted. We quantify the 3D kinematics of forelimbs and hindlimbs from fully aquatic to mostly terrestrial Desmognathus species: D. marmoratus, D. kanawha, D. monticola, D. fuscus and D. conanti. The joint angles at the shoulder, elbow, and wrist are similar between the three most terrestrial species and differ from the two more aquatic species, which have greater excursion. The most aquatic species also used more axial movements (pitch and yaw). The largest interspecific differences occurred in the hindlimb, which is the primary propulsor, with marginal effects due to speed. Kinematic variations between species could be due to the multi-functional roles of limbs for various locomotor and non-locomotor behaviors. More ecologically relevant scenarios are needed to develop biomechanical models of dispersal capabilities and diversification of salamanders.

496 Phoenix Quinlan, Paul Katz

The nudibranch Berghia stephanieae uses visual cues for navigation

Nudibranch molluscs have structurally simple eyes and their behavioral roles have not been established. We tested the effects of visual stimuli on the behavior of

Berghia stephanieae and provide evidence that visual cues are used for navigation. When placed in a circular arena with a visual target on the wall, Berghia approached a vertical stripe that was at least 15º wide and 50% darker than the background. Animals most reliably approached a stripe of 45º, while stripes thinner or wider than this were approached by fewer animals. Berghia did not approach a stripe that was lighter than the background but approached a stripe that was isoluminant with the background, suggesting the detection of spatial information. When placed in an arena with two stripes on opposing sides, animals moved in direct paths to either stripe, and some animals moved back and forth between both stripes. Animals travelled in convoluted paths in an arena with no external markings but straightened their paths when a visual target was present even if they did not approach it, suggesting that visual cues were used as a navigational aid. Animals were less responsive to visual targets when food-deprived or in the presence of a food odor, demonstrating that visually-guided behaviors are influenced by hunger state and odors. Taken together, these results suggest that Berghia uses spatial vision to navigate its environment.

960 Brooke Quinn, Kenneth Breuer, Alberto Bortoni, Sharon Swartz

Sensing on the fly: sensory hairs help bats battle turbulence

In gusty conditions, cluttered environments, and collisions, bat flight performance remains consistently high, demonstrating precise control and robustness. This is due in part to bats' sensorimotor systems, including hundreds of short (< 1 mm) wing membrane-embedded sensory hairs connected to Merkel cells. These hairs cover the wing, with high densities in muscles that control wing stiffness, at the wing's leading and trailing edges, and around joints. This anatomical organization suggests particularly rich information comes from parts of the wing that are most aerodynamically relevant and under active control. To probe the function of the wing hair sensory system, we evaluated flight performance by comparing kinematics from wind tunnel flights under turbulent and non-turbulent conditions, with intact (control) vs. depilated conditions in Carollia perspicillata. In control flights, the range of body pitch over a wingbeat cycle decreased slightly with turbulence. Body pitch range was higher in turbulent flow after hair removal. The mean wingbeat frequency in control flights did not change with turbulence, but was slightly higher (12 vs 10 Hz) when sensory hairs were removed. Depilation also led to changes within the wingbeat cycle; for example, in turbulent flow, the timing of maximum camber shifted from the beginning of the downstroke to the upstroke following hair removal. These data suggest that hair sensors contribute to bats' ability to regulate flight in the face of turbulence.

1709 Md Sadequr Rahman

Effects of temperature on host-microbe dynamics and infection outcomes in red flour beetle

Rising atmospheric temperature is an existential threat to biodiversity, particularly to the ectotherms since they cannot regulate their internal body temperature. It can greatly affect their survival by altering immune responses that normally keep pathogens in check. In this study, we exposed adult red four beetles to eight different temperatures (20, 22, 24, 26, 28, 30, 32, and 34°C) for 12 days and infected them with Bacillus thuringiensis (Bt) to observe how different temperatures can affect survival of the beetle population when infected with a pathogen. The proportion of beetles that survived at different temperatures (3-12%) did not differ appreciably); however, the rate at which the beetles died showed a significant decrease with temperature. No survival differences were observed among sexes. An infection with a lower dose (10x dilution) showed significantly improved beetle survival at 20°C and 27°C compared to 34°C; however, the beetle died at a faster rate with increasing temperatures. In vitro growth of Bt exhibited temperature dependent increase in Bt density which correlated with reduced survival time and heightened mortality rate of host. Interestingly, qPCR analysis of immune genes, Relish2, Defensin1, PGRPSc-2 and Cactus, showed differential expression; however, the expression trends were not correlated with temperature. Together, these results suggest that lower temperature is beneficial against Bt infection in beetles, whereas high temperatures facilitate faster pathogen-mediated killing of large number of hosts.

1678 Aradhya Rajanala, Christopher Pierce, Deniz Kerimoglu, Mingyuan Zhu, Madison Hales, Isaiah Taylor, Philip Benfey, Daniel Goldman

Numerical modeling of heterogeneous cell patterns in plant root growth

Circumnutation - the helical motion of a plant root tip - is a well-documented behavior of plant roots [Taylor et al, PNAS, 2021]. Circumnutation facilitates root growth past obstacles and is regulated by plant hormones. However, the regulatory mechanism of root circumnutation at the cellular level is not well understood. Here we report development of a multiparticle DEM (Discrete Element Method) simulation in which each "particle" represents a single root cell. We create the simulation in LAMMPS, a molecular dynamics software, to run efficient parallelized simulations of many particle systems. Our current model implements a perimeter of 90 particles to match the cell count in rice (O. sativa) roots (0.2 mm diameter) and can model up to 15,000 cells during root growth. We emulate root meristematic (division) and elongation zones in our model, allowing us to connect cell level signals and behaviors to the overall trajectory. This enables exploration of the regulation of circumnutation based on individual cell growth patterns. We use our model to test the effects of both temporal and spatial heterogeneity of cell elongation on the overall shape of roots and cellular stress patterns. We further validate the simulation results through comparison with experimental data from rice roots. Our study integrating computational modeling and live-tracking of root cell growth provides insights into how circumnutation is regulated.

1785 Yash Raka, Trevor Fox, Jon Harrison

Mesocosm approach towards understanding Poleward Expansion of the Zika-carrying Aedes aegypti

Several factors, ranging from global warming to urbanization, have recently allowed for the poleward expansion of various tropical vector species. Specifically, Aedes aegypti (Diptera: Culicidae), a tropical mosquito vector responsible for transmitting pathogens causing the Zika Virus, Dengue Fever, and Chikungunya, has recently expanded northward to Maricopa County, Arizona. Maricopa County Vector Control data indicate that adult populations significantly decrease in winter and spring, and they experience an exponential population increase during the summer and fall, demonstrating that winter conditions hinder A. aegypti in Maricopa County. To understand the cold's effects on their development, larval population levels and their ability to reach adulthood in variable temperature conditions were assessed. Low larval populations during the summer and higher winter populations were observed, demonstrating that the cold suppression of larvae may have prompted the adult population decline. Furthermore, larvae could not reach adulthood during winter. Subsequent data analysis displayed that an increase of 1.7°C would allow larvae to successfully develop into adults, holding implications for global warming's enabling effects. To further understand this suppression, experiments on adult flight, a necessity for survival, were conducted, establishing that flight during winter day conditions in Maricopa County is possible. This capacity for adult flight and larval cold suppression indicates that minor warming may allow A. aegypti populations to develop and grow in Maricopa County year-round with no significant cold suppression.

249 Chidambaram Ramanathan, Ali Akbar, Chidimma Okegbe, Rebecca Koch, Matthew Powers, Ethan Hare, Geoffrey Hill, Matthew Toomey, Yufeng Zhang

Establishing in vitro systems to study vertebrate keto-carotenoid metabolism

Carotenoid-based coloration is a vital criterion for mate choice in different organisms, especially birds. It has become the most widely cited example of a condition-dependent trait that conveys information to a chosen potential mate individual during mate choice. Redness is a primary color parameter used by many animals to select potential mates and to assess rivals in contests. Red coloration in many vertebrates is generated through the metabolic conversion of yellow dietary carotenoids. Recently, our team has identified three genes in birds that, when transient expression in HEK293 cells is sufficient to convert yellow carotenoids into red ketocarotenoid. Here, we cloned these three genes into lentiviral vectors to establish stable cell lines in human HEK293 and DF-1 chicken embryonic fibroblasts. We confirmed that these stable cell lines harbor constitutive expression of these genes. The cells were then treated with different yellow carotenoids, and the bio-converted red carotenoids were measured using HPLC. These stably transduced cell lines provide a powerful tool for studying mechanisms controlling color expression.

1778 Divya Ramesh, Qiyuan Fu, Gargi Sadalgekar, Zachary Souders, Luke Moon, Jack Rao, Mia Urban, Milla Ivanova, Kapi Ketan Mehta, Lucas An, Chen Li

Studying terrestrial fish locomotion on wet deformable substrates

Many amphibious fishes can make forays onto land. The water-land interface often has wet deformable substrates like mud and sand, whose strength changes as they get dryer or wetter, challenging locomotion. Most previous terrestrial locomotion studies of fishes focused on quantifying kinematics, muscle control, and functional morphology. Yet, without quantifying how the complex mechanics of wet deformable substrates affect ground reaction forces during locomotion, we cannot fully understand how these locomotor features interact with the environment to permit performance. Here, we used controlled mud as a model wet deformable substrate and developed methods to prepare mud into spatially uniform and temporally stable states and tools to

characterize its strength. As a first step to understand how mud strength impact locomotion, we studied the Atlantic mudskipper (Periophthalmus barbarus) moving on a thicker and a thinner mud, which differs in strength by a factor of two. The animal performed similar “crutching” walks on mud of both strengths, with only a slight reduction in speed on the thinner mud (from 0.39 ± 0.12 to 0.32 ± 0.14 body length/s, $P < 0.05$, ANOVA). However, it jumped more frequently on the thinner mud (from 1.2 ± 0.7 to 3.2 ± 1.6 times per minute, $P < 0.05$, ANOVA), likely due to it sticking more to the belly and fins and hindering walking. (Please place this before Sadalgekar et al.)

713 Spruha Rami, Karthikeyan Chandrasegaran, Clément Vinauger

Influence of mosquito ecology on the neural encoding of human host odors

Each year, several hundred thousands of people worldwide are affected by mosquito-borne diseases. Female Aedes aegypti mosquitoes vector viruses causing chikungunya, dengue, Zika, etc. when biting hosts for a blood meal to nourish their eggs and meet their reproductive needs. Several factors, both extrinsic (e.g. environmental conditions) and intrinsic (e.g. reproductive status), influence the host-seeking behavior of these mosquitoes. An example of such influential factors is how intraspecific larval conditions affect the host-seeking preferences of adult mosquitoes. Specifically, larger females show a significantly greater preference for host odors while smaller mosquitoes are responsive to plant odors. To further determine the neural basis of this observed relationship between adult female body size and their host and plant-seeking behaviors, we performed electrophysiological recordings from the antennal lobe of female Aedes aegypti stimulated with host and plant odors, both in the presence and absence of carbon dioxide (CO_2), which is a potent host cue. Findings from this study will be discussed in the context of how neural mechanisms mediate the influence of mosquito larval ecology on the representation and response to host and plant odors.

913 Desmond Ramirez, Thi Bui, Paul Katz

Neuronal mapping in the head ganglia of a gastropod mollusc using single cell transcriptomics

Neuroscience research on gastropod molluscs has provided important insights into the neural circuit function, focused primarily on large identifiable neurons in the central ring ganglia (CRG). However, these efforts ignored many smaller cells not amenable to sharp electrode recording and relied on low-throughput techniques to look at neuronal gene expression. Here we use 10x Genomics single-cell sequencing to create transcriptomes for about 2000 cells across the entire brain of the nudibranch, Berghia stephanieae, including the CRG and the peripheral rhinophore ganglia (RhG). Cell types were distinguished based on similarity clustering and differential gene expression. Most RhG neurons formed two distinct clusters, marked either by nitric oxide (NO) synthase, or the NO receptor, soluble guanylate cyclase. Other neuron types included likely mechanosensory afferents, expressing Brn3, and somatic efferents, expressing Lhx1 and ChAT. Putative neuroblasts expressed neural differentiation genes like Sox6, Scratch1, and neurogenin. We mapped gene sets to neurons in the brain by multiplexing fluorescence in-situ hybridization chain reaction. Neurotransmitter and neuropeptide classes were identified, uncovering general rules of neurotransmitter phenotypes. Some genes had widespread expression including CCWamide. Others, including the transcription factor Six6, defined particular zones of neurons or specific ganglia. Previously unannotated genes were expressed in specific neuron types. The results provide insight into the organization and identity of gastropod neurons and provide the basis for future large-scale neural research on Berghia.

1772 Arianna Ramirez, Diego Sustaita

Persistent paddlers: salt marsh harvest mouse hindfoot morphology and kinematics during swimming

The salt marsh harvest mouse (Reithrodontomys raviventris halicoetes) is a federal and California state-listed endemic species prevalent in the Suisun Marsh, California, where they experience natural tidal and managed flooding on a regular basis. Our research focuses on their swimming performance because of its potential importance as a means for locomotion during periods of inundation. As bipedal paddlers, the hindlimbs play a critical role in generating propulsion. Here we compare hindfoot morphology and swimming kinematics among salt marsh harvest mice and co-occurring western harvest mice (Reithrodontomys megalotis), house mice (Mus musculus), and California voles (Microtus californicus). Preliminary results suggest differences in voluntary swim speeds and underlying hindfoot angular velocities, thrust power, and power to recovery phase duration ratios among species, although relationships with hindfoot surface area are diffuse. Understanding the swimming performance capabilities of these rodents allows us to gain insight into how they persist, and ultimately coexist, in natural tidal and managed flooded environments.

152 Kyle Raney, Talia Head, Donald Mykles

Characterization of Catalase and its Role in Molting in G. lateralis and C. maenas

Divided into intermolt, premolt, and postmolt stages, molting is an essential process for crustacean growth and development driven by the X-organ/sinus gland complex (XO/SG) and the Y-organ (YO). During intermolt, the XO/SG periodically releases molt-inhibiting hormone (MIH), which suppresses the YO's production of molt-stimulating ecdysteroids. Entering premolt, the XO/SG reduces the quantity of MIH released, which allows for the excretion of ecdysteroids from the YO. Once the animal has reached postmolt, MIH concentrations increase, and the YO enters a repressed state. Production of ecdysteroids by cytochrome p450 enzymes produces harmful waste products, such as reactive oxygen species (ROS). The defense mechanisms against these are anti-ROS scavenging proteins, such as catalase. From the respective YO transcriptomes, this study identified one possible transcript for catalase in each the blackback land crab (Gecarcinus lateralis) and green shore crab (Carcinus maenas) through bioinformatic and phylogenetic characterization. Previous proteomic analysis of G. lateralis YO across the molt cycle identified multiple catalase isoforms of different molecular weights. We hypothesize a post-translational cleavage of catalase affects the efficiency of the enzyme. This study aims to identify the distribution of catalase transcripts in each species across multiple tissues. Additionally, we hope to track the efficiency of catalase over the molt cycle to determine if it's reaction rate could be used as an indicator of molt stage. Supported by NSF (IOS-1922701).

517 Eesha Rangani, Greg Rouse

Systematics of deep-sea Nereididae (Annelida) from vents, seeps and whalefalls

Nereididae is one of the most diverse families of polychaetes, containing 700 species and 45 genera. Nereidids are commonly found in shallow-water marine biomes, but also occur in deep-sea environments, freshwater habitats, and estuaries. Several species of nereidids have been described from the deep sea; however, only a few species belonging to the genera Nereis have been collected from chemosynthetic-based habitats, and one species of Neanthes from a whalefall. These are Nereis sandersi and Nereis piscesae, described from the eastern Pacific vents and Neanthes shinkai from an Atlantic whalefall. New nereidid samples were collected from Costa Rica (seeps), Gulf of California (seeps and vents), California (seeps and whalefalls), Oregon (seeps), and from the North Fiji and Lau Basins (vents), representing three new species. Also, representatives of N. sandersi and N. piscesae from their type localities were obtained as well as specimens of the type species of Nereis (N. pelagica) and Neanthes (N. vaali). Mitogenomes were generated for all these terminals and analysed with existing mitogenome data for Nereididae allowing for the clear delineation of Nereis and Neanthes. It appears there have been at least two origins of chemosynthetic-associated Nereididae.

429 Joseph Rangel, Joshua Rivera, Matthew Fujita, André Carvalho, Adam Leaché

Deep Homology of Follicular Glands in Divergent Lizard Clades

Intra- and interspecies communication is vitally important among animals, with the oldest form of communication involving chemical signaling. Lizards accomplish this by secreting chemicals via their skin, feces, and glands. Generation glands are a conglomeration of novel cell types that sit within an undifferentiated layered epithelium and do not have an external pore. Follicular glands, however, do excrete chemicals via a pore and function morphologically and chronologically independent of the surrounding epidermis. This research will focus on using follicular glands to understand their evolution and to infer the deep homology through the lizard tree of life. We conducted field work and collected follicular glands from several species of lizards from divergent families. We then sequenced and de novo assembled the transcriptomes of the follicular glands before using tools to determine gene orthology and ontology. We used a comparative approach to identify the gene composition of the transcriptomes to identify whether divergent lizards share similar or distinct genetic circuity that can inform the deep homology of follicular glands. This research will allow for a deeper understanding of the evolution of epidermal gland types through their genetic pathways, contributing to our perception of how these mechanisms have shaped communication in diverse lizard clades over time.

559 Racine Rangel, Kristy Kroeker, Matthew Bracken, Luke Miller, Cascade Sorte

Climate Change Impacts on the Shell Structure of an Ecologically Important Shellfish

Calcifying shellfish species are experiencing reduced availability of shell-building materials due to ocean acidification. At the same time, exposure to increasing temperatures may alter their metabolic processes related to growth. Acidification and warming could operate independently or interactively, amplifying or mitigating impacts on individuals. Thus, it is critical to evaluate the impacts of combined stressors on habitat-forming shellfish. We evaluated effects of simulated ocean acidification and warming on shell thickness and shell strength of the Pacific blue mussel (Mytilus trossulus) over 6 months in coastal tide pools in Sitka, Alaska. Twenty pools were factorially manipulated including an unmanipulated control, warmed, CO2-added, and combined warming and CO2-addition treatments. Temperature was manipulated using submerged heaters, while pH was altered using CO2-producing yeast reactors. Standardized mussel shell thickness was measured using calipers, and shell strength was measured using an Instron universal testing system. We tested for differences in shell thickness and strength over time among treatments using linear mixed-effect models. Results indicate a decrease in thickness and strength in mussel shells from CO2-addition pools. However, we detected an increase in shell strength for mussels from the combined warming and acidification pools. The findings suggest ocean acidification negatively impacts shellfish in situ and that these effects may be mitigated in the presence of moderate warming, leading to an interactive effect of acidification and warming in this critical habitat-forming shellfish.

241 Akshaya Ranjit, Michael Patton, Michele Johnson

Lateralization in the Social and Visual Regions of the Green Anole Lizard Brain

Behavioral lateralization occurs when the right or left side of an organism is preferentially used to perform a function, and is often underlaid by lateralization in the brain. Though lateralization has been observed in many species, reptiles offer an excellent model to understand how lateralization in brain and behavior may be associated, as reptiles lack a corpus callosum, the net of fibers that facilitates communication between each side of the brain. The green anole lizard, Anolis carolinensis, is particularly amenable to studies of lateralization, due to its easily identifiable lateralized behaviors, including aggressive displays in which lizards orient to display from the right or left side of their body. In this study, we observed the lateralized behaviors of 18 wild-caught male green anoles and cryosectioned their brains. We measured the volumes of structures involved in the visual processing system of anoles (nucleus rotundus, lateral geniculate nucleus, and the optic tectum) and those involved in aggressive display (preoptic area and amygdala) on the right and left side of the brain, as well as the entire left and right brain hemispheres. Preliminary data suggest that the nucleus rotundus exhibits a slight bias, such that this region in the left hemisphere may be larger than in the right. Ultimately, these results will help us understand how brain lateralization may facilitate lateralized social behaviors.

1829 Jason Rasgon

CRISPR in non-model organisms through ReMOT Control

Genetic manipulation is a powerful technique for addressing research questions in animals. Current approaches rely upon delivering gene-editing material to eggs or embryos by microinjection. However, embryonic microinjection is very challenging and is inefficient even in optimized species. There is a critical need to develop methods for genetic manipulation that are simple, accessible for many researchers and generally compatible for a large variety of invertebrate and vertebrate species. We have developed a technology called Receptor-Mediated Ovary Transduction of Cargo, or ReMOT Control, to specifically deliver gene-editing cargo to the developing animal germline by easy injection into the circulatory system of female animals. ReMOT Control can bring the power of genetic modification technology to any model or non-model species without the need for injecting embryos, allowing any lab to use these powerful tools for their research questions. The ReMOT Control technology is being developed for arthropods, fish, birds, and mammals.

740 Noa Ratia, Eliza Grames, Matthew Forister, Michael Logan

Still alive: Scientists have been shockingly bad at predicting extinctions

One of the most important yet difficult challenges facing modern biology is to accurately determine extinction risk in our rapidly changing world. Many populations of a wide range of taxa have been predicted to become extinct prior to present day. We conducted a metanalysis of over 1,400 published studies which forecasted population extirpations or species extinctions and evaluated the accuracy of each prediction. Preliminary results indicate that populations predicted to become extinct generally meet one of three fates. The population 1) becomes or remains viable as a result of conservation efforts, 2) drops below a hypothesized population size threshold for extinction but persists beyond the predicted extinction date with an extinction debt, or 3) becomes or remains viable due to biological mechanisms that were neglected in the population model. By and large, extinction predictions have been extremely inaccurate. A myriad of factors have likely contributed to this pattern, including the fact that very few studies account for in situ adaptation (e.g., acclimation, genetic adaptation), effective population sizes are rarely considered or reported, and species interactions and dispersal abilities may be known but are unlikely to be included in the predictive model. Our work highlights the importance of incorporating realistic processes in extinction models to better understand, anticipate, and prevent losses of wild populations into the future.

1546 Aleksandra Ratkiewicz, Julia Molnar, Melody Young, Michael Granatosky, Edwin Dickinson

Testing an automated workflow for the reconstruction of in situ muscle fascicles

Diffusible iodine-based contrast-enhanced computed tomography (DiceCT) has been extensively applied to the study of skeletal muscle over the past decade. Traditional means of gross dissection can provide muscle volume and fascicle lengths, but tomographic quantification of muscle architecture also facilitates measurements of 3D fascicle orientation and resting tortuosity (i.e., compression of fascicles at resting length). Numerous manual and automated workflows have been proposed, but comparisons of accuracy and replicability are sorely needed. In this study, we explore how input parameters during algorithmic resolution affect resultant fascicles across a broad range of masticatory muscle datasets using the XFiber extension in Amira. We demonstrate that simple, parallel-fibered, or unipennate muscles are easily resolved, but increasing fascicle complexity/heterogeneity poses additional complications. In several muscles, the implementation of multiple correlation cylinders is required (e.g., temporalis, in which individual portions are highly heterogeneous in fascicle orientation). We outline several best practices, including adjusting masks to minimize surface artifacts and and the use of isosurfaces to establish optimal parameters for minimum seed correlation values within each muscle. We also evaluate which input parameters induce most variation in the resultant fascicle length, orientation, and tortuosity data, and finally provide a broad framework that may be applied to novel datasets by future researchers.

760 Juliette Rault-Wang, Arpitha Parthasarathy, Audrey Yung, Susan Park, Jenna Monroy

Exercise decreases muscle stiffness in mice with a deletion to titin

It is well known that progressive resistance exercise training leads to increased strength and mobility of skeletal muscles. However, the underlying mechanisms that occur in response to training are not well understood. Recent studies have suggested that the giant muscle protein titin, specifically its PEVK region, functions as a spring in muscle, and that changes to titin stiffness affect an animal's walking gait. Here, we investigated whether titin properties and gait kinematics change with progressive resistance training. We used the TtnΔ112-158 mouse, characterized by a 75% deletion of the PEVK region and increased passive muscle stiffness. We hypothesized that walking is affected by the increased passive stiffness in TtnΔ112-158 mice, and that exercise training reduces the effects of the PEVK deletion by decreasing muscle stiffness. To test our hypothesis, we conducted an 8-week progressive resistance training program with weekly increases in carried load and intensity. Kinematic variables were analyzed from mice walking at their preferred speeds. Results demonstrated that neither stride frequency nor stride length changed following exercise. Furthermore, ex vivo physiology tests showed reduced stiffness in soleus muscles from exercised mice. Combined, these data suggest that progressive resistance exercise training leads to a change in titin and muscle stiffness and decreases the deleterious effects of the TtnΔ112-158 mutation.

624 Shrika Ravichandran, Kelly Diamond, Heiko Schoenfuss, Richard Blob, Amanda Palecek-McClung

Bigger, faster, stronger? The influence of body size on goby fast-start performance

In amphidromous species of gobiid fishes, postlarvae migrate upstream from the ocean toward their eventual adult habitats, which for many species are above waterfalls. In the Hawaiian Islands, postlarvae must evade predators during initial portions of this migration, though habitats above waterfalls are free from predators. Previous studies have found relatively lower fast-start performance among adults from above waterfalls, compared to postlarvae collected below waterfalls. However, these data made categorical comparisons, and it is unknown whether the decline in performance among adults occurs through a continuous relationship with size, or whether it occurs more suddenly after a threshold size is achieved. To better understand the influence of body size on fast-start performance, we used high-speed video (1000 Hz) to record fast-starts from individuals of the goby species Sicyopterus stimpsoni across a broad range of body sizes collected from streams in Maui. Fast-starts were elicited in an aquarium using a jet pulse of water, simulating the bow wave of a predator strike. We found that fish at intermediate body sizes tended to escape at greater angles than those which had shorter or longer body sizes. These results suggest that changes in performance among adult gobies through ontogeny may be influenced by factors in addition to strictly scaling relationships.

140 Emily Ray, Julie Butler, Karen Maruska

Neural mechanisms of mouthbrooding, maternal care, infanticide, and fry release in a cichlid fish

Parental care is present across taxa and is critical for offspring success. Infanticide, however, can co-exist with parental care in the same species, though the mechanisms underlying the switch from care to consumption are largely unknown, especially in fishes, the oldest and most speciose vertebrate group. Mouthbrooding is an extreme form of parental care in which parents hold their developing young in their mouth, often while starving themselves. The maternal mouthbrooding African cichlid fish Astatotilapia burtoni broods developing offspring for 14 days, then provides post-release maternal care. Following this post-release care phase, mothers exhibit infanticide and can consume some or all their offspring. We used immunohistochemistry for the activation marker pS6 to compare neural activation among mouthbrooding, maternal care-providing, and infanticide-exhibiting females, and between offspring pre- and post-release from the mother's mouth. We identify nuclei in mothers that may support the transitions between parental care states and from care to infanticide, and distinct co-activation networks that suggests different circuitry involved in offspring-promoting versus offspring-hindering behaviors. We also identified neural circuitry in offspring that may support the increased cognitive demands during transition from inside to outside the mother's mouth. These results highlight the brain regions involved in both mothers and their offspring during crucial lifestyle transitions and provide comparative data towards better understanding the evolution of neural circuits involved in infanticide and parental behaviors.

258 Daniella Ray, Elizabeth Sheldon, Lynn Martin, Aaron Schrey

Screening Histone Acetylation in House Sparrows

House sparrows (Passer domesticus) are an introduced species that have been successfully introduced to all continents except Antarctica. House sparrows have managed to thrive in nearly every environment, which begs the question, how are they able to adapt to novel environments on the short timescales needed during introductions? One possible explanation is that house sparrows are employing epigenetic mechanisms as a mediator for rapid phenotypic variation in the introduced range. To date, DNA methylation is the only epigenetic mechanism that has been investigated in house sparrows; yet, there are other molecular epigenetic mechanisms such as histone modification. Histones are protein octamers that package DNA to form chromatin. Each histone has an N-terminal tail on which covalent modifications can occur. One such histone modification is acetylation, which often involves the addition of an acetyl group to a lysine residue. Histone acetylation decreases the histone tail's affinity for DNA, making the DNA more accessible for transcription to occur. We will report results from the first measurement of histone acetylation in wild collected house sparrows. We hypothesize that histone acetylation will be variable among house sparrows, and that histone acetylation will vary at a similar magnitude as DNA methylation among individuals. The goal of this research is to expand the scope of molecular epigenetic studies in cases of phenotypic plasticity.

1695 Maya Rayle, Daniel Paluh, James Hanken

Evolution of Salamander Dentition

Teeth are critical for capturing and consuming prey and are important for defense, competition, and communication. Because these functions are essential for survival and reproduction, vertebrate dentition is under intense evolutionary selection. Salamanders exhibit a wide variety of dentition patterns along with significant diversity in body size, diet, territoriality, courtship behavior, life history, and habitat. They may inhabit fossorial, aquatic, terrestrial, or arboreal habitats, and change environments at key life stages such as metamorphosis or sexual maturity, a transition that often coincides with significant alterations in dentition. For these reasons, salamanders are an excellent clade for evaluating how dental diversity relates to phylogenetic and ecological factors. Yet, dentition has been poorly studied in salamanders relative to other vertebrates. Using phylogenetic comparative methods and micro-computed tomography scanning, we assess the evolution of tooth number, size, and location across all extant salamander genera. We also analyze the effects of diet, territoriality, habitat use, life history mode, and body size on patterns of tooth morphology.

564 Olivia Redding, Jacob Lasala

Invasive Plant Root Penetration in Loggerhead Nests on the Gulf of Mexico

Sand dunes are supported by the extensive root systems of dune plants that anchor the dune and protect it from erosion. Dunes are important features of coastal landscapes that stabilize the beach so species, like sea turtles, can use the natural system. They also protect nearby residential and commercial areas from coastal flooding and storms. While all plants that grow on the dunes support their structure, invasive plants can outcompete the native dune plants for resources such as nutrients, sunlight, and space to grow. During the summer, sea turtles use the beaches in Florida to lay their nests; however, their eggs and hatchlings are at risk of destruction by dune plant root penetration. Dune plant roots can penetrate sea turtle nest cavities, thus decreasing the hatch success of the eggs and the emergence success of the hatchlings. We hypothesize that invasive species of dune plants decrease the hatch and emergence success in loggerhead nests on Casey Key, Sarasota County, Florida. Nests were excavated in 2022 to determine the extent of root penetration and species of plants were documented. Models were run to identify which variables had the greatest effect on root penetration. It is important to understand how and if invasive plants are affecting loggerhead reproductive success in order to call for their removal and better conserve the threatened loggerhead sea turtle species.

1708 Julia Redpath, Alyssa Stark

How sticky is too sticky?: gecko locomotor performance in high adhesion conditions

Geckos with adhesive toepads must retain their ability to run at high speeds when attaching and detaching their adhesive system over many stride cycles. At high ambient relative humidity (RH) and low ambient temperature, gecko adhesion is remarkably strong but running speed is slow. Because geckos are ectothermic, it is unclear if this result is simply because geckos cannot move their bodies quickly at low temperature (reducing speed), or if high adhesion at the substrate surface produces adhesive forces that are too strong to overcome (i.e., the gecko does not have enough muscular power to release their adhesive system in this context). To determine if there is a point where gecko adhesion is "too sticky", forcing geckos to slow their speed, we varied substrate surface temperature (12 and 32?) on a 1m racetrack. We also measured behavioral tendencies like stopping, slipping, and avoiding the racetrack. We predicted that gecko running speed would slow and the frequency of avoidance behaviors (e.g., jumping off the track, turning around) would increase on the highly adhesive 12? surface temperature racetrack. The results of this work will help us understand the fundamental mechanism(s) responsible for gecko adhesion, and how this relates to locomotor performance and behavior of geckos.

1703 Susan Reed, Alex Jahn, David Sinkiewicz, Ellen Ketterson

Migration Distance and Reproductive Readiness in a Common Songbird

Accurately timed annual cycle transitions are especially important for migratory species, which occupy multiple environments throughout the year. Migrants must integrate cues from one environment to make decisions that affect fitness in a different environment. In this study, we explore the effects of migration distance on reproductive readiness in two breeding populations of a common songbird, the American robin (Turdus migratorius)—one population in Bloomington, IN and another in Anchorage, AK. Migration distance was measured using stable hydrogen isotopes of claw samples as an index to infer overwintering latitude. Sex steroid hormones—testosterone (T) in males and estradiol (E2) in females—were measured during the early breeding season for each population. In males, we followed a standardized gonadotropin-releasing hormone (GnRH) injection procedure to capture the physiological maximum T level that an early breeding season male can produce. We predicted lower variation in sex steroid levels among the Alaska population compared to the Indiana population because the length of the Alaska breeding season is limited by a combination of higher latitude and longer-distance migration, creating strong selective pressure for accurate and precise timing. This research improves our understanding of how species tune their phenology to match the environment, which is crucial for predicting population dynamics as species are faced with challenges of rapid environmental change.

415 Hannah Reich, Marley Gonsalves, Elizabeth Harvey

CLUE special edition: Resolving the mysterious zombification of marine microalgae

Bacteria and microalgae together represent a considerable fraction of global CO2 sequestration, and the ocean carbon pump. The interactions between the two are ubiquitous in the photic ocean, with environmental and biological forces regulating the success of these symbiotic interactions. For example, global interactions between the cosmopolitan coccolithophore (Emiliania huxleyi) and bacteria (Pseudoalteromonas piscicida) are disrupted following bacterial production of cell stasis and lysis chemicals. The bacterially produced quinolone, HHQ (2-Heptyl-4-quinolone), induces cell stasis and eventually cell lysis in coccolithophores. It is possible that bacterial HHQ production and induction of coccolithophore cell lysis is incentivized during spells

of nutrient limitation to acquire and consume nutrient-rich (algal) organelles. To test the hypothesis that bacterial HHQ production is incentivized by nutrient deficiency, the following treatments were exposed to control (unmodified culture media) and media deplete of (Iron, Zinc, Cobalt, Phosphorus, or Nitrogen): axenic E. huxleyi cultures (CCMP 2090), bacterial cultures (P. piscicida A757), and algal-bacteria co-cultures. Cultures were monitored for growth rates, the presence of (algal) calcification, relative cell size, and HHQ production. Eventual cellular currencies of symbiosis cross-talk will be evaluated by paired metabolomics and proteomics. Broadly, these results will provide information on the biogeochemical drivers of symbiosis success, algal blooms, and the ocean carbon pump.

595 Tristan Reinecke

Trabecular Bone In Mammalia and Reptilia and its Potential as a Proxy for Posture and Locomotion

Trabecular bone is bony tissue arranged as struts found within cortical bone. Trabeculae are optimized to strengthen bone by orienting perpendicular to directions of external stress. They remodel five to ten times faster than cortical bone and offer a more reactive record of the effect of loading strain on bone than gross morphology. Although previous research has explored the characteristics of trabecular structures in humans, other primates, and several model species, there has been minimal work quantifying trabecular variation across extinct or extant Tetrapoda. Our project seeks to quantify the effects of posture on trabecular structures, and to potentially determine whether trabecular architecture can be used to compliment and test results from range-of-motion studies. We sampled the trabeculae of forty-three mammalian and non-avian reptile species. Specimens were selected to reflect a wide range of ecomorphotypes, clades, body masses, and generalized postural grades. Trabeculae from the proximal head of the humerus and femur were sampled, with both bones uniformly oriented regardless of how these elements were held in life. We measured five trabecular characteristics: anisotropy, bone volume, trabecular thickness, trabecular number, and primary orientation. Our results suggest the greatest variation in trabecular characteristics stem from locomotory behavior associated with ecological niche, and that these features may be potential proxies for locomotion and posture in extant and extinct taxa.

852 Joanna Reinhold, Ella Halbert, James Hurley, Gabriel Isaacman-VanWertz, Teresita Insausti, Claudio Lazzari, David McLeod, Chloe Lahondere

In cold blood: deciphering the mechanisms underlying mosquito-frog interactions

Mosquitoes feed on a large range of hosts, including warm and cold blooded animals. While most research focuses on species that feed on humans, one species, Culex territans, specializes in feeding primarily on amphibians and reptiles. Although this species is fairly widespread in North America and Europe, surprisingly little is known about its biology and ecology. For this project, we focused on understanding how these mosquitoes locate their cold blooded hosts and how they manage to imbibe cold and viscous blood. We first performed olfactometer experiments with green frogs and bullfrogs, two of the common hosts this mosquito feeds on in the wild, as well as tests with frog urine, feces and carbon dioxide to determine the cues Cx. territans uses to locate and feed on their hosts. We also used solid-phase microextraction scent collection with gas chromatography coupled with mass spectrometry to analyze the scents of these two frog species and identify key compounds released by the frogs that drive mosquito attraction. Finally, we studied the anatomical structures inside the mosquitoes' head using microtome sectioning, as well as feeding assays coupled with thermographic imaging to elucidate the mechanisms that allow this mosquito species to feed on cold and viscous blood. Results emerging from this project provide critical information to help build a more complete picture of the evolution of blood feeding in mosquitoes.

1015 Adam Reitzel, Sarah Estvander, Amy Klock

Genomic regions contributing to temperature response in an estuarine cnidarian

Nematostella vectensis has emerged as a model cnidarian for comparative and functional ecological genomics due to the availability of an annotated genome, the ease of experimental manipulation and laboratory culturing, and the extensive geographic distribution in estuaries along the coasts of the United States and parts of Canada and England. Previous research with this species has shown higher thermal tolerance in lower latitude locations under both acute and chronic temperature regimes. In this presentation we will synthesize genomic, transcriptomic and metabolomic data that reveal substantial variation in how anemones from different locations along the Atlantic coast respond to temperature variation. We relate these temperature responses to the dynamics of protein chaperone expression and client interactions. Next, we will discuss results showing how thermal tolerance windows for developmental stages vary throughout the native range for this species. Ongoing research comparing offspring thermal performance with controlled parental crosses from different locations will be insightful for identifying potential genomic loci that impact temperature thresholds for developmental stages in the life history of N. vectensis.

1591 Julie Rej, Alex Gunderson

High temperatures lead an invasive lizard to exhibit increased aggression towards native competitor

Invasive species cause major disturbances to endemic wildlife and often displace native species. Behavioral aggression can contribute to invasive species success, but how temperature and aggression might interact is relatively unknown. We tested how temperature and aggression interact in interactions between an invasive lizard (Anolis sagrei) and a native lizard it has displaced, A. carolinensis. We hypothesized that temperature-dependent aggression of A. sagrei towards A. carolinensis could play a role in A. sagrei's success. We measured interspecific aggression across five temperature regimes spanning from conditions in cool spring to warm summer days. Additionally, we tested whether the presence of A. sagrei leads to the thermal displacement of A. carolinensis in a thermal gradient. Based on the thermal biology of each species, we predicted they would exhibit similar aggression at low temperatures but A. sagrei would be significantly more aggressive at high temperatures. Results were consistent with our prediction, as A. sagrei displayed greater aggression towards A. carolinensis with increasing temperature. Furthermore, the presence of A. sagrei compromised the thermoregulatory ability of A. carolinensis in a thermal gradient. Therefore, temperature-dependent interspecific aggression could contribute to the success of A. sagrei relative to a native competitor and rising global temperatures may exacerbate their advantage. Our results support temperature-mediated behavioral aggression as a mediator invasive species success.

1545 William Reyes

Endocranial variation of the Aetosauria (Pseudosuchia) from the Late Triassic Dockum Group

The Aetosauria, which currently includes ∼26 species, is one of the most diverse pseudosuchian clades of the Late Triassic. In recent years new skull material for a variety of aetosaur taxa was described allowing for studies focused on the interspecific variation of the cranium and mandible. Paleoneuroanatomical studies of this clade provided a proxy for exploring their paleobiology and determining if there is a morphological endocranial phylogenetic signal. Currently, endocranial data exist for only three aetosaur taxa, the monospecific taxon Neoaetosauroides and both species of Desmatosuchus. I present new data for two monospecific taxa, Longosuchus and Lucasuchus, which provide new insight into the endocranial variation of the Aetosauria, more specifically within the inclusive clade Desmatosuchini. Unlike Desmatosuchus, these two taxa exhibit a constriction of the olfactory tracts which delineates them from the cerebral hemispheres similar to Neoaetosauroides. Also, Lucasuchus exhibits a proportionately large olfactory trough relative to that of the other taxa. The forebrain-midbrain flexure is more acute in Longosuchus and Lucasuchus in comparison to Desmatosuchus. Thus, Longosuchus and Lucasuchus exhibit a strongly sigmoidal endocast of the dural envelope similar to Neoaetosauroides. Additionally, the new data indicate that aetosaurs generally exhibit a dorsoventrally oriented hypophysis, however in Desmatosuchus it is more posteroventrally inclined. Overall, the new data suggest that among the Desmatosuchini Desmatosuchus exhibits a more derived endocranial morphology.

417 Noe Reyna, Murielle Ålund, Janette Boughman, Hans Hofmann, Mariana Rodriguez-Santiago, Becca Young

Coming to one's senses: Stickleback molecular processing and neuroanatomy vary across environments

Anthropogenic climate change forces organisms to adapt to rapidly changing environments and colonize new habitats, as their survival and fitness depend on their ability to respond to novel ecological challenges. How animals respond to these challenges and (sometimes) opportunities is not well understood. Here, we use the three-spined stickleback fish Gasterosteus aculeatus to ask how adaptation to novel environments is reflected in genetic population structure, neuromolecular processing, and neuroanatomy of three sensory modalities - olfaction, vision, and mechanosensation. Originally a marine species, sticklebacks have invaded freshwater lakes and streams across the Northern hemisphere, exhibiting an impressive capacity to adapt to widely different environments. Focusing on the waters of Iceland, we collected individuals from eight populations from marine, lowland spring-fed, highland spring-fed, and highland glacial environments, which vary in turbidity. We first assessed the transcriptomes of three sensory brain regions involved in olfaction (olfactory bulb), vision (optic tectum), and mechanosensation (torus semicircularis) and identified gene expression variation associated with ecotype. We then identified SNPs across the entire transcriptome and asked whether genes that contribute to genetic population structure and are also differentially expressed might be causal to the differences. We also associated quantitative neuroanatomic traits including brain area and volume with turbidity across populations. Our results reveal how variation in selective pressures and evolutionary divergence is reflected in genetic, transcriptomic, and anatomic changes in the brain.

1571 Crystal Reynaga, Jenifer Fabian-Dubon, Madison Kearns, Isabelle Kuszyk

Limb form and function in anuran quadrupedal walking

Quadrupedal walking frogs use multiple strategies (mechanistically and evolutionarily) to circumvent an ancestral anuran body plan. Walking frogs accommodate a quadrupedal gait by moving away from the very short forelimbs typical of a frog and have limb proportions more similar to cursorial mammalian quadrupeds. Previous work has shown some species actively adjust three-dimensional limb and joint postures in a combination of ways between the fore- and hindlimb via crouched, extended, abducted, and adducted limb postures. However, it remains unclear how asymmetry in forelimb and hindlimb lengths differentially affect limb function. To better understand how differences in limb length asymmetry within the fore- and hindlimb affect force transmission and limb function, we investigate three species of quadrupedal walking frogs, the red banded rubber frog (Phrynomantis bifasciatus), the tiger legged monkey tree frog (Pithecopus hypochondrialis), and the Senegal running frog (Kassina senegalensis). We use 3D high-speed videography and force-plate ergometry to quantify 3D limb postures, GRF vectors, and joint torques in the forelimb and hindlimb during walking. Preliminary results show despite sprawled limb postures walking frogs generate larger forces in the dorso-ventral direction, with the forelimb applying the greatest magnitude during a stride. Both fore- and hindlimbs generate similar magnitudes of force in the mediolateral and anterioposterior directions. These results suggest a sprawled forelimb contributes largely to force transmission and propulsion.

1423 Cassidy Reynolds, Esmeralda Rosas, Matthew Barnes, Romi Burks

Large snails & small DNA: Relating Pomacea maculata biomass & environmental DNA concentration

To combat non-native species, conservationists need the means to detect organisms quickly and reliably and rely increasingly on environmental DNA (eDNA) [remnant genetic material shed from organisms]. Aquatic eDNA research most often involves fishes and rarely focuses on snails. Ampullariids, or apple snails, includes Pomacea maculata, a non-native species that establishes large reproductive populations across the southern US. No work currently addresses whether the same relationship between abundance and eDNA that occurs for fish exists for a nontraditional model organism with less activity and a large shell. Our efforts sought to measure eDNA in a controlled laboratory environment using a known volume (13-L) across an increasing biomass of P. maculata (0, 2, 4, 6 snails). We collected ~200 adult snails from the San Antonio River and weighed them to standardize total biomass per treatment ($N = 8$). Both accumulation and degradation occurred for 24-hours in either distilled water or stream water free of apple snails. Extractions took place from 1.2 μm filters (after 250 mL filtered) and we quantified eDNA using species-specific primers with quantitative PCR. Generally, containers with more snails should generate more eDNA, but the presence of decomposers in the stream water may accelerate degradation. Consequently, we may see both linear and logarithmic trends. Our ability to understand the relationship between eDNA and biomass of P. maculata will help inform future management efforts.

872 Daniel Rhoda, Kenneth Angielczyk

Diversification of the ruminant skull along an evolutionary line of least resistance

Morphological integration is relevant to evolutionary biology because the structure of variation within populations determines the ways in which a population can respond to selective pressures. However, understanding the macroevolutionary consequences of morphological integration is elusive because the adaptive landscape is dynamic and population-level constraints themselves evolve. By analyzing a previously published dataset of 2857 ruminant crania with 3D geometric morphometrics and phylogenetic comparative methods, we find that variation within and between ruminant species is strongly biased by a highly conserved mammalian-wide allometric pattern, CREA, where larger species have proportionally longer faces. Ruminant species with variation more aligned with CREA diverge from their ancestors farther, and Ruminantia as-a-clade diversifies farther than expected given a Brownian motion model of evolution, but only in directions anticipated by CREA. Our analyses indicate that CREA is acting as an evolutionary 'line of least resistance' and is facilitating morphological diversification due to its alignment with the browser-grazer continuum. Our results demonstrate that biological processes constraining variation at the microevolutionary level can produce highly directional phenotypic evolution over macroevolutionary timescales and provides an empirical example of morphological integration acting as a facilitator, rather than an impediment, to morphological diversification.

695 Emma M. Rhodes, Kang Nian Yap, Paulo H. C. Mesquita, Hailey Parry, Andreas Kavazis, Jesse Krause, Geoffrey Hill, Wendy Hood

Mitochondrial respiratory function varies between migratory and non-migratory White-crowned Sparrows

The energetics of migration and the role mitochondria play remain an enigma. We studied mitochondrial function of two subspecies of White-crowned Sparrow (Zonotrichia leucophrys), migratory Z. l. gambelii and non-migratory Z. l. nutalli in California. Collection occurred during three different time points: pre-migration, mid-fall migration, and winter. We hypothesized that mitochondrial adaptation plays a significant role in bird migration. We predicted that migratory birds would have higher maximum mitochondrial respiration, respiratory control ratio (RCR), mitochondrial density, and complex enzymatic activity compared to the non-migratory group. Through differential centrifugation, we isolated mitochondria from the pectoralis muscle and polarographically tested mitochondrial oxygen consumption. For the mid-migration timepoint, our results show that for both Complex I and II respiration, Z. l. gambelii has significantly higher maximum respiration compared to that of Z. l. nutalli and migrant RCR values were higher for complex I respiration but not complex II respiration. Migrants overall had significantly higher mitochondrial density than residents. For complex enzymatic activity, we found no patterns with the residents. Among migrants, complex II and III activity were significantly lower for the mid-migration timepoint compared to the spring and winter timepoint. We observed mixed seasonal effects for the migrant subspecies, indicating that subspecies difference could be due to both fixed and plastic traits. Our study supports the hypothesis that mitochondria may play a crucial role in migration.

1793 Gal Ribak

Do insects fly at optimal Strouhal numbers?

Insects are the smallest flying animals, representing nature's solutions for the problem of flapping flight at Reynolds (Re) numbers in the range of 10asurments and models I show that one of the reasons for the high flight cost is the low aerodynamic propulsion efficiency. Propulsion efficiency of heaving and pitching plates or flapping wings is optimal when vortex shedding is properly synchronized with the flapping motion. The maximal efficiency is achieved in a relatively narrow range of Strouhal (St) numbers (St = 0.2-0.4). A previous work showed that cruising birds, bats, and some insects fly in Strouhal numbers tuned for high propulsion efficiency. The present work will show that due to restrictions on the flight speed and stroke plane angle of most insects, the insects flying at 0.2St are the exception rather than the norm. In fact, forward flying insects fly at much higher Strouhal numbers, a consequence of their primary adaptation for hovering and low-speed flight.

345 Kyra Ricci, Grascen Shidemantle, Jessica Hua

Communicating disease ecology through art: an empirical investigation

Comic books and other visual narratives are promising tools for science communication and science education, yet empirical examination of the direct effects of visual narratives on both perceptions and knowledge of science remains scarce. To evaluate this gap in a population with emerging science identity, we developed two educational resources containing identical content about biodiversity and disease designed to educate and engage third grade students: (1) an "Art" resource designed as an original graphic novel, and (2) a "Traditional" resource designed as a PowerPoint presentation. Third grade teachers from 26 classrooms across 10 local schools participated in an educational workshop where they were instructed in how to teach the lessons to their students. Each class was then randomized to receive either the "Art" or "Traditional" lesson. Before and after the lesson, students completed a survey to measure their (1) perceptions of science (e.g., attitudes, trust, engagement with science generally and with this specific topic) and (2) knowledge of this topic (e.g., comprehension of the material). Following the lesson, "Art" students reported feeling more engaged in science than "Traditional" students ($p = 0.022$). Conversely, "Traditional" students reported more trust in science ($p = 0.008$) and performed better than "Art" students in the knowledge assessment ($p = 0.041$). These findings point to the importance of identifying specific intervention objectives and employing mixed methods approaches to maximize gains in all areas of learning.

894 Amber Rice, Joan Marie Spinelli, Austin Russell, Noel Martinez, Alex Huynh, Scott Taylor, Timothy Roth

Impacts of hybridization on cognition in wild-caught and captive-reared chickadees

When hybridization occurs, selection against hybrids reduces gene flow and maintains species barriers. Although learning and memory are known to play important roles in preventing hybridization, whether they contribute to selection against hybrids is less understood. Further, although hybridization is widespread and cognition is linked to fitness in many taxa, whether and how hybridization affects cognition remains unclear. Black-capped (Poecile atricapillus) and Carolina chickadees (P. carolinensis) naturally hybridize, and also rely on learning and memory to cache and retrieve food as an adaptation for overwinter survival. Here, we asked how hybridization impacts cognition in wild-caught chickadees from a hybrid zone transect in the eastern United States. We also tested for effects of hybridization on cognition in captive-reared chickadees, after controlling for variation in environment and experience during development. In both wild-caught and captive-reared chickadees, we tested performance on a series of cognitive tests, including associative spatial learning, reversal learning, problem solving, and response to novelty. Our results provide insight into whether cognition may contribute to reproductive isolation, and whether any cognitive differences among hybrid and parental chickadees result from the intrinsic effects of hybridization.

37 Jacquline Rich, Jonathan Cowart, Dara Orbach

Anatomy Inspiring Technology in Novel Artificial Vagina Design

Artificial vaginas (AVs) are an essential tool for collecting ejaculates for artificial insemination. Modifications to AVs, such as adding a warmed bladder, have improved the efficacy of AVs. However, no current AV model mimics both the shape and elastic features of the vaginal lumen. Using common bottlenose dolphins (Tursiops truncatus) as a model species, we developed an AV from post-mortem female dolphins that reflect the natural features of vaginal tissue. As female and male genitalia coevolve in shape in dolphins, we hypothesize that an AV design that simulates the shape and skin-like texture of the vagina will enhance the quality of ejaculate collected. Ejaculates will be collected from ten trained sexually mature male dolphins at aquaria using the AV and traditional manual stimulation techniques. The quality of the ejaculates collected with each technique will be compared through motility, morphology, and integrity analyses using computer-aided sperm analysis software and histochemical staining techniques. This pilot study has significant broader applications in influencing future AV designs for other marine and terrestrial species to improve ejaculate quality at the time of collection for conservation applications.

38 Jacquline Rich, Katie Doyle, Dara Orbach

Future of Open Educational Resources: Student Teaching in a University-Middle School Collaboration

Middle school is a pivotal time in students' academic trajectory to develop higher education aspirations. Despite anecdotal examples of collaborations between middle school and university-aged students, few publications have empirically assessed the value of such a collaboration for empowering and inspiring both groups of students. We facilitated a formal collaborative learning experience in South Texas between senior university students in an anatomy course at a Hispanic Serving Institution and middle school students where most students are considered "at risk" of dropping out. University students created age-appropriate animal anatomy presentations that were recorded for international dissemination via YouTube as an Open Educational Resource (OER) and presented interactively to local middle school students. Participants completed voluntary pre- and post-presentation surveys to assess learning experiences, which were analyzed using descriptive statistics and ANOVA. The cross-generational collaboration resulted in positive outcomes for both groups of students. After participating in the presentations, 98% of middle school students were interested in attending college/university and 84% of university students found the experience of teaching middle school students empowering. We conclude by outlining recommendations for facilitating successful OER development and cross-institutional collaborations which benefit all participating institutions.

664 Emilie Richards

Genetic basis of natural variation in sleep and metabolism in cavefish

While metabolic state and sleep seem to be strongly integrated in animals, in which sleep loss correlates with increased appetite and insulin resistance, little is known about the mechanistic and genetic basis for the integration of sleep and metabolic state. This has been a challenge in part because most animals do not display dramatic, natural differences among populations of the same species in both sleep and metabolic traits. However, cave and surface populations of A. mexicanus display such natural variation, in which cave fish sleep less and are more obese. Here we leverage that variation to identify novel genetic regulators of sleep and feeding. We combined novel high-throughput behavioral analyses and innovative population genomic sequencing strategies to identify the genetic architecture associated with sleep loss, hyperphagia, and adiposity in multiple independently evolved populations of cavefish. QTL analyses of F2 hybrid populations between cave and surface fish reveal that sleep and metabolic traits in cavefish are related to each other either through physical linkage, similar genetic basis, or pleiotropy. This relationship varies across hybrid populations, suggesting a unique genetic basis for these traits across independent cave populations. Additionally, cave ancestry patterns in natural hybrid populations indicate regions of the genome associated with sleep and metabolic state are under strong selection and suggest that these correlations may have been essential for adaptation to cave environments.

31 Corinne Richards-Zawacki, Yusan Yang, Kimberly Howell, Layla Freeborn, Marco Gonzalez-Santoro, Justin Yeager, Matthew Dugas, Maria Servedio

Lessons in evolution and speciation learned from a polymorphic poison frog, Oophaga pumilio

What can a poison frog the size of your thumbnail teach us about how new species form? In the case of the strawberry poison frog, Oophaga pumilio, we'd argue a lot! The striking variety of color morphs this species exhibits, as well as its rare form of parental care, have drawn the attention of evolutionary biologists like us for decades, who ask: How and when did this amazing phenotypic diversity evolve? What function(s) does their color serve? Seeking the answers to these questions, has taken us on a journey that has taught us surprising things about aposematism, perception, mating, fighting, and learning that is reshaping the way we think about sexual selection's role in speciation and about the capacity for learning to shape the evolution of phenotypes.

799 Kentrell Richardson, Kamari Boyd, Megan Barlowe, Kelsey Reider

Understanding context dependent responses to climate change in Arizona Tiger Salamanders

Climate change can reduce the effectiveness of thermoregulatory behavioral adaptations to temperature fluctuations which could push animals to face more thermal stress events. Understanding the relationship between thermal environment, amphibian physiology, and metamorphosis, provides insight into how well organisms can evade thermal stress. Arizona Tiger Salamander (Ambystoma mavortium nebulosum) live in multiple thermal environments by becoming a semi-terrestrial adult, metamorph, or a fully aquatic adult, paedomorph. We expected semi-terrestrial metamorphs exist in a more variable environment and therefore will display a higher warming tolerance and respond more readily to climate change than their aquatic counterparts. We compared CTmax and warming tolerance of metamorphs, paedomorphs, 2nd year larvae and hatchlings to understand the relationship of morphology and age class on variations in CTmax. To determine the upper critical thermal limit of salamanders, we gradually warmed salamanders at a rate of ~0.25?/minute until loss of righting response occurred. CTmax occurred at similar ranges for 2nd year larvae (32.83 $\pm$ 1.48?), metamorphs (33.41 $\pm$ 1.98?), paedormorphs (33.15 $\pm$ 2.96?), with hatchlings (23.40 $\pm$ 1.36?) being lower than other groups. Data will be analyzed using mixed-effects models to determine significant differences in the upper critical thermal limits. Understanding how differences in environmental context and age influence warming tolerance may improve our knowledge regarding the ability of organisms to respond to more extreme environmental conditions due to climate change.

275 Melanie Richter, Beth Roberts, Mark Sandfoss, Steve Reichling

Seasonal variation in fecal hormone levels in the endangered Louisiana pinesnake

Endocrinology in reptiles is a vastly under-studied field ripe for investigation, particularly in egg-laying snakes. The Louisiana pinesnake (Pituophis ruthveni) is an endangered, egg-laying, colubrid occurring in the southeastern United States. The Memphis Zoo leads a captive breeding/reintroduction program but despite successes in breeding, little is known about annual hormone cycles and reproductive phenology of this species. We collected 200+ fecal samples from captive, adult snakes (23F, 20M) housed under conditions that mimic the seasonal changes of their native habitat. Samples were collected over 1.5 years, dried and extracted, prior to utilizing ELISAs to measure four hormones: testosterone, progesterone, estradiol, and corticosterone. Using 2-way ANOVA and pair-wise comparisons on 50-day binned data (significance set at $p < 0 .05$), we found that males and females display different seasonal hormonal changes, and some changes reflect reproductive state. In females, fecal corticosterone levels are significantly higher immediately before and after brumation; estradiol and testosterone levels are not significantly influenced by time of year or individual, but progesterone levels vary significantly depending on individual. In males, we found elevated corticosterone during

the first half of the active season and testosterone significantly elevated only during breeding, but neither progesterone nor estradiol changed with time or individual. We intend this to be a preliminary study into seasonal hormonal patterns in egg-laying snakes and, especially, to aid in recovery of this endangered species.

149 Johannah RIckman, Abby Burtner, Tate Linden, Sharlene Santana, Chris Law

Differences in limb bone micro-anatomy across ecotypes in Sciuridae

The assertion that bones remodel to adapt to their mechanical environment is referred to as Wolff's Law. While researchers have examined the external shape of skeletal elements, there have been relatively fewer studies examining microanatomical internal bone structure despite its potential significance to locomotor biomechanics. This study quantifies and compares internal differences in long bone skeletal morphology of squirrels (Sciuridae) across four ecotypes: ground, chipmunks, tree, and gliding. We test the hypothesis that forelimb and hind limb internal bone structure reflects adaptations to these ecotypes. To test our hypothesis, we micro-CT scanned the humeri and femora of 78 species and conducted bone structure analyses using 3D Slicer. We assessed cortical bone composition by measuring global compactness, diaphysis elongation, and cross-sectional shape at midshaft. We predicted that gliders would have relatively less compact long bones with more elongated diaphyses due to the gravitational/aerodynamic constraints of gliding, whereas ground squirrels would exhibit highly compact long bones with more robust diaphyses to resist the reaction forces associated with burrowing. Overall, our results were not consistent with our predictions. Instead, size had an important influence on the scaling patterns of internal limb properties between ecotypes. Furthermore, no significant differences were observed between internal bone structure (size-corrected) and ecotypes. This study lays the groundwork for further biomechanical and behavioral work to examine the mechanisms linking limb form and function.

274 Lourdes Ricks, James Newcomb

The Role of Cell Division in Regeneration of Rhinophores in Berghia stephanieae

Regeneration is exhibited by certain animals, such as the nudibranch Berghia stephanieae. The goal of this study was to investigate the role of cell division in Berghia regeneration, using phosphorylated histone 3 (H3P) as a marker for cell division. For each animal, the right rhinophore was amputated at the base, while the left rhinophore was left intact, to be used as a within-animal control. Following amputation, cell division was assessed via H3P immunohistochemistry, and comparison of the number of H3P-positive cells between regenerating and control rhinophores. Each animal was fixed immediately ($n = 12$), or at 4 hours ($n = 8$), 24 hours ($n = 6$), 3 days ($n = 7$), or 7 days ($n = 8$) after amputation of the rhinophore. H3P-positive cells were present in all control rhinophores, indicating a baseline level of cell division. At the initial time point, amputated rhinophores had a significantly lower number of H3P-positive cells than control rhinophores ($p = 0.003$). However, by 4 hours, the number of H3P-positive cells was the same between lesioned and control rhinophores. Three days after amputation, the number of H3P-positive cells in the regenerating rhinophores was almost significantly higher than controls ($p = 0.057$), and 7 days after lesion, the regenerating rhinophores exhibited significantly more H3P-positive cells ($p = 0.017$). These data indicate that regeneration of rhinophores in Berghia involves cell division, but not until at least several days after injury.

1265 Eric Riddell, Colton Poore

Conflicting patterns among indices of climate vulnerability between two species of bumble bees

Due to the threat of global climate change on biodiversity, biologists have tried to identify the characteristics that make a species more vulnerable to environmental change. From a physiological perspective, the traits that have received the most support are acclimation capacity, thermal tolerance, and physiological sensitivity to warming, but rarely are these traits evaluated simultaneously to assess consistency in vulnerability metrics. We compared the thermal physiology of queen bumble bees from a species currently in decline (Bombas auricomus) and a stable species (B. impatiens) in a long-term acclimation experiment to evaluate acclimation capacity, critical thermal maxima (CTmax), and thermal sensitivity of metabolic rate and water loss rate. Neither species were capable of acclimating to temperature by adjusting metabolic rate, water loss rate, or thermal tolerances. The declining species exhibited a higher CTmax compared to the stable species, yet they also exhibited a higher metabolic sensitivity to temperature compared to the stable species, illustrating conflicting patterns among indices of vulnerability. Moreover, the species with the higher CTmax experienced the lowest survival in the days following the thermal tolerances trials. Our study discovered highly inconsistent indices of climate vulnerability within and between species, indicating that physiological studies should evaluate the relationship between these indices and species decline to develop more accurate metrics of vulnerability.

1011 Jeff Riffell

The olfactory gating of color vision in mosquitoes

Mosquitoes track odors, locate hosts, and find mates visually. The color of a food resource, such as a flower or warm-blooded host, can be dominated by long wavelengths of the visible light spectrum (green to red for humans) and is likely important for object recognition and localization. However, little is known about the wavelengths that attract mosquitoes or how odor affects mosquito visual search behaviors. Furthermore, with respect to mosquito attraction, is there a stable association between specific odors and certain bands of the visual spectrum? We use a real-time 3D tracking system and wind tunnel that allows careful control of the olfactory and visual environment to quantify the behavior of mosquito trajectories. We find that CO2 and other host odors induce a strong attraction to specific spectral bands, including those that humans perceive as orange and red. Sensitivity to orange and red correlates with mosquitoes' strong attraction to the color spectrum of human skin, which is dominated by these wavelengths. The attraction is eliminated by filtering the orange and red bands from the skin color spectrum and by introducing mutations targeting specific long-wavelength opsins or CO2 detection. Collectively, our results show that odor is critical for mosquitoes' wavelength preferences and that the mosquito visual system is a promising target for inhibiting their attraction to human hosts.

849 Joshua Rinehart, Keegan Foster, Arun Rajamohan, Julia Bowsher

Methylation inhibitor 5-aza-2-deoxycytidine induces diapause in Megachile Rotundata

Diapause is an important stage in the life cycle of the alfalfa leafcutting bee (Megachile Rotundata) life cycle that allows them to survive harsh overwintering. Not all bees enter diapause, with some individuals directly developing to emerge as an adult the same summer. Many studies that have explored potential cues for diapause in M. rotundata, and results suggest that the cue is maternal. In other insects, maternal cues are mediated by methylation of DNA. Our goal was to test whether methylation in M. rotundata parents regulates diapause status in their offspring. Adult bees were fed 10 μM of the methylation inhibitor 5-aza-2-deoxycytidine mixed into a sucrose solution before being released into the field to build nests. We used x-ray images of the nests to observe the diapause status of the progeny. We found that bees fed the methylation inhibitor laid offspring that were more likely to initiate diapause. Our results suggest that low methylation rates transmitted from parents to offspring during egg laying contributes to the initiation of diapause in the offspring.

1196 Danielle Rios, Elizabeth Borda, Davida Smyth, Jose Valdez

Plant-Vector-Microbe Interactions of Texas Grasslands

Hemipterans are potential vectors of agricultural plant pathogens and wild host plants worldwide. Asymptomatic non-native host plants are often the source of these pathogens, which includes ornamental, crop, or pasture species. The role of hemipterans as disease vectors of crop or ornamental diseases in central Texas is known; however, their role as vectors in pasture or native grassland species remains understudied. In response to this initiative, we study the potential role of hemipterans as vectors of grass pathogens such as phytoplasma from invasive asymptomatic non-native and native hosts. We select two sites where non-native invasives are well established and native species are present. At each site we setup 50m transects, harvest plant tissues, and collect hemipterans using sweep nets and light traps. Hemipterans are sorted, DNA is extracted for barcoding, and microbial DNA is isolated from aboveground plant tissues and hemipteran specimens. We hypothesize that asymptomatic microbes have an antagonistic effect on the surrounding native species, and in part explains non-native invasive dominance. Additionally, we hypothesize that microbiomes of hemipterans associated with native grasses will differ from hemipteran associated with non-native grass microbiome. Our study provides new protocols to study microbiomes of hemipterans and grass in addition to increasing our understanding of the role microbiomes have in non-native grass establishment.

180 Madison Rittinger, Rafael Rodriguez

How Pholcus phalangioides Cellar Spiders (Araneae: Pholcidae) Solve Prey Capture Problems

Animals encounter and solve a myriad of problems daily. Predators encounter many problems while subduing prey and how they solve those problems may vary based on the environment, prey qualities, and can be specific to the species or individual. Species-specific solutions likely evolved and are innate, while individual-specific solutions may be learned or even novel. Pholcus phalangioides cellar spiders have a species-specific solution to capturing prey; yet, how cellar spiders solve new or rare problems capturing prey may vary between individuals. This research will test hypotheses about the problem-solving capabilities of cellar spiders by analyzing variation, both within and between individuals, in the behavior they use to capture multiple prey simultaneously. This research explores how the behavioral flexibility of animals such as web-building spiders, whose behavior is typically explained via 'hard-wired' motor routines or basic learning abilities, can help understand the range of cognitive abilities different brain architectures can afford and how animals evolve to confront problems that arise in their lives.

175 Clare Rittschof, Rebecca Westwick

The impacts of early life on adult behavior and health in the honey bee (Apis mellifera)

Early-life is a critical period for bees, as the larval stage is the predominant feeding stage that sets morphology, physiology, and behavior for the rest of life. The honey bee is renowned for the social sensitivity and behavioral plasticity of the adult worker caste, but relatively little is known about the impacts of social and environmental experiences during the larval stages. We have been evaluating these questions in the context of defensive aggression. Honey bee nest defense requires sophisticated social coordination. On an acute timescale, workers coordinate this response using an alarm pheromone. However, threatening experiences, the perception of alarm cues from nestmates, and even ecological conditions that signal food shortages lower the worker threshold for defensive response. I discuss evidence that the early-life colony environment experienced by worker larvae impacts aggression once these bees emerge as adults. The larval environment affects the molecular profile of the brain and peripheral tissues leading to diverse potential impacts on health outcomes. New work suggests that adult nurse bees are sensitive to alarm cues in the nest, and may even prioritize these cues over larval begging signals, even though nurses are not defensive specialists. Larvae seem to receive social information about threats to the nest through their interactions with nurses. On-going work explores how developmental effects are regulated, and how they combine with adult experiences to shape aggression.

269 Joshua Rivera, Joseph Rangel, André Carvalho, Adam Leaché, Matthew Fujita

Epidermal Gland Evolution in Whiptail Lizards (Aspidoscelis)

The secretion and recognition of chemical stimuli in squamate reptiles has been a burgeoning field of research. These chemical stimuli (i.e., pheromones) serve a role in various intraspecific and interspecific behaviors (e.g., kin identification, mate choice, heterospecific aggression). Furthermore, studies have shown that some morphologically conservative lizard radiations exhibit divergence in pheromone composition. Whiptail lizards of the genus Aspidoscelis possess femoral glands, though neither the composition of the pheromones, nor the underlying genetic mechanisms regulating expression of the glandular content, are understood. In this study, we compare pheromone expression between parthenogenetic and sexually reproducing whiptails. Due to the presence of pseudocopulation in the all-female parthenogens, we expect there to be minimal differences in expressed genes, though there may be some expressed genes that are absent in asexuals that are specific for male-male aggression. Lizards caught in the field were immediately processed, which included extraction of the gland chemicals and excision of both the femoral gland tissue and forelimb tissue (control). Transcriptomic data, acquired through gland RNA extraction and library preparation, were used to perform gene ontology analyses to investigate the diversity of proteins associated with glandular tissue. Combined pathway analyses were then conducted to infer potential biochemical pathways involved in the femoral glands. The results of this study help illuminate the genetic machinery responsible for maintaining these evolutionarily ubiquitous structures necessary for chemical communication.

548 Micaela Rivera, Rosalyn Putland, Lilly Hall, Allen Mensinger

Auditory Sensitivity in Developing Little Skates (Leucoraja erinacea)

Anthropogenic sound continues to increase in aquatic environments however its impact on aquatic life is just beginning to be understood. While many free swimming animals can swim away from sound sources, sessile and/or developing organisms can be impacted by sound. The little skates (Leucoraja erinacea) reproduce by laying egg cases that remain fixed to the substrate throughout the embryo's development and therefore can be subjected to extended sound exposure. Chondrichthyes (cartilaginous fish) evolved over 450 million years and despite their ancient lineage, auditory sensitivity in Chondrichthyes remains relatively unexplored compared to teleost fish with even fewer studies focusing on ontogeny. The current study investigates the auditory sensitivity of little skates both in the egg case and over the course of their first seven weeks post hatch. Auditory evoked potentials (AEPs) were recorded weekly during the skates' development. Preliminary results show that juvenile skates are sensitive to 100 to 500 Hz, primarily at 130-145 decibels, with peak sensitivity at 100Hz. These results suggest that the auditory sensitivity of skates within the egg case are similar to recently hatched skates. This study provides a baseline on the auditory sensitivity in little skates and creates a pathway for research to investigate how anthropogenic sound may impact the hearing of juvenile and embryonic little skates.

1170 Dan Rivera, Madhusudhan Venkadesan

Crossbridge stiffnesses do not add in parallel

The stiffness of active muscle is thought to scale in direct proportion to the number of myosin crossbridges that are formed. The underlying assumption is that the crossbridges may be treated as if they act in parallel and the effect of filament compliance is manifested as a net series compliance. But the filaments are not infinitely stiff, which implies that crossbridges are not exactly in parallel. Here we show that even the small degree of compliance of the filaments has a profound effect on the net stiffness of an ensemble of crossbridges. We exactly account for the filament compliance and calculate the resultant stiffness $k*$ of a pair of filaments of stiffness k between which a fixed number of crossbridges of stiffness $kb \ll k$ are formed. The discrepancy between the exact accounting and the lumped compliance approximation depends on the number of crossbridges, but the lumped compliance approximation underestimates the net stiffness by over two fold for a pair of filaments in a half sarcomere. Moreover, the net stiffness takes on different values depending on the spatial ordering of crossbridges, with normally distributed stiffnesses in the exact accounting versus heavily right-skewed for the lumped compliance approximation. We speculate that the dependence of net stiffness distributions on the spatial ordering of crossbridges has mechanochemical consequences and may affect the active response of muscle to external perturbations.

1310 Beth Roberts, Mark Sandfoss, Matteo Oliveri, Melanie Richter, Tonia Schwartz, Alexis Lindsey, Jessica Cantrell, Steve Reichling

Achieving multi-paternity clutches: Developing AI in the endangered Louisiana pinesnake

Assisted reproductive technology has great potential for reptile conservation. The development of artificial insemination (AI) for endangered reptiles could be used to increase paternity within a clutch and promote gene flow between in situ and ex situ populations. To develop AI techniques for the endangered Louisiana pinesnake we used coelomic palpation and ultrasound to monitor the follicular development of six females during the 2020 breeding season. Once active follicular growth was detected, females were inseminated every 3 to 5 days for up to 3 weeks with fresh collected semen. Females were inseminated 3 to 5 times depending on follicular development, with an average of 0.5ml of semen delivered into the oviducts using a 3 French tomcat catheter and an otoscope with speculum to visualize. Different males were used at different follicle stages to potentially allow for the narrowing of the best fertilization window. Five of the six females became gravid (83%) and laid a total of 35 eggs with 26 showing evidence of fertility (74% fertile), and 23 hatchlings emerged (65% hatch). AI dose volume, concentration, and timing contributed to paternity success. Every male used contributed genetics to at least one clutch and multi-paternity occurred in all clutches produced. The most hatchlings were produced from sperm delivered around ovulation. Our results demonstrate that AI and multi-paternity can be achieved with AI for the Louisiana pinesnake.

122 Alexus Roberts-Hugghis, Edward Burress, Brian Lam, Peter Wainwright

Pharyngognathy enhances — not reduces — evolutionary integration in the fish feeding apparatus

The modified pharyngeal jaw apparatus in cichlids is widely viewed as a morphological innovation that played a key role in the diversification of this iconic fish lineage. Liem 1973 famously postulated that the pharyngeal jaw novelty reduces evolutionary integration of the oral and pharyngeal jaw systems, enabling further ecomorphological diversification of the feeding apparatus. Though several recent studies show a weak but significantly integrated feeding system in pharyngognathous cichlids, these findings lack any information as to how these dynamics compare to those in non-pharyngognathous fishes. Examining trophic structures in over 500 specimens, we conduct comparative phylogenetic analyses of integration within the feeding apparatus of 85 species of Neotropical cichlids and 30 species of North American centrarchids, who lack the specialized pharyngeal jaw system. Contrary to Liem's decoupling hypothesis, we find that evolutionary integration between the oral and pharyngeal jaws is significantly stronger in cichlids than in centrarchids. However, we find no significant differences between the two lineages in strength of integration within each jaw system, rates of morphological evolution, or disparity. Our results indicate that the modified pharyngeal jaw apparatus in cichlids resulted in less evolutionary independence of the overall feeding system, not greater independence as has long been thought. Thus, we raise the possibility that the classic cichlid novelty enhanced feeding performance, but did not substantially alter the evolutionary dynamics within the feeding apparatus.

330 Christopher Robinson, Matthew Hale, Tyler Wittman, Christian Cox, Henry John-Alder, Robert Cox

Changes in androgen sensitivity of melanogenesis genes underlie ventral color loss in fence lizards

Sexual dimorphism often develops due to sex differences in autosomal gene expression, which can be regulated by maturational changes in hormones such as testosterone. However, it is generally unknown whether evolutionary changes in hormonally mediated sexual dimorphism occur via upstream changes in expression of genes that mediate hormone availability and signaling, downstream changes in expression of gene pathways activated by hormonal signaling, or both. Here, we use comparative transcriptomics to test these alternatives in two species of Sceloporus lizards that exhibit different patterns of sexual dichromatism: S. undulatus males develop blue and black ventral coloration in response to testosterone, whereas S. virgatus does not develop ventral coloration in either sex. We administered testosterone implants to juvenile lizards, collected ventral skin, and used RNAseq to quantify gene expression. Genes downstream of androgen signaling related to melanin synthesis, including POMC and TYR, were upregulated by testosterone in S. undulatus but were unresponsive in S. virgatus. This could be partly due to differences in upstream genes that affect hormone availability and conversion in the skin; S. undulatus exhibited higher expression of SRD5A2, which encodes for an enzyme that converts testosterone to 5α-dihydrotestosterone, while S. virgatus exhibited higher expression of SHBG, which limits the ability of free testosterone to bind its receptor. Overall, evolution of downstream pathways, with potential mediation from upstream mechanisms, contributes to evolution of sexual dimorphism.

1658 Alana Robinson, Emma Elliott-Smith, Alexi Besser, Martin Tinker, Seth Newsome

Amino acid metabolism in southern sea otters

The determination of stable isotope ratios within individual compounds, such as amino acids, has emerged as a powerful tool in animal ecology. However, important methodological questions remain including (1) how physiology and tissue synthesis impact amino acid isotope values and (2) how accurate amino acid δ13C analysis is in tracing energy flow through food webs. To address these issues, we measured carbon isotope (δ13C) values of essential and nonessential amino acids within bone, whisker, muscle, and liver of southern sea otters (Enhydra lutris nereis) from Monterey Bay, California. Individuals in this population exhibit high degrees of individual dietary specialization, making this an excellent case study to examine the above questions in a wild population. We found δ13C values of glutamic acid, proline, serine, lysine, and threonine differed significantly among tissues, indicating isotopic discrimination during tissue synthesis. Threonine δ13C values were higher in liver relative to bone and muscle, which may indicate catabolism of threonine for gluconeogenesis, an interpretation supported by the correlation in δ13C values among threonine, glycine, and serine. These tissue specific differences in amino acid δ13C values resulted in different multivariate “fingerprints” of samples from the same individual. We thus recommend cautious application of this technique with samples from different substrates/tissues. Our results indicate that physiology strongly influences amino acid δ13C values and highlight the need for additional research and laboratory studies.

447 Dulce Robles-Martinez, Kelsey Woldt, Diego Sustaita

Climbing kinematics of salt marsh harvest mice and co-occurring rodents in the Suisun Marsh, CA

Salt marsh harvest mice (Reithrodontomys raviventris) inhabit the San Francisco and San Pablo Bay estuaries, where they are subjected to daily and/or seasonal flooding. However, during floods they tend not to disperse to nearby uplands, suggesting that climbing emergent vegetation is critical for their survival. The climbing performance of R. raviventris was compared to R. megalotis and Mus musculus, co-occurring species with different microhabitat preferences. Individuals were filmed traversing dowels of different orientations (horizontal, 45° and 90° descents) and diameters (5, 10, and 20 mm) to quantify gait metrics and tail use. Preliminary data suggests greater use of asymmetrical gaits than symmetrical gaits across all dowel types. Reithrodontomys raviventris and M. musculus showed equal use of forelimb and hindlimb support with higher limb support durations on narrow horizontal substrates. During descents, R. raviventris exhibited relatively greater forelimb support, suggesting forelimbs are used more for breaking. The higher limb support durations employed by R. raviventris suggest slower, more cautious movement on narrow and inclined dowels, which is supported by velocity measurements. Compared to M. musculus, R. raviventris used their tails more for grip support on narrow and inclined descents. These patterns partly reflect expectations for scansorial species, suggesting that salt marsh harvest mice are well adapted for climbing, which may be critical for their survival during tidal inundation in their brackish marsh environment.

1808 Matt Rock, Diane Nacci, Bryan Clark, Jeffrey Markert

Rapid Evolution of Pollution Resistance in Atlantic Killifish

We examined genetic variation in Atlantic Killifish (Fundulus heteroclitus) populations to better understand their ability to persist in Superfund sites like New Bedford Harbor (Massachusetts, USA), which is polluted with a mix of organic toxicants and heavy metals. By combining information from GenBank and published sources, along with our own population genetic analysis, we identified allele frequency differences in loci consistent with this adaptation. We collected 500+ fin clips from killifish present along the Rhode Island and Massachusetts coast at 11 different locations. We observed two patterns. The first being the expected pattern of genetic isolation by distance when all loci were examined as a group. The second pattern is that genotypes at some loci are consistent with selection at polluted locations around New Bedford Harbor. As predicted by other researchers, loci associated with the Aryl Hydrocarbon Receptor (AHR) receptor system show large differences in allele frequencies between polluted and non-polluted sites. One axis of a Principal Components Analysis suggests a pattern of divergence by geography while the second axis shows a pattern of divergence associated with pollution level.

1184 Ian Rockel, Charles Watson

Comparative physiology and differential thermal environment usage in a South Texas lizard community

It is important to understand differences in thermal physiology and usage of the thermal environment as wildlife communities are forced to adjust to increasing temperatures that accompany anthropogenic climate change. Many studies aim to document the thermal physiology of a single species and comment upon how changes in temperature affects their biology as an individual and, by extension, a population. We argue that a community-based approach that, unlike the summary community-temperature index, takes into consideration differences among member species is required to more broadly appreciate how relationships may change as some species experience greater risk and others realize opportunities in the context of a competitive landscape when faced with increasing temperatures. Here, we measure thermal habitat suitability and thermal sensitivity of metabolism and performance of a small community of lizards in South Texas to better understand how members of this community may react to changes in temperature. While we know that there are many additional variables that accompany both adaptation and local climate, this study represents an attempt to extend our understanding of physiological patterns seen within populations to an actively interacting community.

340 Leonardo Rodriguez, Cecilia Doan, Alexis Ayala, Rachael Tang, Derrick groom

High-temperature effects on behavior and torpor in Calytpe anna

Ambient temperatures have consistently exceeded record highs each year in the past decade, and there is an increasing risk of mortality for small bird species. One possible strategy for improving survival is the utilization of torpor. Torpor is a unique physiological state used by many small endotherms to temporarily depress their metabolic rate and is typically used in response to seasonal variation and other environmental stressors. But, it remains unclear how high daytime temperatures may influence the duration, frequency, and intensity of torpor bouts for small avian taxa. We hypothesize that high daytime ambient temperatures will increase overnight torpor duration, frequency, and intensity because of reduced foraging and activity due to high temperatures. We conducted temperature acclimation trials on six Anna's hummingbirds. The birds were held at a 14:10 light cycle and placed into an environmental chamber for one of two temperature trials: constant 20°C or cycling between 35°C and 20°C during the light and dark phase, respectively. Body mass, food consumption, and time spent perched was measured. Respirometry was also performed overnight three times per week to quantify overnight metabolic rates and torpor use. Our findings will uncover the energetic strategies and behavioral mechanisms for small avian species during high temperatures.

951 David Rodriguez, Maria del Mar Moretta-Urdiales, Rebecca Brunner, Ryan Lynch, Juan Manuel Guayasamín-Ernest, Shawn McCracken

Leveraging portable instrumentation to inform host-pathogen dynamics in tropical amphibians in situ

Measuring genetic diversity contributes to the delineation of operational taxonomic units, evolutionarily significant units, designation of management units, and informs evolutionary hypotheses explaining underlying patterns of diversity across a landscape. Moreover, host diversity data are needed to test for potential patterns of host specificity in the amphibian-chytrid system, which would provide insight into fine-scale host-pathogen dynamics. In understudied regions with potentially high rates of cryptic diversity, host identity is needed to more accurately estimate pathogen prevalence and host competence, the ability of a host to carry and transmit pathogens to other hosts. Therefore, in the field, our goal was to 1) sequence regions from the amphibian mitochondrial genome to perform taxonomic assignment by leveraging nanopore sequencing, and 2) to measure infection loads of Batrachochytrium dendrobatidis via quantitative PCR using a small form-factor Magnetic Induction Cycler in Ecuadorian amphibian communities. Our results demonstrate that rapid assessments of both host identity and pathogen infection intensity are feasible with molecular field techniques and portable equipment.

992 Alexander Rodriguez, Ethan Bailey, Amy Payne, Eduardo Balreira, Michele Johnson

Complexity of post-autotomy lizard tail movement

Many animals can adaptively autotomize (or, release) a body part when they are threatened. In lizards, tails are frequently autotomized under the threat of predation, and in many species, tails continue independently moving after autotomy to distract the potential predator while (the rest of) the animal escapes. Species vary in how tails move after autotomy, but why? In this study, we examined 7 species to determine if tail length, width, or musculature are associated with the curvature or distance of post-autotomy tail movement. To this end, we captured lizards and removed approximately two-thirds of their tails. The movements of these autotomized tails were video-recorded, and these movements were then analyzed using MATLAB. Tail tissues were cryosectioned to measure the cross-sectional area of tail musculature. Preliminary results suggest that the curvature and distance of tail movement are correlated with the length of the tail, such that longer tails move a further distance and exhibit less curvature than shorter tails. Yet, post-autotomy tail movement does not seem to be associated with tail diameter or size of the muscle fibers in the tail. This study will contribute to our understanding of the mechanisms underlying the adaptive value of lizard tail autotomy.

1159 Sierra Rodriguez, Jennifer Phillips

The Effects of Sensory Pollution on Insect Diversity and Pollinator Behavior

Pollinators provide a key ecological function to all healthy terrestrial ecosystems, yet in recent years, they have encountered unprecedented declines. Sensory pollution can interfere with visual and auditory systems of animals that regulate daily behaviors. While vertebrate response to sensory pollution is relatively well studied, little is known about how invertebrate pollinator behavior is affected. Here, I test the hypothesis that noise pollution affects pollinator behavior and insect abundance both experimentally and observationally. First, I investigate the insect diversity in Rattlesnake Canyon Habitat Management Area (RCHMA), a long-term study system in northwestern New Mexico pinyon pine–juniper woodlands that contain natural gas wells. Some sites continuously produce noise from compressors (Noise treatment) and other sites are quiet (Control). Additionally, we created Light and Light+Noise treatments to understand the effects of combined sensory pollutants on insect diversity. We used pitfall and sticky traps to estimate species abundance, richness, and beta diversity across treatments, and supplemented this data with pollinator observations and identification. Second, I test whether noise disrupts pollinator movement, using captive leaf cutting bees in a controlled experiment with Noise and Control treatments. I predict that orientation behavior will be impacted by the noise treatment, thus reducing overall movement during experimental trials. Preliminary analyses indicate variation in insect diversity across treatments, and that bee movement is disrupted by noise.

1813 Gloria Rodriguez, Davida Smyth

Developing a faster, inexpensive, accessible, microbial detection method for wastewater surveillance

Used since the 19th century, wastewater surveillance has been used to monitor and track diseases within our community but there are many places in the United States where it is not being used to its full potential. Wastewater surveillance predicted the emergence of the Omicron variant of SAR-CoV-2 before it was identified clinically. SARS-CoV-2 is spread via contaminated aerosols and droplets. People infected can have no symptoms or mild to moderate symptoms such as fever, chills, cough, shortness of breath, fatigue, or muscle aches. However, some will become severely ill, requiring hospitalization. Wastewater surveillance can detect virus levels, or new variants early on before they start to spread and can alert public health authorities to investigate potential outbreaks within our community and develop any countermeasures to prevent further spread. As humans shed other microbes beyond SARS-CoV-2 in their urine and feces daily, testing wastewater is easier and inexpensive to collect, detect, and analyze. This additional public health tool will allow us to see trends on a larger scale than testing individuals and can be applied to other emerging microbes, such as monkeypox. Our goal is to develop a wastewater surveillance program in the San Antonio region, using faster and relatively inexpensive detection methods, with the potential to detect every infected individual within our community and allow public health authorities to determine appropriate actions.

1561 Magrieli Rodriguez-Ruiz, Kristen Mazzarella, Jacob Lasala

Measurement relationships for sea turtles nesting on the Gulf of Mexico

Sea turtle growth rates vary between nesting populations due to diverse foraging habitats and foraging quality. Subsequently, comparisons of sea turtle measurements can be difficult between regions and models defining the relationship between curved and straight measurements are needed. Nesting beaches found in Sarasota County, Florida host the largest loggerhead sea turtle (Caretta caretta) rookery on the Gulf of Mexico and a rapidly growing green sea turtle (Chelonia mydas) nesting population. Tagging programs on Casey Key and Manasota Key have documented nesting sea turtle activity at night since 1983 and this long term data set provides an opportunity to assess female size over time. Sea turtles were measured using calipers (straight carapace length and width) and with flexible measuring tape (curved carapace length and width). Tagging records were compiled over the study timeframe and included 15,624 encounters between the two beaches. Conversion equations were established between the two types of measurements using two types of analyses and a generalized additive model was run to assess how female size has changed over time. These analyses are important to identify how turtles nesting in the Gulf of Mexico compare to higher density nesting beaches in the Atlantic and to determine whether the nesting population has changed over time.

281 Carlos Rodriguez-Saltos, Fernanda Duque, Kathleen Lynch

Transcriptomic correlates of brood-parasitism in cowbirds

Despite maternal care being ancestral and widespread in birds, some species have evolved brood-parasitism in just a few million years. To understand the mechanisms behind such transition, previous work from our laboratory compared gene expression between brood-parasitic bronzed cowbirds versus closely-related, parental red-winged blackbirds. Several genes were found to be differentially expressed, including that encoding prolactin receptor. Here, to increase the sensitivity to detect differences in gene expression, we aligned transcripts to the reference genome of a brown-headed cowbird, a closely related species to both bronzed cowbirds and red-winged blackbirds. In addition, we used a candidate-gene approach to reduce the number of statistical comparisons, and thus type I error. The list of candidate genes was generated by reviewing literature on maternal care in birds and mammals. Similar to the previous study, we focused on expression in the preoptic area, which is a brain region that is critical to maternal behavior across vertebrates. Transcript abundance was compared between prolactin treated and untreated birds in the cowbird species to identify differences related to species and prolactin treatment. By using a sensitive transcriptomic approach and comparing species that naturally lack or show maternal behavior, our study will contribute to understanding the neural physiology of maternal care in vertebrates.

1488 Mariana Rodriguez-Santiago, Esteban Russi, Maite Sánchez, Erik Zornik, Paula Pouso, Kim Hoke

Variability in the vocal repertoire of a South American treefrog

Animals communicate in diverse environments using complex sequences of acoustic signals. In anuran species, males produce advertisement calls that they can modulate depending on the immediate social context. For example, males can emit different types of vocalizations, such as territorial, fighting, or courtship calls, all of which can differ in temporal and spectral properties. Understanding the patterning of calling behavior in anurans provides comparative insight into the complexity of animal communication. Borrowing methods from information theory and linguistic analysis, we examine how variability in the patterning of male calls changes over time and with social feedback. To do so, we study the dynamic calling behavior of the South American treefrog, Boana pulchellus. We analyzed field recordings of male calls and quantified call variability over time using Shannon Entropy and collocation analysis. We found that the complex calls of male B. pulchellus can contain three distinct note types that vary in frequency and duration, and that the calling sequences are dynamic and can be modulated by social feedback (such as the presence of a female or competitor male). Taken together, our results suggest multiple temporal scales of consistency in calling behavior, and nominate ways in which social context alters temporal patterning.

1233 Elizabeth Rogers, Alexander Gerson

Does water stress increase protein oxidation in birds? An investigation using 13C breath analysis

Birds primarily fuel migration with stored fatty acids, but they also burn protein sourced from lean tissues. This reduction is greater under low humidity conditions which may help increase endogenous water production. Although increased protein breakdown in response to high rates of water loss is well established at rest and during flight, the fate of the resulting mobilized amino acids has not been determined. To determine if greater protein breakdown results in greater amino acid oxidation during water restriction, we fed captive House Sparrows (Passer domesticus) 13C-labeled leucine for four weeks and used established water-restriction protocols repeated weekly to increase protein breakdown. We measured body composition changes, resting metabolic rate, and the enrichment of 13C in exhaled CO2. We hypothesized that if birds catabolized proteins to produce endogenous water via amino acid oxidation, we would simultaneously observe greater lean mass loss and elevated d13Cbreath in water-restricted birds. Alternatively, if water-restricted birds increased protein catabolism to influence intracellular osmolality but did not increase amino acid oxidation, we expected greater lean mass loss but no difference in d13Cbreath. Accounting for metabolic rate, we found that water-restricted birds lost more lean mass and had enriched 13Cbreath compared to control birds, demonstrating that birds not only increase protein catabolism when dehydrated, but also increase amino acid oxidation to produce metabolic water as a mechanism for maintaining osmotic homeostasis.

1418 Loranzie Rogers, Nicholas Lozier, Yulia Sapozhnikova, Kelly Diamond, Joseph Sisneros

Functional plasticity of the swim bladder in a vocal fish

Among fishes, particle motion is the most salient acoustic component of sound detected by the inner ear. However, among certain groups of fishes, sound pressure is indirectly detected via secondary structures that function to transduce received sound pressure to the inner ear. Here, we investigate whether the plainfin midshipman (Porichthys notatus), which is a seasonally breeding fish that produces long-duration courtship vocalizations via contraction of sonic muscles surrounding the swim bladder, is sensitive to acoustic pressure. We show, using micro-CT scanning, that the male swim bladder undergoes seasonal changes in morphology, whereby hypertrophy of the sonic muscles in reproductive males leads to approximately a 2.5-fold increase in the distance between the swim bladder and inner ear saccule when compared to non-reproductive males. Additionally, by recording the auditory evoked potentials from saccular hair cells in non-reproductive and reproductive males with intact or removed swim bladders in response to behaviorally relevant sound, we show that the presence of the swim bladder enhances auditory sensitivity up to 4-fold and extends the frequency bandwidth of sensitivity in non-reproductive males, but does not afford any additional sensitivity in reproductive males. This enhanced sensitivity in non-reproductive males to sound pressure and higher frequencies may facilitate the acquisition of auditory information during the non-reproductive season while protecting the inner ear of reproductive males from self-induced masking while calling during the breeding season.

1613 Michaela Rogers, Jennifer Hellmann

Paternal exposure to novel predator cues reduces offspring survival in threespined stickleback

Climate change induces rapid changes to the environment such as introducing invasive species. Organisms can cope through transgenerational plasticity (TGP), occurring when parental experiences influence offspring phenotypes. TGP can prime offspring for future environments, but it is less known how parents use sensory cues to detect environmental shifts (i.e. increased predation). Individuals may rely on one type of cue (e.g. visual, olfactory) or use different cues simultaneously. I exposed threespined stickleback (Gasterosteus aculeatus) males to cues of a novel trout predator prior to fertilization for 10 days. I examined paternal behavior pre and post-exposure, and measured MHC expression with qPCR using the head kidney removed at the time of fertilization. MHC expression is known to reflect condition: sticklebacks with high MHC expression have worse condition and more stress. I generated offspring after the last exposure with in-vitro fertilization and tested them for antipredator behavior and survival against a live predator. Fathers exposed to visual cues oriented more to and spent time closer to the novel predator post-exposure on day one; MHC analysis is currently ongoing. Further, offspring of fathers exposed to visual cues survived less against a live predator. The visual cue was the only cue to elicit a change in behavior in fathers and have a transgenerational effect on offspring, suggesting it may be important for the recognition of novel predators in sticklebacks.

1841 Thea Rogers, Gözde Yalç?n, Natalie Grace Schulz, Darrin Schultz, Carrie Albertin, Oleg Simakov

Novel regulatory units underlie the evolution of complex traits in coleoid cephalopods

Our understanding of how genomic changes translate into organismal novelties is often confounded by complex and multi-layered genome architecture. Coleoid cephalopods have large, uniquely structured brains, as well as many species-specific innovations, such as camouflaging ability, complex behaviours and novel organs. These have recently been identified to be the result of an interplay of various of genomic mechanisms, including largescale genome reorganization in the ancestor of all coleoid cephalopods, repetitive element expansions, and tandem gene duplications. However, regulatory aspects of this genomic architecture remain understudied. We use Micro-C, ATAC-seq and transcriptomic data from several cephalopod species in order to address how mode of regulatory evolution has yielded unique cephalopod innovations. We extend and redefine microsyntenies associated with cephalopod innovations (MACIs) and test the evidence that these regions of the genome evolved under the gene bystander model, in contrast to ancestral, metazoan microsyntenies. Furthermore, we test for association of key genomic features with MACI emergence, including, but not limited to, noncoding elements, alternative splicing, and patterns of RNA editing, and suggest that mechanisms of novel cephalopod gene regulation evolved under different selective constraints to that of the pre-coleoid genome. Taken together, our results describe a distinct 'unit' of regulatory evolution for coleiod cephalopods.

868 Pankaj Rohilla, Johnathan O'Neil, Victor Ortega-Jimenez, Prateek Sehgal, Saad Bhamla

Physical and computational models of vortex recapture during Microvelia's walking on water

Amongst many species of water striders, Microvelia exhibits alternating tripod gait to locomote on water and land. One of the striking features associated with their interfacial locomotion is the "vortex recapture" phenomenon. During power strokes, the middle legs create vortices, the magnitude of which diminishes as the stroke ends; these vortices are re-energized when the hind legs step in these vortices. Here, we combine physical and computational fluid dynamics (CFD) models, to establish the role of "vortex recapture" phenomena on the kinematics of Microvelia. By exploring ranges of leg speeds, inter-leg phase lag duration, and spatiotemporal distribution of the leg tip relative to the vortex, we establish the upper- and lower limits for this intriguing vortex recapture phenomenon. Beyond advancing our understanding of these fascinating water-walking organisms, this work can offer fundamental insight into fluid-structure interactions between aquatic microrobots and soft interfacial propulsors.

1073 Shari Rohret, Elizabeth Borda

Benthic meiofaunal diversity in karst subterranean estuaries of the Yucatan Peninsula, Mexico

Karst subterranean estuaries (KSEs) provide a unique opportunity to study the ecology and diversity of organisms inhabiting a range of physico-chemical gradients. Their peculiar environmental characteristics and endemic fauna have drawn interest from many, but we are just scratching the surface of the diversity and ecosystem functioning within these complex systems. To date, most studies of KSEs in the Yucatan Peninsula (and Cozumel Island) have focused on the water-column community. Recent biogeochemical studies show that carbon and energy derived from chemoautotrophy are being used by cave-adapted pelagic crustaceans. Despite these initial efforts into describing ecosystem functioning within the water column, very little is known about the role of the benthos. Better understanding of the diversity and community composition of benthic meiofauna (small eukaryotic organisms, including foraminifera) in these systems is a crucial first step toward understanding their role in KSEs. Sediment samples collected from coastal caves in the Yucatan Peninsula and Cozumel Island will be analyzed to establish a baseline for benthic meiofaunal diversity in these systems. Community-structure variation will be evaluated throughout each cave using metabarcoding (Metazoa: 18S) of environmental DNA (eDNA). This research will serve as the first benthic meiofaunal biodiversity assessment of Yucatan cave sediments using next generation sequencing approaches. Funded by NSF OCE 2136377 to JMB and DB and NSF OCE 2136322 to EB.

1794 Moey Rojas, Amberle McKee, Madeleine Frey, Kelly Dorgan

Use of a novel "Ant Farm" tank to explore the role of hydraulic fracture in burrowing

Marine worms burrow through muddy sediments by fracture. When burrowing through gels, their behaviors have been shown to depend on the mechanical properties of the gel. Unlike homogenous gels, however, sediments are complex, heterogeneous materials. Mechanical testing of marine sediments suggests that their mechanical responses to force depend strongly on the way the force is applied. When hydraulic fracture is used, the sediment fracture appears to be more brittle —and ultimately more energy efficient than non-hydraulic fracture mechanisms. Thus, we hypothesize that hydraulic fracturing is important in burrow extension in muddy sediments. To test this hypothesis, we employ a novel "ant farm" tank that suspends a vertical layer of mud between two transparent layers of gelatin that mimic some elastic properties of muddy sediments. We used video recordings of Nereis virens burrowing and simultaneously obtained pressure signals to investigate how the forces applied by burrowing to the surrounding sediment correlate with burrow extension and water flow within the burrow. This method also allows for comparison of burrowing behaviors and sediment responses in varied sediment types. Ultimately, our work should allow for a clearer understanding of not only the work costs associated with burrowing, but how different behaviors affect sediment responses to burrowers.

958 Victoria Roper, Catherine Swinsky, Janina Krumbeck, Jennifer Grindstaff

The oral microbiota of the house sparrow (Passer domesticus)

The microbiome influences physiology, health, body condition, and life history strategies of hosts. Microbiomes can also differ between the sexes and between age classes. For example, as individuals age, some microbes may be selected and increase in number. In house sparrows, the abundance of Proteobacteria decreases with age and the relative abundance of Firmicutes increases. Furthermore, there are potentially unique microbiota colonizing different parts of the body. Most studies have characterized the fecal and gut microbiota, but the oral microbiota is composed of polymicrobial biofilm communities that aid in carbohydrate breakdown, and may be of relevance to human health. These communities have not been detected in other microbiota. Our objective was to study differences in the oral microbiota between the age classes and sexes of wild house sparrows (Passer domesticus). We also tested for relationships between morphological measures and microbiota composition. We predicted that the oral microbial community found in younger individuals would have greater diversity due to a more diverse diet. This may aid in digestive efficiency which tends to be lower in young birds. We found several opportunistic pathogens, including: Clostridium perfringens, Corynebacterium kroppenstedtii, Rothia nasimurium, Staphylococcus gallinarum, Rothia spp., Staphylococcus kloosii, and Streptococcus sp. These pathogens have human health implications and warrant further investigation.

986 Michael Rosario, Abigail Downes, Hailey Smith

STRECH: Strain Tension Recorder Engineered from Cheap Hardware

While measuring the material properties of biological materials is one of the many fundamental techniques used to understand the functional morphology of organisms, the cost of these machines can be prohibitive to purchase for teaching labs, outreach, and researchers on a limited budget. The purpose of this study was to design, build, and test cheap p and reliable materials testing machines using consumer electronic parts (raspberry pi, miniature 80/20, and 3D printed parts). To test the accuracy of our machine, we measured the Young's modulus of tail tendons from rats and compared our results to those found in the literature and found that our estimates of Young's modulus (1016+/-550 MPa) were within the range of previously reported values. The addition of a light polarizing filter allowed visualization of fibril crimp of tendon fascicles during testing as well. Given the machine's accuracy and cost, it is now possible to produce multiple units and help high school teachers develop lesson plans to introduce the basics of solid mechanics and biomaterials in the classroom.

736 Emily Rose, Darshi Patel, Dalila Sanchez

Investigating effects of algal turbidity on the dwarf seahorse (Hippocampus zosterae) mating system

Dwarf seahorses (Hippocampus zosterae) are an excellent environmental indicator species because they spend their entire lives in coastal communities that are threatened by human-induced eutrophication. The goal of this study was to quantify laboratory reproductive success and identify the mate preferences in clear vs turbid treatments. The experimental design included paired (1F:1M), female-biased (2F:1M), and male-biased (1F:2M) treatments, in clear and turbid waters with a total of 128 seahorses across 8 replications. Of the 48 potential matings, the study yielded 40 males with reproductive success, 7 with brood reductions, and 1 non-mating. Mating latency was shorter for turbid treatments compared to their respective treatments in clear water. However, there was no detectable effect of algal turbidity on reproductive success. For paired treatments, size matched mates' body weights were correlated with the brood size in the clear water but not in the turbid water. In sex-biased treatments, fish's weights best predicted the brood sizes when females were given a preference in mates. For sex-biased treatments, 75% of matings in clear water were size assortative, whereas mate preference was random in turbid treatments. Ongoing behavioral analyses will further elucidate the relationship between mate choice and reproductive success. This study's results highlight the critical need for interpreting the results of behavioral studies conducted in pristine lab conditions when investigating mating systems of coastal fishes adapted to eutrophic waters.

250 Jack Rosen, Cassandra Donatelli, Karly Cohen, Adam Summers, Matthew Kolmann

Fruit ninja: puncture performance of frugivorous fish dentitions (Serrasalmidae)

Surprisingly, fishes, not mammals or birds, were the earliest seed-dispersers in the tropics. The pacus, a recently evolved sister clade to piranhas (Serrasalmidae), are one of the primary seed dispersers in the flooded forests of the Amazon; consuming fallen fruits and excreting their seeds far from the parent plant. Here we examined how tooth performance differs among herbivorous and carnivorous serrasalmids, asking: how do frugivorous (fruit-eating) fish teeth function? To test this, we 3D-printed serrasalmid dentitions in plastic resin, placed these models in a mechanical loading frame, and punctured fruits and nuts. We contrasted tooth puncture performance, force and work, among carnivorous, omnivorous, and frugivorous serrasalmids. We measured force and work to max load and work to puncture the material. We also used polarized light videography to visualize and describe how serrasalmid teeth form stresses and widen cracks in prey. This paper demonstrates that frugivorous fish teeth perform analogously to fruit-eating mammal teeth, engaging prey first with low puncture forces and then high work post-puncture, while carnivore teeth exhibit both low force and work pre- and post-puncture. This helps the frugivores to grip slippery prey, and then engage fruit tissues with high work after puncture to facilitate cell wall pulverization. We also found that the presence of lingual teeth in frugivorous and some omnivorous pacus impact their ability to efficiently puncture and crush prey.

225 Adam Rosenblatt, Laura Habegger

Decreasing humidity leads to dramatic increase in American alligator egg failure

Egg failure rates are increasing for many reptile species, threatening population stability. Yet the mechanisms of reptile egg failure have not been studied for most species, especially in the context of global climate change. One reason an egg might fail is because eggshell morphology could become mismatched with the environment as climate change continues and environmental conditions deviate from normal ranges, like during drought. We explored the effects of low humidity conditions (caused by drought) on American alligator (Alligator mississippiensis) eggshell morphology and embryo viability. We exposed alligator eggs to high (>92%), medium (86-90%), and low (80-84%) humidity conditions. Eggs in the high humidity treatment had a 71% hatch rate, while eggs in the medium and low humidity treatments had dramatically lower hatch rates of 19% and 13%, respectively. The main cause of egg failure appears to have been water loss from the eggs, which resulted in desiccation and separation of the interior membrane of the eggshell. These results suggest that even very small changes in humidity within an alligator's nest can lead to a precipitous drop in embryo survival, likely affecting population dynamics over the long-term if drought conditions persist. Future research should focus on how drought may affect humidity levels in actual alligator nests and how eggs respond in more realistic incubation conditions.

189 Jean Ross, Vikram Iyengar

Intruder Alert!: Intruder sex and size affect maternal nest guarding behavior in the maritime earwig

Parental care is found in a variety of forms across the animal kingdom. However, parental care is relatively rare in insects, where parents typically maximize the number of offspring produced rather than promoting the survival rate of offspring. Exclusive maternal care, the main type of parental behavior in insects, typically involves egg guarding, which is essential for reproductive success in areas where nest predation or microbial infection is common. Nest guarding is often accompanied by some degree of filial cannibalism, or the eating of oor the eating of one's own offspring, as this behavior allows the parent to remain guarding the nest without leaving to forage elsewhere. The maritime earwig (Anisolabis maritima; Order Dermaptera) is an excellent candidate for the study of maternal care because they live in dense populations where mother must aggressively guard their eggs against cannibalistic conspecifics. Because individual aggression varies based on both sex and size, we studied how these intruder characteristics influenced maternal nest guarding and cannibalistic behaviors. Our results demonstrated that both size and sex influenced the likelihood of a mother abandoning her nest as well as her specific aggressive behaviors toward the intruder. Size of intruders also influenced the number and length of aggressive interactions between the individuals. Mothers were often effective in protecting their eggs against intruders, and filial cannibalism was not as common as expected.

1582 Kaitlyn Ross, Katie Talbott, Ellen Ketterson

Investigating factors driving the impact of Plasmodium on songbird sperm quality

Studies suggest that Plasmodium, the parasite which causes avian malaria, can negatively affect the reproductive success of its host. However, it is unclear whether Plasmodium infections in parents can impact the health of their offspring. Sperm quality is a possible mechanism that could connect effects of parental infection on offspring quality. In mammals, sperm count, and motility are reduced in hosts naturally infected with Plasmodium, and higher levels of testosterone are associated with higher parasite loads. However, little is known about the relationship between Plasmodium and avian sperm quality, and a causative relationship between Plasmodium infection and decreased sperm quality has not been established in any taxon. Therefore, we used an experimental approach to investigate the relationship between maximum (GnRH-induced) testosterone levels, Plasmodium exposure and sperm quality in Dark-eyed Juncos (Junco hyemalis). We predicted that juncos experimentally inoculated with Plasmodium would show a decrease in sperm quality, signified by lower sperm counts, higher proportions of deformed spermatozoa, and increased biomarkers of oxidative stress, compared to controls. In addition, we predicted that males with higher maximum levels of testosterone prior to inoculation would show higher levels of oxidative stress and lower sperm counts following inoculation. We will discuss the results of this project from the perspective of testosterone as a potential mediator of the effects of parasitism on sperm quality.

929 Giulia Rossi, Kenneth Welch

Packing on the pounds: The role of leptin in the premigratory fattening of hummingbirds

In mammals, leptin is an important energy homeostasis hormone produced by the white adipose tissue. Circulating leptin concentrations correlate positively with fat mass and act in a negative feedback fashion to inhibit food intake, thereby preventing excessive fat gain. For some species, leptin resistance is advantageous during times of year where excessive fat gain is necessary (e.g., prior to hibernation). While the function of leptin in birds remains controversial, seasonal leptin resistance may similarly benefit migratory species. We used the ruby-throated hummingbird (Archilochus colubris) to test the hypothesis that leptin resistance promotes fattening prior to migration. We predicted that during the premigratory period, leptin levels should correlate positively with fat mass but should not inhibit food intake, resulting in excess fattening. We tracked the body (fat) mass, urine leptin concentration, and food intake of 13 captive hummingbirds. In a subset of hummingbirds, we also quantified voluntary activity. Changes in fat mass were strongly associated with food intake and reduced activity. However, we found no correlation between leptin concentration and fat mass or food intake. In an experimental manipulation of circulating leptin via an intraperitoneal injection ($\sim$4 mg/g), we similarly found no change in food intake, fat mass, or nocturnal torpor use. Overall, our findings suggest that leptin may not act as an adipostat in hummingbirds, nor does leptin resistance regulate how hummingbirds fatten prior to migration.

1845 Alicia Roth-Weigel

Putting the 'I' in LGBTQIA+: law and policy implications

While the recent influx of partisan legislation opposing the use of gender-affirming hormonal and surgical procedures for transgender children and teenagers has received considerable press coverage, little attention has been given to the pages of text within these bills allowing the continued use of such medical interventions on intersex youth. And even as activist movements have familiarized much of the US public with transgender identities, awareness of the realities, needs, and challenges faced by the estimated 2% of the population born with sex trait variations that fall outside the male/female binary remains extremely low. Although intersex activists have been protesting the use of nonconsensual, non-medically necessary surgical interventions to "normalize" the bodies of intersex children since the 1990s, the continued widespread lack of knowledge about these issues has enabled the protection of these harmful interventions within anti-trans bills to go unchallenged. The ideology that forces the same medical procedures on nonconsenting intersex children while banning their use for consenting transgender youth is based in enshrining a narrow definition of anatomical and gendered "normality," regardless of the emotional, physical, and psychological costs. Challenging the legal, medical, and social forces that continue to oppress intersex individuals will require a collective shift in education, science, politics, and medicine to hear, understand, and accommodate the needs of those of us born in bodies beyond the sex binary.

1059 Greg Rouse, David Caress, Shana Goffredi, Ekin Tilic

Observations on deep-sea Xenoturbella (Xenoturbellida, Bilateria)

We present in situ observations by Remote Operated Vehicles of Xenoturbella profunda, including juveniles, near the Pescadero Basin hydrothermal vents (Mexico) at ∼3700 meters depth). High-resolution photomosaics allow for plotting the distribution of the Xenoturbella in relation to the clam field they inhabit. Xenoturbella profunda is gonochoric, unlike the simultaneous hermaphroditism that has been reported for Xenoturbella bocki, and we present ultrastructural details on spermiogenesis and oogenesis and other anatomical features. We assess the presence and role of symbiotic bacteria in the gastrodermis with regards to the previous reports of this phenomenon. Anatomical observations on a new deep-sea species of Xenoturbella are presented from Costa Rica. This brings the total of known Xenoturbella species-ranked taxa to seven. This new species occurs across depths of ∼1000-2000 meters near methane seeps. The phylogenetic placement of the new Xenoturbella is shown in relation to the other taxa based on its whole mitochondrial genome.

575 Leah Rubin, Elizabeth Sibert

A novel morphological code to describe dermal denticles and reconstruct fossil shark communities

Microfossil dermal denticles are preserved in nearly all deep-sea sediments, providing a window into the evolution of open ocean sharks. We present a morphologic code based on both modern denticles and fossil denticles from Neogene and Paleogene sediment cores. Extant denticle morphological diversity was compiled via a comprehensive literature review. In addition, to address the limited sampling of prior studies, and the relatively high degree of variability of denticle morphology across the body of sharks, we are developing a catalog of modern shark denticle morphology by sampling 27 locations along bodies from all genera of sharks. Traditional geometric morphometrics were unable to effectively describe the diversity of denticles, so we developed a trait-based character coding scheme with 30 traits that define denticle morphology. The code has been written to make it replicable with other samples and for the addition of novel character categories and can be analyzed within a common framework using the R package ichthyoliths. We used this code to define denticle morphotypes, unique combinations of character traits. While most sharks have multiple denticle types on their bodies, generally morphologically similar denticles are found on taxonomically related elasmobranchs. When combined with ecological factors, morphological analysis of denticles can identify temporal periods and spatial regions of importance in both modern and paleo-ocean ecosystem dynamics and aid historical ecologists in describing shark communities of the past.

376 Stephanie Rudisill, Haley Martin, Clare Scott-Chialvo

Expanding our understanding of toxin tolerance in mushroom-feeding Drosophila

Understanding the associations between insects and plant/fungal hosts and how insects feed on hosts that contain defensive compounds is an active area of research. These results of these studies suggest that in most cases generalist species are not able to use hosts that contain highly toxic compounds. Yet, mushroom-feeding flies in the immigrans-tripunctata radiation that are generalist feeders (on fleshy white mushrooms) can consume species that contain high doses of deadly cyclopeptide toxins. While the occurrence of cyclopeptide tolerance in this clade is the focus of many studies, the ability to detoxify other mushroom toxins that occur in suitable potential hosts is under-studied. In this study, we aim to address the question by analyzing tolerance levels to two other classes of mycotoxins and evaluating whether tolerance to these compounds is a complex genetic trait. To identify the occurrence of tolerance to additional mycotoxins, we reared larvae of six species from across the immigrans-tripunctata radiation on diets containing muscimol and methylviologen. We also assessed whether variation for tolerance to these compounds was present within a population of Drosophila tripunctata. For each assay, we measured survival to adulthood, larval development time, and thorax length. The results of our study will provide a greater understanding of mycotoxin tolerance in the immigrans-tripunctata radiation.

1024 Elizabeth Rudzki

Field Safety Manuals: Addressing Exacerbated Field Risks for Marginalized Scientists

Historically, scientific fields of research such as ecology, evolutionary biology, and geology, have struggled to recruit and retain researchers from different racial, ethnic, gender identities, sexual orientations, and disabilities. Thus, recruitment of marginalized persons to these scientific career fields requires specific policies to promote inclusion and additional attention for these policies to be successful. Field research is an important component to the advancement of these fields of science, but these conditions can also present unique challenges and personal safety risks for everyone involved. Researchers from marginalized groups will often face compounded safety risks compared to their colleagues, and the discrepancy in the experienced risks must be addressed to promote diversity and equity, and to retain marginalized researchers in the field sciences. The development of a field safety manual is an important step for all departments and organizations where field research is conducted and including such a manual as a part of research proposal applications will now be a requirement of the US NSF starting in January of 2023. This talk will cover topics related to: (A) The importance and necessity of field safety manuals, (B) Examples of heightened risks for marginalized researchers, and (C) How to develop a field safety manual that explicitly considers risks for marginalized identities.

222 Breh Ruger, Nate Haan

Distance from prairie strips and cropping system management as effects on natural pest suppression

Predatory and parasitic arthropods provide valuable pest suppression services to agriculture. However, the expanding footprint and increasing intensity of agronomic systems have decreased abundance and diversity of service-providing arthropods. Agricultural practices such as prairie strips (PS) can be implemented to modify landscapes, including habitats for predatory arthropods. We used plasticine sentinel caterpillar mimics, which record imprints from attacking organisms, to ask if pest suppression services 'spill over' from PS into crop fields, and at what scale. Plasticine caterpillars went in two types of wheat cropping systems at the Kellogg Biological Station LTER Main Cropping System Experiment; 'reduced input' (emulates conventional practices but with reduced fertilizer and pesticide use), and 'biologically based' (lacks external inputs). Caterpillars were placed within PS and at 1, 5, and 20m into the field as well as the turf outside the field. Caterpillars were evaluated for attack marks from rodents, birds, or arthropods. Rodent attacks were most frequent, and the lack of arthropod attacks outside of the fields may indicate that arthropods are coming from within the fields rather than from the outside. However, we did not find strong evidence that attack rates are higher within or near the PS during the early growing season. Forthcoming data from the end of the season will provide more information on whether there is a 'spill over' of pest suppression services from prairie strips.

462 Carlos Ruiz, Jamie Theobald

Habitat structure and natural history shape stabilizing responses in three species of fruit flies

Flies respond to perturbations with fast, accurate corrections. To evaluate visual information quickly, flies have evolved optimizations, such as parallel processing by separate visual regions. Drosophila melanogaster, respond strongly to dorsal rotational flow, and ventral translational flow. They are sensitive to both parallax and density of ventrally moving elements, but these vary dramatically between habitats, but it is unknown if these responses are matched to the structure of their native environment. To address this, we compared dorsal and ventral optic flow responses in three species: Drosophila melanogaster, a cosmopolitan fly native to habitats with dense vegetation, Zaprionus indianus, which flies under fig trees that potentially induce heavy dorsal optic flow, and Drosophila mojavensis, which flies in arid regions which may generate mostly ventral optic flow. We found modulation of stabilizing responses to ventral element density in all three, but the range of responsiveness in D. mojavensis is narrower. To dorsal sideslip, Z. indianus responds more strongly, and to a broader range of densities than D. melanogaster, while in D. mojavensis responses appear inhibited shortly after being elicited. Our findings suggest dorsoventral differentiation and response tune to the general structure of a visual environment, with potential specializations for flying beneath overhead structures or in barren environments. Subtle response modifications to in-flight visual patterns could allow fly species to navigate disparate habitats, opening a door to diversification.

1079 Andrea Rummel, Brooke Quinn, Aaron Corcoran, Sharon Swartz

Cold flights on cold nights: extreme regional heterothermy in desert bats

Bat wings are highly modified mammalian forelimbs, with elongated bones of the arm, forearm and hand supporting a wing membrane that comprises the wing's aerodynamic surface. The length of the limb and large surface area of the wing membrane, combined with forced convection across the wing associated with flight, enhance the wing's capacity for heat loss. Wing muscles, like the pectoralis, biceps, and forearm muscles, are active during flight and temperature sensitive: cold slows them down. Thus, the extent to which these muscles cool during flight has implications for flight performance. Previous laboratory and field studies demonstrated a proximal-distal temperature gradient in tropical bat wing muscles. Here, we expand our understanding of natural, in-flight wing temperatures with measurements of muscle temperatures immediately before and after flight in a large, enclosed flight tent in bats from 10 species, captured at the Southwestern Research Station, Portal, AZ, in May, 2022. Temperatures of distal wing regions (forearm and wrist) were significantly and substantially lower immediately post-flight than pre-flight, while temperatures in proximal wing regions (pectoralis, biceps) and rectal (core) temperature were relatively stable. Air temperature had a significant effect on the difference between rectal and distal wing muscle temperatures. This suggests that bats can regulate core, but not wing, temperatures during flight, which likely necessitates physiological and biomechanical adaptation in wing structures to maintain flight performance across temperatures.

518 Avery Russell, Tia-Lynn Ashman, Parker Campbell

Microbes on the mind: effects on learning in a generalist bumble bee

Microbes frequently modify host behavior and ecology. Bees foraging on flowers are a model system for the study of animal cognition and, increasingly, for the study of host-microbiome interactions. Bees foraging on flowers frequently encounter diverse floral microbes, which could potentially modify bee behavior via effects on floral cues, as well as via colonization of the bee gut microbiome (i.e., the gut-brain axis). Here we asked whether (1) floral microbes on flowers could serve as a cue to bumble bees (Bombus impatiens) and (2) whether floral microbes consumed by bees modified learning and memory. We strictly evaluated associative learning using a differential conditioning protocol. In one experiment, naïve bees were trained to associate the presence or absence of floral microbes on artificial flowers with a pollen reward. In a subsequent experiment, naïve bees were inoculated with floral microbes and we assessed learning to associate flower color with a pollen reward. Bees rapidly learned to associate floral microbes with the pollen reward. However, we found no evidence that microbes consumed by bees modified learning and memory. Our findings indicate floral microbes can modify the floral display (in particular, scent cues) and thus bee behavior, but may not affect the bumble bee gut-brain axis, suggesting that bee gut microbiomes and cognition may be generally robust to influence from the microbes they regularly consume while foraging.

1026 Khalil Russell, Eric Hilton

Morphological differentiation between introduced and native populations of three cichlids in Florida

Cichlid fishes are well-known for their diversity and propensity for diversification. Numerous species are established outside their native range, with reproducing populations occurring in south Florida. In this study, we investigated the potential for rapid evolution in the most successful cichlids invading Florida. We compared external morphology between native and non-native (Floridian) populations of three cichlid species (Pelmatolapia mariae, Mayaheros urophthalmus, and Parachromis managuensis). Using both linear measurements and 2D landmark morphometrics we found that all three species have diverged in multiple traits: P. mariae in head length (HL), snout length (NL), and inter-orbital width (IO), P. managuensis in maximum depth (MD), NL and IO, and M. urophthalmus in MD and IO. We also found that P. mariae and P. managuensis collected from non-native populations display morphology beyond the range of variation exhibited by specimens from native populations. The observed differences may be the result of natural selection or phenotypic plasticity, although further work is needed to determine the roll of each. Regardless, this study suggests that the conditions exist to promote rapid morphological evolution in introduced populations of cichlids in Florida.

630 Melissa Ruszczyk, Donald Webster, Jeannette Yen

A freshwater copepod's response to dissipation-scale turbulent flowstructure

Turbulence exists across many length scales and affects the ecology of all organisms subject to flow in the environment. Copepods are particularly subject to small-scale fluid motion, which can affect metabolic rates, predator-prey encounter rates, grazing rates, egg production, swimming behaviors, and population dynamics. A Burgers vortex can mimic dissipative-scale turbulent eddies to investigate how copepods interact with a specific microscale turbulent feature. The behavior response of male and female Hesperodiaptomus shoshone, a freshwater copepod found in shallow alpine lakes and ponds, to four Burgers vortex intensities (plus a stagnant flow control) in two different orientations is quantified. Swimming behavior was quantified using swimming speed, swimming path, angles in relation to the flow, and time spent in the vortex to determine whether a behavioral response was dependent on sex, turbulence intensity, or vortex orientation. Hesperodiaptomus shoshone show little behavioral change in response to the presence of a vortex. The results are compared to the behavior of marine species to determine how copepods from different ecological and geographic niches respond to microscale turbulence. Hesperodiaptomus shoshone behavior reveals a notable difference to the response of marine copepods exposed to the same flow feature who elicit spiral trajectories in the same direction as the flow.

157 Kelsi Rutledge, Malcolm Gordon, John Dabiri

Fluid dynamics of chemical scent detection in stingrays

Stingrays and their relatives (batoids) are macrosmatic, meaning they rely on their sense of smell as one of their primary senses for survival. Olfaction is crucial for prey recognition, navigation/tracking, and reproductive signaling. While these fishes rely on water flow to direct odors into their nose, there are few studies on the fluid dynamics of their olfaction. With an odor-impeding boundary layer and no direct pump-like system, how do these fishes efficiently capture chemical stimuli? To understand how nasal morphology influences chemical detection, models of 4 nasal morphotypes seen in batoids were 3D printed and mounted in a water tunnel and the incoming flow was visualized using particle image velocimetry methods. Models were tested at varied Reynolds numbers, respiratory processes, and head pitch angles. To obtain velocity data, a continuous wave laser beam was spread into a thin sheet by a cylindrical lens. The resulting laser sheet was oriented to illuminate streamwise cross-sections of the flow near the nostrils. Image sequences were cross-correlated to determine the local flow velocity. We found that different nasal geometries produce different patterns of flow and odor capture mechanisms. Pitch and respiratory processes are also crucial parameters for odor detection. This study lends insights into the fluid dynamics of chemical sensing in the marine environment and highlights the importance of the morphology of the system for odor capture and circulation.

1009 Amy Rutter, Matthew Fuxjager, Thomas Roberts

Using sound to understand relative force and mechanics in woodpecker drumming

Woodpecker drums are unpitched percussive signals created by the bird hitting its beak against a substrate. Due to physical acoustic properties, easily accessible audio recordings of woodpecker drums may provide clues about the relative impact forces generated during a drum, potentially shedding light on the musculoskeletal mechanisms underlying this mechanically challenging behavior. Acoustic intensity, the amount of energy transported by a soundwave over a given area and time, is related to perceived loudness and proportional to amplitude squared. It seems likely that, within a drum event, sound amplitude is also proportional to impact force, given the law of conservation of energy, with more forceful drumming plausibly producing signals with larger amplitudes and more intense sounds. Given this, amplitude pattern, which is measurable from audio recordings, could act as a proxy for impact force. Rather than giving an exact force measurement, the amplitude patterns could reveal information about the mechanics underlying drumming by showing relative force changes. Other patterns in woodpecker drums, such as length, speed, and rhythm, have been shown to be important signal components. We collected amplitude pattern data and observed that many woodpecker species exhibit a ramp up in amplitude at the beginning of the drum, where amplitude increases over time; however, at least one species does the opposite. This suggests there may be more than one mechanical strategy for how woodpeckers drum.

117 Michael Ryan

Mate choice in túngara frogs: an analysis of brain, behavior, and evolution

Choosing a mate is one of the most impactful decisions an organism can make. It can result in divergence among species (e.g. species recognition) and elaboration of traits within species (e.g. sexual selection). It is also a phenomenon that requires the integration of different levels of analysis. I review our studies of brain, behavior, and evolution in mate choice by the túngara frog and emphasize recent studies that reveal some of the cognitive scaffolding underlying these decisions.

907 William Ryerson, Cassidy Goulet, Ben Sweesy

Arboreal prey-handling in boas and pythons

Snakes are known for a suite of adaptations centered on feeding. The best studied are those focused on prey capture and swallowing. However, snakes also manipulate their food after subduing it prior to swallowing which we refer to as prey-handling. Without the ability to use limbs, snakes employ different prey-handling behaviors dependent upon a variety of factors, including prey size and type. The one unifying factor is that the snakes have been observed feeding in terrestrial or semiaquatic habitats, where a solid substrate supports the body weight of both the snake and its prey. We investigated the prey-handling in three species of boas and pythons while feeding in a simulated arboreal environment: the boa constrictor, ball python, and reticulated python. We found that the boa constrictors and reticulated python exhibited previously undescribed behaviors that provided support for the prey item during transport and swallowing, behaviors that we hypothesized insure the movement of the prey with the direction of gravity. We observed faster swallowing times and increased likelihood of success compared to primarily terrestrial ball pythons. We also observed "resetting behaviors" where snakes would pause the swallowing process and shift the position of their body to restore the proper support and direction. Finally, we suggest behaviors can be adapted to larger prey items, as well as anecdotal evidence in other primarily arboreal pythons.

1850 Sangjin Ryu, Haipeng Zhang, Mary Salcedo, Jake Socha, Günther Pass

Transient perfusion flow patterns in a dragonfly forewing elucidated using a microfluidic model

Insect wings are composed of a network of tubular veins and thin membrane. Hemolymph (blood), nerves connected to vital sensory organs on the wing, and tracheal branches (oxygen delivery) exist within these veins. Because blood flow provides the sensory organs and other tissues with water and nutrients and removes waste products, hemolymph flow through veins is crucial for flexibility, stability, and functionality of the sophisticated wing blade. However, it remains poorly studied how wing venation and hemolymph circulation are related. Previous experiments tracking hemocytes (blood cells) in partly transparent veins of living specimen offered limited insight into some flow patterns. For detailed investigations of hemodynamics in complex wing venation, we employed photo/soft-lithography to fabricate a microfluidic wing vein model of the forewing of the dragonfly, Anax junius. Transient blood flow was simulated by injecting dyed water into the veins using a range of flow velocities and inflow locations. Microbeads were used to visualize local flow patterns within the veins. Visualized flow patterns suggested that the perfused portion of the vein network increased in a certain scaling relation with respect to time. Our biomimetic wing vein device enables further investigation into the unique circulatory system and transport phenomena of the insect wing.

1355 Julia S.-Parreiras, Tod Reeder, Edward Stanley, David Blackburn

Evolutionary processes and environmental pressures underlying skull diversity of New World toads

The vertebrate skull serves critical functions and is likely under multiple evolutionary pressures (e.g., phylogenetic history constraining diversity; allometry limiting phenotypes due to body size; and environmental pressures driving traits to diverge or converge). The diverse New World (NW) toads of the genera Anaxyrus (North America), Incilius (Middle America) and Rhinella (South America) form an ideal clade for investigating the evolutionary processes promoting skull diversification given they occupy varied microhabitats and elevational ranges. Although their overall external morphology is relatively conserved, they exhibit remarkable cranial diversity: large variation in size and skull shape, including variation in cranial crests and skull ossification. Using CT scans, 3D geometric morphometrics and phylogenetic comparative methods, we quantified the skull shape diversity and tested whether phylogenetic history, allometry, and elevation influence skull diversification. We demonstrate substantial variation in skull diversity, with a strong effect of phylogenetic history. Allometric scaling influenced shape across species; distantly related small-sized species possess slender skull bones and pointed snouts. We found a significant relationship between skull shape and elevation; distantly related species inhabiting similar elevation possess similar skull shape. Lowland species have more shape variability, indicating higher elevation might be posing selective pressure on skull diversity. Our study quantified the diversity of skull morphology within NW toads and highlighted the importance of taking into consideration multiple evolutionary processes that may influence the diversification of phenotypes.

1735 Gargi Sadalgekar, Qihan Xuan, Qiyuan Fu, Chen Li

Template-level robophysical models for studying sustained terrestrial locomotion of amphibious fish

Studying terrestrial locomotion of amphibious fishes informs how early tetrapods may have invaded land. The water-land interface often has wet, deformable substrates like mud and sand that challenge locomotion. Recent progress has been made on understanding limbed and limbless tetrapod locomotion by studying robots as active physical models of model organisms. Robophysical models complement animals with their high controllability and repeatability for systematic experiments. They also complement theoretical and computational models because they enact physical laws in the real world, which is especially useful for studying locomotion in complex terrain. Here, we created the first robophysical models for studying sustained terrestrial locomotion of amphibious fishes on controlled mud as a model web deformable substrate. Our three robots are on the template level (lowest degree-of-freedom to generate a target locomotor behavior) and represent mudskippers, ropefish, and bichirs that use appendicular, axial, and axial-appendicular strategies, respectively. The mudskipper robot rotated two fins in phase to raise the body and "crutch" forward on mud. The ropefish robot used body lateral undulation to "surface-swim" on mud. The bichir robot combined body undulation and out-of-phase fin rotations to "army-crawl" forward on mud. Each robot generated qualitatively similar locomotion on mud as its model organism. We are currently refining the robots and performing systematic experiments on mud of a wide range of strengths. (Please place this talk after Ramesh et al.)

1203 Mary Salcedo, Tyler Ellis, Geoffrey Osgood, Emma Goethe, Spencer Hobbs, Jueliet Menolascino, Spencer Collins, Derek Hertzell, Michael Boggs, Sana Doorani, Jasmine Avery, Taylor Palmrose, Dhanak Kainaat, Emily Cossey, Syeda Mehreen Tahir, Joseph Gazing-Wolf, Abigal Bahamonde, Matthew Johnson, Tristan Lober, Jake Socha, Rick Overson, Arianne Cease

Wing expansion in gregarious migratory locusts

Wing expansion, a critical event in an insects' metamorphosis, occurs when hemolymph is pumped into soft, folded wing tissue, allowing the wing to morph to a stiff, flight-capable structure. If expansion mechanics are disturbed, insects may lose the ability to fly, mate, or even feed. Some insects have additional pressures: when reared in close quarters, they become susceptible to cannibalism. Due to its impact on agriculture, the migratory locust (Locusta migratoria) is the focus of many population, agricultural, and management studies. In collaboration with the Global Locust Initiative (ASU), we investigated wing expansion in gregarious L. migratoria. Locusts were kept on a 40:25 degrees Celsius cycle to promote emergence. Late-instar locusts were removed from crowded cages and put in individual cages for emergence observation. When wings were freed from the juvenile wing pads, locusts were put on ice. All four wings were then dissected, weighed, imaged, and preserved. Locusts were sampled in 5 min intervals, from 0 (wings out) to 120 min ($n = 200$). Full wing expansion occurred at 20 minutes where, compared to mass at time zero, forewings were approximately 8.5 (left) and 6.4 (right) times heavier, and hindwings were 11.5 (left) and 8 (right) times heavier. Further experiments will investigate wing expansion in solitary-reared locusts, the role of evaporation in wing stiffening, and dissection methods. Supported by NSF PRFB (1812215) and JEB Travelling Fellowship (JEBTF2110592).

344 Wael Salem, Benjamin Cellini, Eric Jaworski, Jean-Michel Mongeau

Drosophila adaptively control flight to compensate for added inertia

Animals experience significant fluctuations in weight throughout their lifetime, which could be due to developmental growth, feeding, gravidity, etc. Large changes in mass or inertia can impact the stability of locomotion. Therefore, animals have developed strategies to compensate for these changes. These compensatory strategies are critical for animals that rely on flight for survival. To shed light on these strategies, we implemented a control theoretic framework to study how fruit flies (Drosophila) compensate for added inertia. Flies with added inertia were placed inside a virtual reality arena which enabled rotation about the vertical (yaw) axis. We presented flies complex visual stimuli to study their gaze stabilization response to added inertia spanning 1–64 times flies' yaw inertia. Using system identification, we discovered that adding inertia increased the fly's response time yet had little influence on overall gaze performance. Interestingly, flies maintained similar stability following addition of inertia, hinting at an adaptive control scheme. Flies achieved similar stability by modulating both actuations gain and damping. Adding inertia altered saccade dynamics, however the velocity profiles of saccades during initiation and termination remained symmetric. This suggests that flies may have recalibrated an internal model to account for the added inertia. Understanding adaptive flight strategies in insect flight could help inspire control strategies for flapping-wing robots and drones carrying loads.

1707 Michael Sandel, Kayla Fast, Eric Benbow, Heather Jordan, Jennifer Pechal, Alex Rakestraw, Magdalene Dogbe, Alexandra Bauer, Matthew Scott, Jean-François Guegan, Sophie Picq, Joseph Receveur

Compensatory Duplication of Heterodimeric TLRs Suggests Coevolution with Mycobacterial Pathogens

Vertebrate Toll-Like Receptors (TLRs) function as Pattern Recognition Receptors (PRRs) which bind Pathogen-Associated Molecular Patterns (PAMPs). TLR1 is a member of a gene family that also contains three paralogs known from mammalian genomes (TLR2, TLR6, TLR10) and at least three additional paralogs among non-mammalian vertebrate genomes (TLR2b, TLR14, TLR15, TLR18). Members of this gene family encode membrane-bound glycoproteins containing a Leucine-Rich Repeat (LRR) domain. Most TLR1 family members form dimers, including heterodimers with other TLR1 family members, and TLR heterodimerization has been shown to differentially bind individual PAMPs during exposure. Specifically, the TLR2/1 heterodimer is known to bind tri-acylated lipopeptides, though the TLR2/6 heterodimer binds di-acylated ligands. Mammalian TLR2/1 and TLR2/6 heterodimers have been implicated in the innate immune response to Tuberculosis. Despite the wealth of information available regarding the mammalian innate immune response to mycobacteriosis, relatively little is known about non-mammalian vertebrate species. We quantified and compared the three-dimensional structures of non-mammalian TLR1 family members, paying particular attention to retention of products of duplicate genes (paralogs). Computational genomic analysis reveals evidence for conservation of TLR1 paralog number, and molecular dynamic simulation results provide evidence for compensatory functional variation among paralogs descended from independent tandem duplications. Together, computational genomic and molecular dynamic analyses provide evidence suggesting coevolutionary processes between vertebrates and mycobacterial pathogens are partly responsible for the functional conservation of the TLR1 gene family.

869 Joseph Sardina, Cameron Currie, Prashant Sharma

Evolutionary origins of the fungus-farming ants' symbiont-housing organ

Mutualistic symbioses between an animal host and a microbial symbiont can provide innovative solutions to evolutionary and ecological challenges. Selective pressure on the host to sustain the symbiosis and its associated benefits has repeatedly resulted in the evolution of a wide variety of specialized symbiont-housing organs (SHOs). Despite the critical role of these SHOs, the processes underlying their evolutionary origins remain largely unknown. Here, I use an evo-devo approach to investigate the evolution of the SHOs of the fungus-farming ("attine") ants. The majority of attine ants engage in a mutualistic symbiosis with a bacterium, Pseudonocardia, which produces pathogen-inhibiting antibiotics that help protect the ant colony. In return, the attine ants house and feed the Pseudonocardia symbiont in specialized cuticular SHOs populating the entire exoskeleton of the ant. Interestingly, previous work has shown that the attine SHO has independently evolved three separate times. To investigate the mechanisms behind this parallel evolution, we have began characterizing the physical and temporal ontogeny of the SHO in the leaf-cutter attine ant Acromyrmex echinatior, as well as identifying its underlying developmental genetics. More broadly, this work will shed light on the processes underlying the origin of SHOs, a structure crucial to symbioses across the tree of life.

60 Audrey Sarin, Steve Lonhart, Emily Nazario

Implications of sea urchin culling in Monterey Bay National Marine Sanctuary

Purple sea urchins (Strongylocentrotus purpuratus) play an important role in the iconic kelp forest ecosystems of Monterey Bay National Marine Sanctuary (MBNMS). To determine if recreational divers could facilitate kelp forest recovery in Monterey Bay, California's Fish and Game Commission amended recreational take of sea urchins at Tanker Reef in MBNMS, allowing unlimited culling in place. I measured the gonadosomatic index (GSI) of purple urchins to assess ecosystem health, comparing urchins in a culled area, an adjacent reference area, and a distant urchin-dominated ecosystem. GSI was significantly different ($p < 0 .01$) between the three areas, with high GSI's found in the culled area (where kelp is recovering) and low GSI values in the urchin barren sites. In a separate experiment at Tanker Reef, I used qualitative (visual scoring) and quantitative (imageJ) techniques to characterize the extent of damage to organisms or substrate underneath an urchin when it was culled using a welding hammer. The data are under statistical analysis, but it is clear that soft-bodied organisms, such as anemones, frequently experienced the most extensive damage. Organisms with harder structures either crumbled (e.g., foliose bryozoans) or remained relatively unscathed (e.g., chitons). This improved understanding of collateral damage to marine organisms will directly inform permitting and rule-making decisions by regulatory agencies in the future.

968 Valeria Saro-Cortes, Jose Yañez-Salas, Yuhe Cui, Brooke Flammang, Aimy Wissa

A Flying Fish Robotic Model Organism: Multibody Dynamic Modeling and Experimental Validation

The flying fish is both a skilled long-distance flyer and highly maneuverable swimmer which makes them attractive study subjects in the design of bioinspired unmanned underwater-aerial vehicles (UUAVs). A valuable asset in bioinspired research of flying fish is a

robotic model organism (RMO) which offers a venue for experimental validation of flying fish hypotheses and broader exploration of a flying fish inspired UAAV design space. The co-authors of this study have developed a flying fish inspired RMO for this purpose, but a more fundamental analytical understanding of flying fish inspired RMO is necessary to determine its biological relevance. This talk presents a multibody dynamics model for the locomotion of a flying fish inspired RMO. Analytically derived equations of motion were validated via simulation software and compared with experimental aerodynamic and hydrodynamic results measuring lift, drag, and pitching moment at varying pitch angles. Aerodynamic experiments of the RMO representing both two-winged and four-winged flying fish were performed in a wind tunnel at Re = 30k. Hydrodynamic experiments were performed in a water channel using an RMO equipped with a carangiform locomotion inspired caudal fin mechanism. These experimentally measured loads were used as inputs for a forward dynamics simulation. The output trajectories were compared to trajectories obtained via video analysis of the flying fish to determine biological relevance of the RMO and analytical model.

394 Darien Satterfield, Peter Wainwright, Thomas Claverie

Body Shape and Mode of Propulsion Do Not Constrain Routine Swimming in Reef Fishes

It is widely believed that because of biomechanical trade-offs, fish body shape and the mode of propulsion are strong predictors of swimming performance, with the best cruisers, maneuverers, and accelerators having different body forms and emphasizing different propulsion mechanisms. This paradigm is regularly projected onto routine swimming behavior and dominates the ecomorphological literature, despite the paucity of field measurements. In this study, we measured variation in swimming behavior among 48 species of Indian Ocean coral reef fish using recordings from a remote stereo video system. We measured average swimming speed, average swimming bout distance, frequency of turns, and percent of time spent station-holding and looked for the predicted trade-offs between them. We find little evidence of the expected relationships between swimming behaviors across species, little evidence that body shape affects swimming, and few differences between species that swim by undulating the body and those that emphasize the use of median and paired fins. Taxa widely thought of as archetypical maneuverers (Chaetodon) and cruisers (Caranx) were not outliers in any behaviors. Our results indicate that swimming behavior is not easily predicted from simple measures of body shape and that alternative locomotor modes can produce comparable behavioral profiles.

144 Erin Sauer, Chloe Connelly, Weston Perrine, Ashley Love, Sarah DuRant

Male-biased disease dynamics of Mycoplasma gallisepticum

Heterogeneity in exposure risk, susceptibility, and infection severity can have major impacts on transmission dynamics. One such driver of heterogeneity is host sex. Sex differences in behavior and immunocompetence have been demonstrated to contribute to infection and transmission biases. In vertebrate systems, males are generally thought to be more likely to be become infected and harbor larger infection burdens than females. For example, male-biased mortality and pathology in house finches (Haemorhous mexicanus) infected with the avian bacterial pathogen Mycoplasma gallisepticum (MG) was detected shortly after the pathogen's emergence in the mid-1990's. However, direct assessment of sex-biased transmission in the system remains unexplored. Here we examine the potential for male-biased sex-dependent transmission of MG using a multistate transmission model parameterized with exposure-controlled pathological data and transmission rates from flocks of varying sex ratios. Isolated experimental exposures suggest that male immunological susceptibility is contributing to MG transmission dynamics independent of sex-biased behavioral differences. Males have shorter incubation periods, longer recovery rates, and higher pathogen loads than females. Transmission model simulations that varied population sex ratios further supported male-biased MG transmission. Epidemic size drastically increased with the proportion of birds that were male. Our results are consistent with prior research suggesting that male-biased transmission and susceptibility are common among wildlife host–pathogen systems.

127 Tanner Saussaman, Gal Ribak, Wing Lai, Roi Gurka

3D Flow Analysis of Wing-Wake Interactions: A Case Study of Beetles

Aerial insects are characterized by their small body, wing size, and high wingbeat frequencies. They operate at relatively lower Reynolds numbers yet are still able to generate ample lift for long flights and impressive hovering capabilities. Another unique facet of their aerodynamics is due to the complex wing-wake interactions that occur during flight. When an insect flaps its wings, each wing generates its own distinct wake.

With high proximity between wings, these wakes interact. It is theorized that these interactions exchange momentum and energy during flight, altering their aerodynamics. Thus we ask: Are these wing-wake interactions constructive or destructive in the generation of aerodynamic loads as well as to the wake flow dynamics? To examine this, a study at low Reynolds numbers (Re∼10000) and body/wing ratio (∼1.1) was conducted by performing 3D-PTV (particle tracking velocimetry) measurements on a set of beetle wings (Batocera rufomaculata) rotating in an enclosed glass chamber. This 3D-PTV system allows for capturing all three velocity components and their spatial gradients, creating a volume of flow information. By systematically altering wing size and angle of attack (AoA), the effect of these different configurations on the flow dynamics is studied. These results may shed light on the role of wing morphology and alignment, when multiple-proximate-wings system are present, on the aerodynamic performance during flapping flight.

1197 Madelyn Scarmack, Joshua Corrette-Bennett

The effect of beta-alanine on the rate of wound healing and limb regeneration in axolotls

Urodele amphibians, such as axolotls, are especially good at healing and regenerating certain tissues following damage or loss. Axolotl limb regeneration occurs in three stages: wound healing, de-development, and then redevelopment. This study focuses on the first and second stages because our treatment is thought to affect these stages the most. This study examined how beta-alanine affects the rate of wound healing and limb regeneration following amputation of a hind limb. Beta-alanine is a nonessential amino acid that is naturally produced in the body and converted to carnosine via carnosine synthetase. Carnosine is thought to act as a pH buffer, allowing the tissue to rebuild faster. A previous study looked at wound healing in rats following the addition of beta-alanine to their diets. The study determined that diets containing beta-alanine enhanced the rate of wound healing. For this study, we introduced high and low concentrations of beta-alanine via intramuscular injection on days 0 and 7, following amputation of the hind limb. Results show that injection of beta-alanine had a significant increase in the rate of limb regeneration and wound healing during that time period.

832 Emma Schachner, Aracely Martinez, Karl Bates, Andrew Moore, Clinton Grand-Pre, Raul Diaz-Jr, Scott Echols, Brandon Hedrick

Pulmonary diverticula as functional structures in the red-tailed hawk (Buteo jamaicensis)

The avian respiratory system is composed of an immobilized minimally compliant-gas exchanging lung (GL), unidirectionally ventilated by a series of flexible air sacs (AS). There is also an array of diverticula that emerges from both the GL and AS, extends around joints, between muscles, and variably pneumatizes the adjacent skeletal tissues. In addition to ventilation, the AS and diverticula have been experimentally shown to be active in vocalization and behavioral displays. Here, we evaluate the patterns of postcranial pneumaticity and the non-ventilatory function of the subpectoral diverticula in the red-tailed hawk (Buteo jamaicensis; n = 6) using dissection, ultrasound, microCT, 3D segmentation, and 3D multibody dynamics biomechanical models. Contrary to previous descriptions, pneumatization of the synsacrum and pelvis is accomplished by pelvic diverticula emerging from the GL. The abdominal AS pneumatizes only the femora. The GL directly pneumatizes the thoracic vertebrae, and diverticula from the interclavicular sac pneumatize the pectoral girdle. The subpectoral diverticulum is a structure of varying size that emerges from the interclavicular sac in the axillary region, and dives between the thoracic fibers of the m. pectoralis and m. supracoracoideus. Our data show that when inflated (both artificially and during sedated ventilation), the thoracic fibers of m. pectoralis are displaced ventrally, independent of the movement of the sternal keel, thus impacting the moment arm of the muscle and potentially impacting function during flapping movements.

1100 Calvin Schaefer, Connor Downs, Guinevere Wogan

Ecological and Evolutionary Correlates of Venom Complexity and Venom System Morphology in Snakes

Venom has evolved repeatedly across the Tree of Life and is an ecologically relevant phenotypic trait that is tied directly to the fundamental need for animals to acquire sustenance. Many aspects of the morphology of the venom delivery system have also been shown to vary according to dietary specialization. As a taxonomic group with incredible variation in diet and foraging mode, snakes represent an ideal model system to examine the influence of feeding ecology on morphology, protein structure, and evolution of complex phenotypes. The goal of this project is to examine ecological drivers of variation in venom system morphology of front-fanged and rear-fanged venomous snake species. To achieve this goal, we sampled a subset of venomous snake species across all families of colubriform snakes from museum specimens. We conducted diet analyses using Squamatabase to classify snakes into one of three trophic niches (obligatory specialist, facultative specialist, and generalist). We used a combination of micro and diceCT to gather skull/tooth morphology and calculate venom gland volumes with SlicerMorph. Finally, we performed a phylogenetic comparative analysis of the trait data collected in combination with venom protein profiles generated using the ToxCodAn toxin annotator.

789 Paul Schaeffer

Manipulation of photoperiod induces fat storage, but not fat mobilization in a migratory songbird.

Avian migration requires appropriate timing of fuel storage in preparation for flight and delivery of stored energy to the working muscle during flight. As such, migratory birds display considerable phenotypic plasticity during migration with expansion of adipose stored, increased flight muscle capacity and overall enhancement of metabolism. The cues that trigger these phenotypic changes are poorly understood, but changing light conditions have long been used to induce migratory phenotypes in captive populations. We found that shifting catbirds caught in the beginning of fall migration to either a summer light cycle (14L:10D) or a fall, migratory light cycle (10L:14D) led to a large expansion of the adipose tissue, as expected. We also found that this tissue had inhibited lipolytic activity, suggesting that only the storage program was being activated. Further, we found no difference in several energy metabolic endpoints, all of which served as markers of energy use, supporting that light cycle manipulation was insufficient to fully induce a migratory phenotype.

1085 Megan Schellhase, Tia Bottger, Vermilion Villarreal, Brett Klaassen-van-Oorschot, Rachel Pepper

The effect of oscillatory flow on the orientation and feeding flow of Vorticella convallaria

Vorticella are microscopic sessile suspension feeders present in diverse aquatic environments. The protists live attached to surfaces and serve a key role in their ecosystems as consumers of bacteria and detritus, feeding with a self-generated current. Understanding feeding flows and rates is important for determining their impact in aquatic ecosystems and their ability to filter contaminants as participants in wastewater treatment and bioremediation. Previous study revealed this rate is highly dependent on ambient flow and the orientation of the organism with respect to the flow and surface of attachment. This prior work, however, was conducted in unidirectional laminar flow, representative of slow streams and rivers. Many common habitats of Vorticella have more complicated flows. We, therefore, sought to observe these microorganisms in oscillatory flow. We cultured Vorticella convallaria attached to the bottom surface of a rectangular flow chamber and simulated several oscillatory conditions representative of those in nature. We recorded the 3D orientation of individuals using a simultaneous top and side view microscope and measured flow using particle image velocimetry. We present results comparing orientation and flow in oscillatory motion to unidirectional and still waters.

1551 Perrin Schiebel, Michelle Yuen, Robert Wood

The role of limb compliance in an insect-scale robot traversing obstacle-laden terrain

Insects can locomote readily in unstructured terrains, relying in part on the passive mechanical properties of the limbs to mediate interactions. We use a 1.5 g, insect-scale quadrupedal robot as a model to study how the amount and distribution of compliance in the limbs impacts locomotor performance during open-loop transit of a 3D printed, feature-laden terrain designed to mimic natural environments. We changed the compliance of a single “knee” joint from stiffer than the robot drivetrain to so soft that it was unable to support the robot’s weight. We found that the relationship between performance (ability to bypass taller terrain features) and limb compliance linearly increased to a plateau beyond which performance degraded as the limbs were too soft to provide effective locomotion. Distributing compliance across multiple joints, such that the total stiffness of the limb was approximately equivalent to that of an effective single joint, did not appreciably change performance. However, continually compliant soft legs molded out of silicone were not as effective, suggesting that having a combination of stiff struts and soft joints, as in insect limbs, is better able to balance transmitting forces with managing complex ground reaction forces. This work helps illuminate the role of compliance in insect limbs and rationalize the advantage of their design.

1646 Jake Schmid, Michael Minicozzi

Does Chronic Exposure to Clothianidin Effect Swimming Performance in Rainbow Trout?

Agricultural run-off is the leading cause of non-point source and surface water pollution across the United States. Neonicotinoids are the newest and most widely used class of insecticides in the world. Neonicotinoids act as central nervous system disruptors in insects by binding the acetylcholine receptor. Neonicotinoids also bind to the vertebrate acetylcholine receptor and can have effects on muscular development. Clothianidin is one of the most newly implemented neonicotinoids and the current study investigates whether chronic exposure of environmentally relevant concentrations of Clothianidin will affect juvenile rainbow trout swimming performance. Rainbow trout are among the most important sport and commercial species across the globe, and due to their historically migratory behavior, made a great candidate for this study. Eyed eggs, 15 days post fertilization (dpf) were exposed to environmentally relevant concentrations (0, 0.3, 3, and 30 μg/L) of clothianidin. Starting at 70 dpf, fish were subjected to critical swimming velocity trials which consisted of 30 minutes of low flow (4 m/s-1) followed by serial velocity increases of 1 m/s-1 every 5 minutes until the fish was swept to the downstream barrier or touched the back of the flume 5 times or more within any given increment. Data from these swim trials will elucidate the effects that chronic clothianidin exposure has on juvenile rainbow trout swimming performance and muscle development.

903 Luke Schmitz, Clinton Moran, John Zardus

Temperature effects on larval swimming of an important biofouling barnacle

The striped acorn barnacle Amphibalanus amphitrite is a cosmopolitan marine biofouler on vessels in warm and temperate seas. In addition, plankton dispersal promises poleward range expansions in response to climate change. Despite this likely scenario, not much is known about the impacts of temperature on the locomotor kinematics of larval A. amphitrite. Our objective was to examine the effects of water temperature on swimming performance of A. amphitrite cyprids. We conducted laboratory experiments measuring swimming performance on animals at three temperatures: 18, 24, and 30°C. We predicted that cold temperatures would slow swimming kinematics, while warm temperatures would have the inverse effect. Using high-speed videography to measure the distance traveled during one power stroke of the swimming appendages (thoracopods), maximum- and average-swimming velocity, acceleration, and power-stroke frequency. Surprisingly, our data showed that overall swimming performance was greatest at the intermediate treatment temperature. In fact, distance covered and maximum/average velocity were greater at 24°C than at both the warmer and colder temperature treatments. This study demonstrates that our median temperature treatment of 24°C was optimal for locomotion of this barnacle's cyprids. This suggests that further spread of this species in the environment would be greatest at this temperature, whereas it would be restricted at 18 and 30°C. This data provides insight on possible range shifts for this species as climate warming continues.

485 Nikole Schneider, Christopher Anderson

Kinematics of a direct prey capture feeding strategy in chameleons

Animals have evolved various specialized feeding strategies to obtain food in their environment. One iconic example is ballistic tongue projection in chameleons, whereby the tongue is rapidly launched from their mouths to capture prey up to 2.5 body lengths away. Although chameleons almost exclusively use tongue projection for prey capture, several species have been observed directly capturing certain prey items using their jaws. This uncommon feeding strategy has only been described at a basic level and their underlying mechanisms never examined. We compared the kinematics of chameleons feeding by ballistic tongue projection and direct prey capture to evaluate the extent to which these strategies utilize similar kinematic patterns, or if the evolution of such a highly specialized primary feeding strategy necessitates the evolution of novel kinematic patterns when the system is coopted for another behavior. We found that during direct prey capture, chameleons adopt similar kinematic patterns used by other Iguanian lizards, although initial contact with the prey by the tongue or jaws varied. The tongue was still protruded anteriorly prior to prey contact, but a slow forward lunge and head tilt proceeded prey contact rather than projection of the tongue off the hyoid. These results suggest that chameleons are not constrained to their typical kinematic patterns while feeding by direct prey capture, which has broad implications for the evolution of highly specialized movements.

1450 Stephan Schneider, Gaspar Jekely, Steffanie Meha

Organization and development of multi-ciliated arrays in a marine larva

Larval motility of most marine invertebrates depends on the activity of large numbers of cilia that provide the means to move within the water column, towards food sources, and towards appropriate substrates for settlement. These cilia are generated by multi-ciliated cell types that are organized in ciliary bands called trochs. Most recently the marine annelid Platynereis dumerilii emerged as a powerful model annelid for cell type evolution with substantial molecular tools and resources including two ultrastructural whole-body cellular atlases for a three-day old free-swimming larva, and for a six-day old settled juvenile worm. We leveraged these sources to map each cilium including basal bodies for each individual multi-ciliated cell in these two whole-body EM stacks enabling the first complete count of cilia in an organism, and their precise arrangement within each cell. Within the para-, meta-, and akrotrochs, we found a polarized distribution of different types of basal bodies (aligned/misaligned) and an antero-posterior arrangement of basal bodies with and without cilia. Furthermore, we discovered a correlation between the cell-lineage and basal body number for prototroch cells, and a strong correlation of total number of basal bodies and their arrangement between each individual left-right cell pair in the para-, meta-, and akrotroch. Thus, each multi-ciliated cell controls the number and position of basal bodies precisely establishing an almost perfect bilateral symmetry of cilia-bearing cells.

1810 Samantha Schofield, James Waters, Jannelle Couret

Discontinuous ventilation patterns in nymphal Ixodes scapularis

Ixodes scapularis, the blacklegged tick, transmits no less than seven human pathogens, including Borrelia burgdorferi, the etiologic agent of Lyme Disease. Despite its public health importance, the ventilation patterns of I. scapularis have not been previously characterized. Yet, such patterns are critical to understanding tick energy use and water exchange. In other Ixodid ticks, characterized as gorging and fasting organisms, previous work has demonstrated prolonged survival without access to food or direct standing water; a biological feature attributed to behavioral and physiological adaptations, including active atmospheric water vapor uptake, discontinuous gas exchange and low metabolic rates. These adaptations have not yet been confirmed in I. scapularis. Here, we present patterns of discontinuous ventilation, estimates of metabolic rates, and active water vapor uptake for field collected and laboratory raised I. scapularis nymphs, the life stage most relevant for human disease risk. We further estimated these measures for B. burgdorferi infected and uninfected nymphs, finding that physiological measures differ on the basis of infection status. These findings are foundational for understanding the role of environmental factors such as relative humidity in the survival of I. scapularis off of hosts, a critical period of environmental selection.

205 Aaron Schrey, Kyle Ashton, Melanie Gibson, M. Ellesse Lauer, Andrea Liebl, Lynn Martin, Lance McBrayer, Earl McCoy, Henry Mushinsky, Daniella Ray, Elizabeth Sheldon, David Tevs

Epigenetic buffering in heterogenous and stressful environments

Epigenetic buffering, the use of epigenetic modifications to facilitate evolutionary rescue by generating phenotypic variants, can affect how species respond to heterogenous and stressful environments. We review data from multiple taxa that support epigenetic buffering to identify general shared patterns, to detect areas lacking knowledge, and then to suggest next steps. We present two case studies that highlight the role of epigenetic buffering in wild populations of vertebrates. First, we discuss how DNA methylation follows a pattern indicative of epigenetic buffering in the House Sparrow, a highly successful introduced species. Several DNA methylation-based epigenetic studies indicate that the House Sparrow rapidly generates phenotypic variation in novel habitats, overcoming the challenges of inbreeding. Second, we discuss how DNA methylation follows a pattern indicating epigenetic buffering in the lizards of the Florida scrub habitat. This habitat is maintained by high intensity wildfires, which generate fine-scale heterogeneity in the landscape. Wildfires occur on a dynamic timescale, forcing inhabiting species to rapidly respond to changing environments. Each of the three focal species prefers a different time-since-fire habitat and show a different response in DNA methylation to wildfire: the Florida Sand Skink responding to recent fire, the Six-lined racerunner and the Florida Scrub Lizard responding to longer time since fire. Both case studies show epigenetic buffering as a valuable framework for integrating epigenetic mechanisms into diverse ecological settings.

1062 Natalie Schroth, Jessica Arbour

Quantifying Evolutionary Trends of Color Pattern in Darter Fishes (Etheostomatinae)

Animal coloration serves many important functions, including mate selection, predator avoidance, and kin recognition. Despite playing a key role in the ecology of many groups, macroevolutionary studies of coloration have been limited by our ability to quantify color and pattern. Within family Percidae, the often brightly colored subfamily Etheostomatinae (the lotic "darter" fishes) serves as an excellent study group with well over 200 species. To better understand the macroevolution of darter coloration, we quantified consistent metrics for color and pattern for comparative analyses using wild-caught specimens in nuptial colors from more than 25 species. 'R' packages recolorize and pavo were used to conduct adjacency analysis to describe proportion, diversity and complexity of color patterns. Principal component analysis was used to determine which colors/patterns contributed most to color diversity within Etheostomatinae. We used disparity through time (DTT) analysis and adaptive landscape fitting approaches in l1ou to quantify trends in color diversification. Darter coloration comprised conspicuous (reds, blues, yellows, greens) and inconspicuous colors (browns, blacks), with pattern and color complexity varying among species. Preliminary analyses resulted in positive morphological disparity index values (MDI's), which indicate strong selection on color evolution with increasing color diversity towards the present. The adaptive shift analyses showed shifts towards different peaks, but primarily we see a divergence between darters living in lentic waters and species inhabiting more lotic, rocky environments.

712 Andrew Schulz, Cassie Shriver, Suzanne Stathatos, Benjamin Seleb, Saad Bhamla, Young-Hui Chang, David Hu

A Review of Advancing Conservation Practices using Conservation Tools

We are currently experiencing the sixth mass extinction on earth caused by human conflict into traditional wildlife habitats. A new field known as conservation technology has recently picked up traction in the scientific community. Conservation technology works to develop conservation tools that assist in the wildlife sector and help utilize new and advanced technology to help slow the impact humans have on the ever-changing wildlife climate. In this chapter we discuss the overarching terms that the conservation technology community uses as well as discuss effective case studies and the primary themes that make conservation tools success. Successful tools rely on conservation partnerships while maintaining a drive for open source and accessible solutions that do not over-engineer, but do utilize advancing technology, techniques, and policies. The hope of this chapter is to help inspire the next generation of wildlife scientists to think of technological tools that could help them in the field, lab, and elsewhere to advance wildlife conservation for future generations to come.

719 Andrew Schulz, Amir Patel, Ardian Jusufi

Creating Improved Conservation Reintroductions using observational biomechanics of the Cheetah

Conservation Physiology describes the field of using morphological data to help inform conservation practices. Nearly all of the big cats around the world have been made vulnerable to extinction due to human-wildlife conflict ranging from pet trade to bush meat and illegal hunting. One of the most successful ways to conserve these species in areas they have gone extinct is to work towards reintroduction. The challenge of reintroduction apex predators like big cats can be lack of agile biomechanics needed for prey capture. In this study we test the validity of combining the morphology with biomechanics data to inform more effective re-introduction practices of South African cheetahs. We used videos of captive versus wild cheetahs during agile hunting tasks to determine biomechanical differences between generalized kinematics of the four limbs plus the tail of cheetahs in South African conservation networks. We discuss the ability of utilizing a mechanical device to help aide in captive cheetahs feeding habits to encourage more agile behavior for more effective means of reintroduction. We discuss broadly how this field could impact reintroduction efforts world wild by working alongside the communities of individuals involved in the care and reintroduction of all types of fauna.

1625 Ryan Schwab, Joseph Reade, Mark Jankauski

Reduced-Order Fluid-Structure Interaction Modeling of Chordwise Flexible Wings

Flapping, flexible insect wings deform under the influence of aerodynamic and inertial forces. Wing deformation is believed to be favorable to aerodynamic force production, energetic efficiency and sensing. However, the models used to predict wing deformation often rely on computational fluid dynamics and finite element analysis, which are computationally expensive and not conducive to parameter studies considering variable flapping kinematics, wing morphologies, etc. In this research, we develop a reduced-order fluid structure interaction model to predict the deformation and resulting aerodynamics of chord-wise flexible wings. The model is based on a deformable blade element aerodynamic model and a modal superposition based structural model. We compare the aerodynamic forces and deformation of a simplified rectangular flapping wing predicted by the reduced-order model and high-fidelity methods. We found that our reduced-order model can resolve the wing deformation and bulk aerodynamic forces nearly 5 orders of magnitude faster than the conventional high-fidelity model. We then used this reduced-order model to run a parameter study, investigating the influence of wing mass and stiffness, to better understand how such a model could be used in the design of an artificial flyer. We are currently developing a mid-fidelity quasi-3D unsteady vortex lattice based model that maintains the computational efficiency of the deformable blade element approach while recovering some of the flow structure available to computational fluid dynamics.

1687 Marie Schwaner, Monica Daley

Sources of variation in muscle workloop patterns in non-steady locomotion in guinea fowl LG muscles

Work loops are a useful analytical tool to evaluate mechanical work and power of muscles and to identify a muscle's mechanical role in locomotion. Work loop techniques have mainly been used to characterize cyclic motions under controlled preparations and steady locomotor tasks. Consequently, the sources of variation in work loop patterns under natural locomotor conditions remain unclear, especially for non-steady locomotion. Here, we explore variation in work loop dynamics in non-steady locomotion in response to treadmill belt speed perturbations. These perturbations induce a perturbation to foot speed and muscle strain during stance, to elicit higher covariance between muscle fascicle strain, force, and EMG to explore the how these factors contribute to variation in in vivo work loop patterns. We measured in vivo muscle dynamics and kinematics in helmeted guinea fowl (N. Meleagris, N = 8), equipped with sonomicrometry crystals and EMG electrodes in the lateral gastrocnemius (LG) muscle and a tendon buckle force transducer on the common gastrocnemius tendon. These in vivo measures allow us to identify how multiple factors contribute to variation in work loop patterns and net work output, including fascicle shortening strain, velocity, phase between length and activation, EMG duration and amplitude. Understanding sources of work loop will improve understanding of sensorimotor control strategies and muscle mechanical responses to maintain stability in response to perturbations.

1721 Tonia Schwartz, Amanda Clark

An RNAseq CURE contrasting 18 pipelines from mapping to functional pathway enrichment

Functional Genomics courses, once reserved for graduate students, are now entering the undergraduate curriculum. Curriculum-based undergraduate research experiences (CUREs) provide a valid research experience addressing a scientific question. RNAseq is a standard method to test for differential gene expression among treatment groups and identify functional pathways that are responding to stressors. The analysis of RNAseq data is considerably variable with new programs continually being develop. RNAseq analysis typically consists of distinct steps, each of which utilizes specific programs: mapping to a reference, defining genes/transcripts to obtain the counts of reads that mapped, statistical differential gene expression analysis, and enrichment for functional pathways. Mixing and matching the programs across these steps can produced a maze of potential pipelines and choosing a path through can be intimidating. Using a RNAseq dataset from Daphnia exposed to ad lib feed or caloric restriction, we have now formally developed a user friendly "chose your own adventure" of 18 pipelines that can be easily utilized in a classroom setting facilitating CURE based structure for a functional genomics course that can be easily transported across institutions. Additionally, using these Daphnia data and two other non-model RNAseq datasets we address the question, "to what degree does the path through the bioinformatic maze matter in the context of the biological interpretation of the experiment?".

102 Lorian Schweikert, Daniel Chappell, Zijin Huang, Gabrielle Delpizzo, Krish Wahi, Madeline Saunders, Vivian Slye, Lydia Naughton, Nicholas Rummelt, Laura Bagge

Multisensory Integration of Aposematic Signals by a Mantid Predator

The brain of most animals combines information across separate sensory systems, providing an integrated view of external events that is more information rich than would be predicted by the sum of its individual contributors. In context of aposematism, senders may use combined defenses to reduce predation risk to a greater extent than could be achieved by any defense displayed alone. We set out to explore this possibility by examining the effects of combined warning signals on attack latency in the Carolina mantis (Stagmomantis carolina; N = 48), testing whether 1) multisensory integration is employed by mantids when attacking aposematic prey and 2) prior exposure to defended prey (a learning event) alters their multisensory response. Using artificial prey bearing visual and olfactory defenses of lady beetles, we measured attack latency of prey across four groups: visual only, odor only, combined, and control. We employed a repeated-measure design, first completing the experiment in naïve predators, then repeating the experiment after offering lady beetle prey (Hippodamia convergens). We then used generalized linear mixed models to test the prediction that combined defenses would have additive effects on attack latency and that learning would augment that response. These data provide the first study of multisensory integration by a mantid predator, providing insights into the adaptive significance of multisensory integration and the coevolution of aposematic defense between insect predators and prey.

1490 Sunny Scobell, Kenneth Schneider, Grace Stepek, Kaitlyn Hoang, Madeline Clements, Mohammad Kamal

Investigation of the novel hypothalamic-pituitary-pouch axis in male-pregnant syngnathid fish

All members of the teleost fish Family Syngnathidae (seahorses, pipefish, and seadragons) reproduce via male pregnancy. Females transfer eggs to the ventral pouch of the male where fertilization and development of offspring occurs. Early research showed a clear role for pituitary hormone regulation of the brood pouch during pregnancy. However, the limitations of working with such non-model, small-bodied fishes has slowed the understanding of this novel endocrine axis. We are using traditional histological staining paired with multi-fluorescent immunohistochemistry and scanning electron microscopy to investigate the anatomy of the hypothalamic-pituitary-pouch (HPP) axis. Gross dissection revealed a unique placement of the pituitary in the pipefish, which is situated between the lower hypothalamic lobes of the brain. In contrast, the seahorse has a pituitary that is ventrally offset from the hypothalamus, similar to that of other vertebrates. Using immunolabeling for specific hormones, we are currently creating a map of the pituitary hormone localizations in seahorses and pipefish. We are also investigating the structural and functional changes that occur in the brood pouch epithelium over the course of the reproductive cycle in males. Because the morphological and physiological changes that occur during pregnancy in male syngnathids exhibit similarities with those of female mammals, syngnathids are a promising model for understanding the convergent evolution of mechanisms mediating pregnancy.

804 Carly Scott, Annette Ostling, Mikhail Matz

'Til death do us part? Modeling the costs of fidelity in coral-algal symbiosis

Tropical scleractinian corals normally live within 1-2°C of their thermal maxima, and low-level coral bleaching (loss of algal symbionts) occurs every summer. This appears counterintuitive, as bleaching poses a high risk to coral survivorship. Here, we hypothesize that seasonal bleaching is part of the symbionts' strategy to maximize their chance to infect the next generation of the host. To explore this, we formulated a difference equation-based model. Our model assumed that bleaching is detrimental for the adult host, but the more symbionts leave the host, the better is their chance of infecting new coral recruits. Our model predicts that the more bleaching-susceptible symbiont becomes dominant when most coral growth in the system comes from new recruitment or when adult survivorship is low. However, the overall growth rate of the system is dependent on the fidelity of the symbiont. Interestingly, when the intrinsic growth rate can support it, higher levels of bleaching maximize population increase. This counterintuitive prediction is supported by published in situ observations from the Great Barrier Reef. Together, these results indicate that bleaching may be tied to reproduction - an essential part of the coral life cycle.

1199 Bradley Scott

Competition from jawed vertebrates was not the only cause of Heterostraci (Agnatha) extinction

The most common hypothesis for how jawless vertebrates (agnathans) went extinct and jawed vertebrates (gnathostomes) came to dominate vertebrate faunas is competitive exclusion. A recent study of early vertebrate body form has shown that some groups of gnathostomes are similar in morphology to groups of agnathans, consistent with competition. However, similarity in ecology between these groups has not yet been determined. Among these groups Phyllolepida (Gnathostomata) has previously been hypothesized to outcompete Heterostraci (Agnatha). If Phyllolepida outcompeted Heterostaci, then similarity in form should correspond to similarity in ecological parameters, approximated by performance. To compare performance of body form, three flow forces (drag, lift-to-drag ratio, and ground effect) were simulated using computational fluid dynamic software for 3D models of phyllolepids and heterostracans and a separate model of median values for early vertebrate morphologies. Phyllolepids and heterostracans overlapped with the median model in drag, were similar to each other but different from the median model in lift-to-drag ratio, and were different from each other in ground effect. Similarity in some flow performance is consistent with competition between phyllolepids and heterostracans; however, differences in ground effect make it unlikely that phyllolepids outcompeted heterostracans across all ecological parameters.

1617 Matthew Scott, Kayla Fast, Alex Rakestraw, Magdalene Dogbe, Heather Jordan, Sophie Picq, Joseph Receveur, Jean-François Guegan, Jennifer Pechal, Eric Benbow, Michael Sandel, Alexandra Bauer, Christine Chevillon

Comparative microbiomics of Amazonian freshwater fishes

The Amazon Rainforest is recognized as one of the most biodiverse ecosystems on Earth, particularly when considering macroorganisms (animals, higher plants, and fungi). Relatively speaking, little attention has been paid to the microbiological diversity within this ecosystem, or to the interactions between macro and microbiological communities. Toward this end, we characterized the role of habitat parameters on the dermal microbial communities of four freshwater fishes in three primary watersheds of French Guiana. We conducted field expeditions across three seasons (July-September 2021, March 2022, July 2022) across three zones (headwaters, middle tributaries, and coastal lowlands) of three watersheds (Approuague, Sinnamary, and Mana River) in French Guiana. We used traditional 16s microbial metabarcoding to quantify and compare the dermal microbial communities across species, seasons, microhabitats and macrohabitats. Our study reveals taxon-specific effects on microbial connectivity across watersheds, and seasonal effects on the mucosal dermal microbiomes of multiple species. Results of this work provide novel insights into the role of local freshwater fishes in shaping environmental microbial communities in tropical floodplain forests.

1456 Elaine Seaver

Characterization of a putative stem cell niche in the annelid Capitella teleta

Adult stem cells function during tissue homeostasis, growth, and repair in response to injury. In animals that regenerate complex structures, stem cells reside either in specific locations within the body or are more broadly distributed. Microenvironments that support and regulate the survival and proliferation of resident stem cells are called stem cell niches. Few dedicated stem cell niches have been reported in aquatic invertebrates even though many of these animals have substantial regeneration abilities. Capitella teleta is an annelid that exhibits robust posterior regeneration, regeneration of both somatic and reproductive tissues, and environmentally induced sex change. All these processes require birth and patterning of new cells from resident stem cells. We have identified a single cluster of undifferentiated cells that has a discrete location in the coelomic cavity of the thorax in Capitella. Cells in this cluster express genes of the multipotency cell program such as vasa, nanos, piwi, PL10 and PCNA, and we call it the MPC cluster. Characterization of cell division profiles and expression patterns by in situ hybridization reveal heterogeneity among cells within the MPC cluster. We characterized the maturation of the MPC cluster during the life cycle and have identified progenitors in early stage larvae. We suggest that this cluster is a stem cell niche and hypothesize that cells within the cluster can generate both somatic and germline descendants.

1357 Ibrahima Seck, Jessica Fox

Mechanosensory haltere input structures non-flight wing movements in the black scavenger fly, Sepsis

In active senses, an animal's behavior changes the sensory input that it receives. The specific movements of the sensor itself determine the information that it collects. Animals from cockroaches to rats to humans will actively move their mechanosensory organs in different ways in search of distinct categories of information (e.g. shape or texture). To stabilize flight, flies oscillate a modified hindwing called a haltere, which acts as a gyroscope to detect forces and allows the fly to stabilize its flight path. Some flies also show haltere and wing movements when walking or standing, often as courtship or aggression displays. These movements are distinct from the high-amplitude, high-frequency oscillations observed in all flies during flight. The black scavenger fly, Sepsis punctum, moves its halteres slowly and irregularly while also moving its wings during walking and standing. We hypothesized that these slow haltere movements may provide sensory input that is used to coordinate wing displays. We predicted that modifying the haltere's weight or movement would alter the patterns of wing movements in Sepsis punctum during free walking behavior. Recordings of these flies during walking, aggression, and courtship showed that haltere modification alters wing movements. Thus, Sepsis punctum coordinates its non-flight wing movements in part by using sensory information from slow oscillations of the halteres. This represents a previously unknown function for these crucial dipteran sensors.

129 Jacqueline Seddon, Daniel Powell, Jacob Kazmi, Alexandra Miller, Patsy Dickinson

Dietary diversity correlates with stomatogastric neuromodulatory capacity in majoid crabs

All decapod crustaceans rely on the same neuronal circuits to control the movements of the foregut. The stomatogastric ganglion (STG), which is part of the stomatogastric nervous system (STNS), contains two pattern generating networks that control these movements. Over 30 neuromodulators (amines, amino acids, peptides) have been identified within the STNS of Cancer borealis. The large number of modulators found in this system is surprising given that there are only 25 neurons in the STG. Individual species have been observed to respond to different numbers of neuromodulators, which may correlate with the diversity of a given species' diet. This could be one evolutionary underpinning of behavioral flexibility. Decapod species with broad diets likely require more flexibility in their motor output to better digest a range of foods, while more specialized feeders may only require a limited set of movements. Therefore, we predicted that the STNS of species with broad diets would respond to more neuromodulators than that of specialized feeders. We examined responses to neuromodulators superfused over the STNS in three Majoid crab species. Pugettia producta (kelp crab) eats primarily kelp, while Libinia emarginata (spider crab) and Chionoecetes opilio (snow crab) are omnivorous scavengers. P. producta is more closely related to L. emarginata than to C. opilio. The STNS of P. producta responded to fewer neuromodulators than either L. emarginata or C. opilio.

647 Sara Seidita, Rafael Rodriguez

Enchenopa use spontaneous signals to re-establish duetting communication during wind-induced noise

Natural environments have varying degrees of noise that can disrupt communication signals. Many animals communicate with plant-borne vibrational signals that can easily be influenced by wind-induced noise. Enchenopa treehoppers are herbivorous insects that communicate with plant-borne vibrational signals and use male-female duetting in pair formation. Males use gap detection to initiate signaling during wind pauses, and females respond less during wind-induced noise. We hypothesized that Enchenopa treehoppers compensate for vibrational duetting interference from wind noise by re-establishing communication with a potential mate by producing spontaneous signals. We presented females with plant-borne vibrational playbacks of attractive and unattractive male signals with and without wind generated by a computer fan. Females were more responsive with attractive stimuli than unattractive stimuli regardless of wind, and without wind regardless of stimuli. Females produced spontaneous signals (and wing buzzes) more often in the presence of wind. We conclude that female Enchenopa treehoppers adapt their signaling strategy to re-establish communication with a potential mate according to wind noise conditions.

1108 Abisage Sekarore, Chryssanthi Tzetzis, Julia Cappiello, Erin Patton, Nicole Fuller, Gabriel Rosado, Emily Morgan, Makena Scarlata, Brent Woodworth, Mackenzie Gerringer

Drivers of deep-sea fish community biodiversity in Puerto Rican waters

Biodiversity is a key indicator of the health and stability of ecosystems, including ocean habitats. The deep waters surrounding Puerto Rico contain a variety of habitats and geological features that provide refuge to a wide range of organisms. These habitats and features include seamounts, ridges, trenches, and canyons. In this project, a remotely operated vehicle (ROV) and the submersible Alvin were used to survey the regions off the coast of Puerto Rico and the Virgin Islands to better understand community biodiversity. Data from the National Oceanic and Atmospheric Administration Office of Ocean Exploration Research (NOAA OER) Expedition 1811 (EX1811) and Alvin Science Verification Expedition (AT50-02) suggest that fish biodiversity decreases with increasing ocean depth. Fish taxonomic orders seen at greater depths include the Ophidiiformes, Notacanthiformes, and Aulopiformes. Morphological changes included elongated bodies and smaller head-to-body ratios with increasing depth. The number of families observed correlated with dissolved oxygen concentrations and temperature. Fish observations suggest that sediment type may influence biodiversity. Soft sediments tended to have higher demersal fish biodiversity, compared to rocky and mixed substrates. Anthropogenic debris was observed to depths greater than 6,000 m, showing human impacts on deep-sea ecosystems. This study explored how different environmental parameters including: depth, temperature, dissolved oxygen, and substrate type drive fish community composition, increasing our knowledge of ecosystem function and biodiversity.

684 Benjamin Seleb, Saad Bhamla, Matt Bull

Sled Dog Collective Behavior

Sled dog teams epitomize a human-engineered animal collective. Although humans have been harnessing and optimizing these tethered collectives for almost 10,000 years, their locomotive biomechanics, human-animal control strategies, and emergent collective dynamics have not been described empirically. Here, for the first time, we combine high-resolution drone imaging, DeepLabCut tracking, custom animal-borne wearable sensors, and mathematical models to uncover how these extraordinary teams of diverse dogs run together as an active network. Thus, unlike schools of fish or flocks of birds, sled dog teams are composed of heterogenous individuals that are tethered together and controlled by a human (musher). We discuss the implications of each of these aspects, revealing how physical tethers may offer an additional network for information transfer, how the intrinsic diversity of the dogs and their position in the team may impact team performance, and how mushers control these dog trains from the rear in challenging unpredictable environments. Our work sheds insight into understudied areas in collective research such as the influence of tethers, the role of team heterogeneity, and methods of collective control while offering inspiration for robotics swarms.

460 Christopher Seng, Robyn Crook

Descending inhibitory modulation of nociception in the cephalopod nervous system

Nociceptive sensitization occurs in many species after nerve or tissue injury and is mediated by peripheral and central alterations that range in temporal pattern from transient to life-long. One major cause of long-term upregulation of nociceptive signal transmission is excitotoxic death of descending modulatory interneurons, which has been studied extensively in mammals but has received little investigation in other taxa. Cephalopods have the most complex nervous systems of all invertebrates, and despite being completely independently evolved, their nervous systems show many structurally and functionally analogous features to those of mammals. Cephalopods express nociceptive sensitization after tissue injury that is similar in spatial and temporal character to nociceptive plasticity found in mammals, but whether the same mechanisms are responsible for upregulation of nociceptive signal after injury in cephalopods remains unknown. In this project, we are investigating how inhibitory tone changes after tissue injury in the model cephalopod, Euprymna berryi. Electrophysiological recordings from two peripheral nerves pre- and post-synaptic to the stellate ganglion support our working hypothesis that injured animals show long-term changes to excitability in the post-synaptic, but not pre-synaptic nerve, paralleling central sensitization-like changes observed in mammals. Ongoing studies will test the effect of exogenous GABA and bicuculline washes, to reveal whether chronic reduction in inhibitory neurotransmission is a shared mechanism of long-lasting nociceptive plasticity in diverse species including cephalopod molluscs.

1669 Stephannie Seng, Edward Connor, Gabriela Ponce, Peter Andreas, Anna Kisiala, Neil Emery, Rosemarie De-Clerck-Floate, Don Miller, Ming-Shun Chen, Peter Price, John Tooker

Abscisic Acid: A Secreted Effector from Phytophagous Insects

Abscisic acid (ABA) is an isoprenoid-derived plant signaling molecule involved in many plant processes including facets of plant growth and development, as well as plant responses to abiotic and biotic stress. ABA was previously reported from a wide variety of animals, including insects and humans. We used high performance liquid chromatography-electrospray ionization tandem mass spectrometry (HPLC-MS/MS) to examine concentrations of ABA in 17 species of phytophagous insects, including gall- and non-gall-inducing species from six orders of Insecta. We found ABA in all six orders with no tendency for gall-inducing insects to have higher concentrations. The observed concentrations often markedly exceeded that found in plants. We also used immunohistochemistry to localize ABA to the salivary glands in the larvae of the gall-inducing Eurosta solidaginis. The high concentrations of ABA combined with its localization to salivary glands suggest insects are synthesizing and secreting ABA to manipulate their host plants. Its wide distribution among gall- and non-gall inducing insects and our current knowledge of its role in plant processes suggests that insects are using ABA to manipulate source-sink mechanisms of nutrient allocation and suppress host-plant defenses. ABA joins the triumvirate of phytohormones, with cytokinin and auxin that are abundant, widespread, and localized to glandular organs in insects used to manipulate host plants.

935 Tanner Senti, Matthew Gifford

Prey and Macronutrient Selectivity in a Common Insectivorous Predator, Sceloporus consobrinus

Maintaining nutritional homeostasis is a key challenge for wild animals with important implications for survival and reproduction. The ability of an organism to regulate feeding behavior despite environmental variation is critical for individual success. It is well established that herbivores balance their diet through nutrient-specific foraging, however less clear is how often predators feed selectively from available prey to balance macronutrient consumption. Given the key role that predators play in structuring ecological communities, understanding nutrient regulation by these consumers will contribute to a more mechanistic understanding of food webs and may help predict their response to changes in prey availability. Here we examined the diet and macronutrient selectivity in free-ranging Sceloporus consobrinus, a common insectivorous predator. Previous studies have shown lipids to be most critical to maintenance and reproduction, with S. consobrinus relying on income sources to reproduce. Specifically, we asked whether individuals nonrandomly fed on prey despite availability and whether females targeted lipid-rich prey to fuel egg production during the reproductive season.

1146 Layne Sermersheim, Richard Thompson, Erin Lewis, Susannah French

Effects of roadway disturbances on Side-blotched lizard (Uta stansburiana) behavior and morphology

Human population growth leads to continued urbanization of both urban and rural landscapes. Anthropogenic disturbances affect the surrounding area at both micro and macro levels, which has the potential to alter life history strategies for the species existing there. Little work has focused on reptiles, but a few previous studies found detrimental effects of urbanization. Roads are a dominant urban feature that past research indicates are linked to elevated stress hormone levels and suppressed immunity in lizards, yet the impacts of roadways on lizard behavior and morphology are unclear. Behavior is often the first line of defense when animals are responding to challenges in their environment, and thus an important indicator. In our study population, an interstate bisects the population of Side-blotched lizards (Uta stansburiana), creating an ideal experiment to address whether relative distance of the individuals' home ranges from the interstate impacts easily quantifiable behaviors and morphology. Per individual, we observed in situ behavior for two minutes, then introduced each into an arena where bold and exploratory behaviors were assessed. We then collected morphological data such as mass and obtained a blood sample for oxidative stress analysis. Lastly, environmental metrics like ambient temperature were recorded. By understanding the variation of behavioral responses and how they correspond to disturbances present in the environment, we can better predict how animals will adjust to urban development moving forward.

1851 Valeria Serna-Solis, J Garcia-Israel, C Paredes-Amaya, Brandon Hedrick, Rachel Keeffe, Patricia Brennan

Modularity and integration of copulatory structures in male Ratfish, Hydrolagus colliei

Genitalia are one of the most diverse structures in nature. Different evolutionary processes, such as natural and sexual selection, influence their diverse and complex morphology. A combination of these processes may operate simultaneously in genital structures on a single system because they can have multiple modules and different genes that are responsible for the phenotype development. Male spotted ratfish, Hydralogus colliei, have modular copulatory structures that function together to achieve copulation, these include 2 grasping structures (one on the head and one in the pelvic fin), and one intromittent structure (the claspers in the pelvic fin). We ask what the roles of ontogeny and function are in shaping the modular patterns and the integration among the components of these complex genitalia because they are unlikely to share the same development. We produced 3D models of each of the copulatory structures of adult and juvenile male ratfish and used a 3D geometric morphometric approach to study their allometric patterns, and their integration. While our analysis is still ongoing we find few intermediate morphologies, suggesting a sudden change between juvenile and adult copulatory structures, and possible high levels of integratio.

1445 Ivana Serra, Jeanette Wyneken

Mechanical behavior of sea turtle shells throughout ontogeny

The shells of turtles, formed of bone overlaid by keratin scutes, provide protections for the muscles, nerves, and viscera. The shell has long been perceived as a form of armor because of its shield like form and composite nature. Though this multi-layered structure seemingly serves a protective role, it is recent that the shell's mechanical properties have been investigated, and only in a few turtle species. The majority of this work focused on freshwater turtles and tortoises. Marine turtles receive relatively less attention though their natural history and shell form differ from the species studied. We investigated the mechanical properties of juvenile and adult green turtles (Chelonia mydas), loggerhead (Caretta caretta), Kemp's ridley (Lepidochelys kempii) and hawksbill (Eretmochelys imbricata) turtles shells. Carapace samples were mechanically tested to quantify stiffness (Young's modulus), yield strength and resilience [JW1] under quasi-static compression. Our data suggests that marine turtle shells are much less stiff than their freshwater and terrestrial counterparts. Flexibility likely reflects the pressure oscillations encountered while diving. Additionally, the juvenile life stage samples are highly compliant, deforming substantially under relatively low stresses. These ontogenetic differences may result from gradual changes in the boney microstructure. Variation also exists between species with C. mydas and E. imbricata having much stronger and tougher shells, respectively, than the other species tested. Morphological and ecological differences among species likely drive this interspecific variation.

61 Ryan Sesler, Lisa Whitenack

The Art of Biting: The Effects of Wear on the Morphology and Puncture Force of Shark Teeth

Over their lifetime, sharks constantly replace thousands of their teeth. Previous studies have shown these teeth are mechanically strong, resisting tooth breakage. Therefore, this tooth replacement frequency could be due to tooth wear, not tooth failure. The purpose of this analysis is to quantify the impact tooth wear has on tooth morphology and biting performance. We examined teeth from six species of shark: Carcharhinus plumbeus, C. leucas, C. limbatus, Sphyrna mokarran, Isurus oxyrinchus, and Negaprion brevirostris. Each tooth punctured a standard fish prey item 400 times. The force required for puncture will be recorded every 10 to 30 punctures, followed by microscopic imaging of the tooth and cutting edges. Preliminary testing has shown that for all teeth, visible tooth wear occurs, and puncture force increases across 400 punctures. However, the rate of wear varies with location on the tooth and species. Similarly, forces required for puncture increase anywhere from 10.6 to 19.1 N, varying with each species. These data indicate that even minimal wear may affect tooth performance and therefore the ability of sharks to process prey if teeth are sufficiently dull. However, more studies are needed regarding tooth replacement rates and how many bites teeth are used for prior to shedding to truly understand the link between tooth wear and tooth replacement.

343 Anusha Shankar, Kenneth Welch

Introduction: Daily torpor across birds and mammals: Recent progress and how do we advance the field

Animals that experience energy unpredictability or scarcity have evolved diverse behavioral and physiological strategies to survive these challenges. One such strategy is the use of daily torpor, which is an energy saving mechanism that animals use to minimize metabolic expenditure for a few hours at a time by lowering their metabolic rates, heart rates, and/or body temperatures. Historically, studies focused more on hibernation (multi-day torpor, e.g., used by ground squirrels and bears) than on daily torpor (used by many mammal and bird species). Speakers will present the current state of knowledge on daily torpor and discuss the main unanswered questions in the field. Symposia speakers study diverse taxa from across the globe (tenrecs to primates, hummingbirds, and bats; in Africa, North and South America, Asia, Europe, and Australia). They also study a diversity of conditions under which daily torpor is used: during reproduction, migration, in fire-prone landscapes, at high temperatures and very low temperatures, and in the face of disease. Given the diversity of study systems, many different approaches, measures, and techniques have been developed to study torpor, resulting in a lack of consensus on common metrics to facilitate comparisons across taxa. Very little is known about the physiological or genetic mechanisms underlying daily torpor use. Our goal is to foster a discussion and share knowledge on progress about daily torpor across study systems.

347 Anusha Shankar, Kenneth Welch

Round table discussion: Pressing problems in daily torpor and how to advance the field

Our comparative understanding of daily torpor has flourished with the use of emerging technologies and approaches, including more field-ready methods for measuring metabolism or temperature, increased miniaturization of bio-loggers, and more robust techniques for non-invasively measuring body condition and composition. The diversity of animals, study approaches, and questions about torpor use has led to a variety of frameworks with which to describe or quantify torpor. Further, there is rarely much cross-talk between people who study mammal torpor and those who study bird torpor, or between these physiologists and neuroscientists or geneticists. These factors, we argue, act as barriers to accelerating our understanding of daily torpor. Our goals during this discussion will be to explicitly (1) summarize how this field has advanced in the last 10 years, (2) come up with potential ways to promote consistency and harmony in the definitions, and quantifiable parameters used, to evaluate torpor, (3) identify where the field is headed in the next five and 10 years, (4) brainstorm ways to integrate methods and ideas to push the envelope in the study of daily torpor, and (5) discuss the potential applications of daily torpor in fields such as biomedical science (e.g., for induced hypothermia for surgeries) and space travel (e.g., suspended animation or induced hibernation).

354 Anusha Shankar, Emily Blackwell, Sophia Wolfe, Shenni Liang, Nora Prior, Irby Lovette, Donald Powers

Hold and cold hummingbirds: What genes does a cold hummingbird functioning at 10% express?

Heterotherms are endotherms that can lower their body temperature and metabolic rate to save energy. This strategy, called torpor, is especially useful under challenging environmental conditions. Though we know something of the genetic pathways involved in mammalian torpor, we know nothing of the genetic mechanisms that allow bird torpor users (at least 40 species) to cool and rewarm. We used metabolic rates and surface temperatures to identify the metabolic state of Anna's hummingbirds (Calypte anna) at night. We then euthanized six birds in three metabolic states from normothermic sleep to deep torpor and collected tissue samples to assess gene expression levels in the heart, liver, lungs, gut, skeletal muscle, and four brain regions. Across all non-brain tissues, we found 70 genes significantly upregulated in torpor relative to normothermy, and 116 significantly downregulated (adjusted p-value < 0 .05, log2-fold change ± 0.58). The upregulated pathways involved circadian rhythm, blood pressure regulation, and FSH signaling pathways, while keratin metabolism, and essential aromatic amino acid biosynthesis were downregulated. In the brain tissues, we found 38 genes significantly upregulated in torpor and 71 genes downregulated (same thresholds as above). The genes upregulated in the torpor brain related to circadian rhythms, blood coagulation, inflammation, and oxygen homeostasis, while downregulated pathways involved the cell cycle, DNA damage checkpoints, and heat and energy production. Next, we will compare these pathways with those in mammals.

263 Nicholas Shankey, Taylor Grossen, Rachel Cohen

The effects of melatonin on reproduction in breeding green anole lizards (Anolis carolinensis)

Seasonally breeding animals such as the green anole lizard (Anolis carolinensis) exhibit drastic differences in morphology, physiology, and behavior between breeding states. For example, non-breeding lizards exhibit regressed gonads, low sex hormone levels, and decreased reproductive behaviors when compared to breeding lizards. The transition between breeding and non-breeding states in green anoles is largely due to changing environmental cues, including lower temperatures and shorter photoperiods. Generally, shorter photoperiods result in higher melatonin secretion by the pineal gland and, although previous work supports the notion that melatonin secretion as a factor in regulating reproduction, it remains unclear what function this hormone may have in regulating breeding transitions in anoles. To address this, male and female anoles were treated with melatonin or blank capsules inserted subcutaneously during the early breeding season (April). Lizards were maintained under breeding-like environmental conditions for 5 or 10 weeks and examined for various reproductive outcomes. Preliminary results revealed no significant differences between treatment groups in the weight or gonadosomatic index of testes ($F(3,32)$ 0.209) or ovaries ($t11$ 0.705). This result could indicate that melatonin alone is not sufficient to induce non-breeding-like morphological changes in the gonads. We continue to conduct analyses on reproductive behavior, morphology, gene expression (including melatonin receptors), and steroid hormone levels. This data may provide further insight into the mechanisms that signal reproductive changes across seasonally breeding vertebrates.

1664 Joel Sharbrough

The consequences of whole-genome duplications for cytonuclear stoichiometry

The plant genome is partitioned across three distinct cellular compartments: the nucleus, mitochondria, and chloroplasts. Interactions between nuclear-encoded gene products and those of cytoplasmic genomes (i.e., cytonuclear interactions) underlie the essential cellular processes such as respiration and photosynthesis. Whole genome duplication events are a prominent process of diversification in eukaryotes and are expected to perturb cytonuclear interactions in two fundamental ways: altering the genetic stoichiometry of cytonuclear interactions and increasing cell size. Polyploid lineages are therefore expected to exhibit altered organelle size, organelle genome copy numbers, cytonuclear transcriptomic and proteomic stoichiometry, and, as a consequence, photosynthetic and respiratory capacity. We tested this hypothesis at the genomic and transcriptomic levels, finding that both monocot and eudicot polyploids exhibit elevated cytoplasmic genome copy numbers compared to diploids, allowing cytonuclear transcriptomic stoichiometry to remain balanced following increases in ploidy. To characterize the genomic architecture of how the plant cell modulates cytonuclear stoichiometry, we tested for associations between the ratio of chloroplast:mitochondrial:nuclear sequencing reads and genome-wide variation present in the Arabidopsis 1001 genomes project. Taken together, our results indicate that polyploids appear to compensate for increased nuclear genome content with increased organelle genome copies in both monocots and dicots, indicating that cytonuclear stoichiometry is an important component of successful interactions between nuclear and cytoplasmic genomes.

631 Tushar Sharma, David Cannatella

Breaking Dollo's Law? Evolution of developmental modes in Marsupial Frogs

Phylogenetics can identify patterns of change in characters through ancestral state reconstruction. However, these methods may appear to reach a definitive conclusion, ignoring the presence of gray zones. The Marsupial Frogs (Gastrotheca) include 77 species found in Panama and most of South America, ranging from 500 to >4500m meters. Most species occur in the Andes. Frogs have a plethora of reproductive strategies, and Gastrotheca are unique in having a pouch on the female's dorsum in which they brood fertilized eggs. These are born as either free-living tadpoles (indirect development) or as froglets that bypass the tadpole stage (direct development). The distribution of the two modes is highly phylogenetically labile, and it has been claimed based on ancestral state reconstruction that direct development (froglets) has reverted multiple times to the tadpole stage within Gastrotheca. However, alternatives have not been considered in a nuanced fashion. Here we re-examine the evolution of reproductive modes in a statistical phylogenetic framework using mitochondrial and nuclear DNA sequence data and updated phenotypic data from most species. We discuss how Marsupial Frogs can contribute to future considerations of the efficacy of Dollo's Law. This paper is dedicated to the late David B. Wake in memory of his boisterous discussions with DCC about the evolution of reproductive strategies in amphibians.

1692 Prashant Sharma

Impacts of gene duplication on body plan disparity in Chelicerata

The advent of genomic resources for Chelicerata in the past ten years has revealed that the evolution of chelicerate genomes is more dynamic than previously thought, with multiple waves of ancient whole genome duplications affecting separate lineages. Principal among the evidence for these ancient genomic events are the number and organization of the Hox clusters in different chelicerate orders. Reconstructing the evolution of chelicerate genome duplications has proven challenging, owing to taxonomically incomplete datasets as well as the difficulty of inferring chelicerate higher-level phylogeny. While revitalized study and sampling of poorly studied lineages has aided in closing some of these knowledge gaps, the overall impact of whole genome duplications on chelicerate evolution and development remains imperfectly understood. Here, I review functional datasets for evidence of subfunctionalization or neofunctionalization in taxa that exhibit systemic paralogy of developmental patterning genes. This examination focuses on data from two focal model taxa, the spider Parasteatoda tepidariorum and the harvestman Phalangium opilio, as well as expression data from satellite models. I contend that evidence for sub- or neofunctionalization of duplicated developmental patterning genes in spiders is indirect or fragmentary at present, despite the appeal of this postulate for explaining the success of groups like spiders. Overall, available expression data suggest that the condition of duplicated Hox modules may have played a role in promoting body plan disparity in some chelicerate orders.

408 Allison Sharp, Jean Ross, Vikram Iyengar

Eat, Prey, Love: Sex influences nest intruder behavior in the maritime earwig

The most common form of parental care in insects is the guarding of eggs/juveniles from intruders. The maritime earwig (Anisolabis maritima), an insect found on beaches worldwide, is an excellent organism for studying parental care because they are found in high densities under driftwood during the breeding season. As a result, egg-guarding mothers encounter many types of intruders and are especially threatened by conspecifics that often cannibalize eggs. We studied how sex affects nest intruder behavior by monitoring the behavior of size-matched intruders of different sexes in an arena with a mother and her eggs over twelve hours. The time-lapse videos were then uploaded to BORIS behavioral scoring software, where we scored the number and durations of invasions, cohabitations, attacks, courtships, and matings. We found many differences in behavior based on the sex of the intruder, as males invaded the nest more frequently and remained in closer proximity despite vigorous nest defense by the mother. Overall, we found that female intruders were much less aggressive than predicted, and that male persistence to return to the female's shelter is key to receiving a high number of matings. Our study is the first to monitor these intimate interactions in the maritime earwig, and our results suggest that mothers may protect their eggs and appease male intruders by mating with them.

1018 Sam Sharpe

Developing LGBTQIA+ Inclusive Biology Classrooms and Curricula

Oversimplified understandings of biological sex and gender are often deployed both in STEM classrooms and as a political tool to invalidate the existence of queer, transgender, and intersex individuals. This rhetoric discourages LGBTQIA+ students from continuing in these fields, reaffirms harmful misconceptions about human sex, gender, and sexuality in both these students and their heterosexual, cisgender peers, and neglects the true and extraordinary diversity of life on earth. As scientists, educators, and communicators, we have the opportunity to increase the inclusivity of our research, classrooms, and curricula by exploring and challenging these misconceptions. Although biology education is often presented as value-neutral and divorced from culture, without understanding how eugenics and white supremacy have influenced historical understandings of biological sex, we cannot effectively challenge the biased and binary misunderstandings of human diversity that developed as a result and remain widespread. By incorporating and exploring the diversity and complexity of sex, gender, and sexuality in human biology and across taxa, we can instill in our students and audiences an understanding that biology can serve as a source of empowerment for, rather than invalidation of, queer, transgender, and intersex individuals. Such efforts can play a crucial role in increasing retention of LGBTQIA+ students in STEM and encourage innovative research and science communication exploring sex, gender, and sexuality across taxa.

1807 Sam Sharpe, Kelsey Lewis

Sex, Science, and Society

Individuals who may not fit European colonial ideas of dichotomous male or female bodies, those who are intersex, have been known across cultures and throughout human history. Unfortunately, acknowledgement of and engagement with this aspect of human biological diversity and the ongoing impact of binary misunderstandings of sex have been largely contained within the humanities and social sciences, while sex diversity beyond the male female binary has been either ignored or pathologized in the medical and biological sciences. The perceived social threat of intersex variation to the sex and gender binary has led to institutional and medical regulation of intersex people's bodies, which has been the subject of increasing spotlight recently. Given the historical and ongoing role of the biological sciences in the pathologization of human sex variation and the deployment of medical technologies attempting to suppress this variation, we must actively acknowledge that our work does not exist and is not produced in a vacuum. Biological data demonstrate that sex is diverse and variable in animals, plants, and fungi. Despite this, the paradigm of binary sex has labeled diverse and variable sex as anomalous, especially in human populations. It is far past time to address this paradigm by actively examining the ways that our research, teaching, and communication engage with, articulate, and make legible particular narratives of sex diversity and variation.

1447 Anna Shattuck, Caz Taylor, Alex Gunderson

The effect of infection on thermoregulatory behavioral fever of monarch butterfly caterpillars

Monarch butterfly (Danaus plexippus) populations in the United States are in decline for several reasons, one of which being infection caused by Ophryocystis elektroscirrha (OE), a protozoan parasite. Monarchs in the Gulf South are commonly infected by high levels of OE and have also altered their migratory behavior to remain settled. Ectothermic organisms can respond to parasitism by displaying behavioral fever where an infected individual acutely changes its thermal preference, usually for high temperatures, to favor immune response and thus promote survival. No experiment has yet tested thermal preferences of monarch caterpillars or if thermal preference varies based on infection status. We hypothesize that monarch caterpillars parasitized with OE will favor warmer temperatures to mitigate infection outcomes and increase survival. To do this, we placed caterpillars in a photothermal gradient and measured body temperature using a thermal imaging camera over a set time interval. Preliminary results show that monarch caterpillars prefer temperatures near 33°C, and also suggest an increase in preference temperature as caterpillars grow towards pupation. This work not only elucidates the thermal preferences of monarch caterpillars, but also explores how thermoregulatory behavior might allow for infected monarch caterpillars to survive with a reduced parasite burden into adulthood.

819 Daniel Shaykevich, Daniela Pareja-Mejia, Lauren O'Connell

Spatial cognition in the cane toad (Rhinella marina)

Studies of amphibian navigation often focus on species that display life-history traits implying advanced navigation capabilities, such as tadpole-transporting poison frogs and pond breeding toads. However, other amphibian species can also perform navigation tasks, suggesting spatial abilities are more widely spread than previously considered. Furthermore, although spatial cognition is supported by the hippocampus in mammals, little is known about the neural basis of amphibian navigation. We use the cane toad (Rhinella marina), a common, non-territorial species to identify sensory mechanisms and brain regions supporting spatial cognition. Our previous work with cane toads in their native range suggests toads can navigate home from long distances. Here, we built on this work and conducted field-based translocation studies in their invaded range on Oahu. We found that toads can navigate back to their home range after being moved up to 1000 meters, suggesting advanced navigational abilities. In addition, we piloted ablation studies targeting olfaction and magnetoreception and studied their effect on homing, with our results suggesting multi-modal models of navigation in cane toads. Additionally, we collected brains to compare activity in the medial pallium and other brain regions to determine the neural signature of homing behavior, using phosphorylated ribosomes as a marker of neural activity. Combining field based behavioral studies with laboratory analyses of brain activity allows us to better understand how the amphibian brain governs natural behaviors.

939 Kimberly Sheldon

Behavioral plasticity of dung beetle species in warmer, more variable temperatures impacts fitness

Temperature strongly affects insect development, but plasticity of adult reproductive behaviors can alter the temperatures experienced by earlier life stages. To date, few studies have tested whether adult behavioral plasticity can protect offspring from the warmer, more variable temperatures linked to climate change. Here I discuss laboratory experiments and field manipulations in which my lab has examined whether the adults of three dung beetle species modify their breeding behaviors in response to increases in temperature mean and variance and whether these behavioral shifts can protect dung beetle offspring from temperature changes. Tunnelling dung beetles lay their eggs inside brood balls constructed of dung that are buried below the soil surface. The depth of the brood ball affects the temperatures that the offspring experience and, thus, offspring development. Based on lab and field studies, all three species placed brood balls deeper in the soil in response to warmer and more variable temperatures, but for some species, the greater burial depth came at a cost to brood ball size and/or number, which can impact fitness. Despite greater burial depths, offspring in brood balls in the heated treatments still experienced warmer mean temperatures, which had a large, negative effect on offspring survival of the species with the smallest body size. These findings suggest adult behaviors could partially shield developing offspring from temperature changes.

1569 Analisa Shields-Estrada, David Cannatella

Near-infrared reflectance as a thermoregulatory mechanism in Hyla tree frogs

Investigating patterns of ecological selection and pinpointing resulting thermoregulatory phenotypes in species most at risk of extinction, is paramount to our understanding of how species will fare in a rapidly changing climate. One important thermoregulatory phenotype is color (i.e., visible spectral reflectance). Adaptive variation in color reflects a suite of organismal specific traits and behaviors mediated by natural and sexual selection pressures. The role of color in signaling has been studied extensively; however, how color influences thermoregulation, specifically in taxa with color-specific competing selection pressures, and the roles of other reflection spectra (i.e., the near infrared), have been largely ignored. Our work examines the adaptive role of visible and near-infrared spectral reflectance in Nearctic tree frog (Genus Hyla) thermoregulation. We measured warming tolerance of four species of hylid inhabiting diverse microclimates across Texas and recorded spectral reflectance measurements and photographs in the visible (400-700nm) and near-infrared spectra (700-1100nm) to assess how spectral reflectance mediates thermoregulatory ability in these frogs. All four species demonstrated significantly increased visible or near-infrared reflectance in response to increased environmental temperature. This is the first evidence to photograph and quantify frogs using real-time changes in visible and near-infrared reflectance to thermoregulate. This work identifies an understudied thermoregulatory mechanism in tree frogs and highlights the importance of identifying how species might persistence in an increasingly changing and unpredictable climate.

1022 Erin Shilling, Ashley Carreiro, Ian Combs, Joshua Voss

Efficacy of stony coral tissue loss disease intervention and impacts on coral microbial communities

Since 2014, stony coral tissue loss disease (SCTLD) has spread from Florida to multiple Caribbean coral reefs. These disease outbreaks have triggered mass mortality events in many regions with some northern sections of Florida's Coral Reef experiencing up to 83% mortality. We investigated the effectiveness of SCTLD intervention treatments in situ and considered the impacts of these treatments on corals' surface mucus microbial communities. SCTLD-affected Montastraea cavernosa colonies offshore of Broward County, Florida were tagged and divided into three treatment groups: 1) chlorinated epoxy, 2) CoreRx/Ocean Alchemists Base 2B plus amoxicillin, 3) untreated controls. A fourth set of untreated, healthy colonies were included as well. Results from tracking of both lesion progression and healthy coral tissue surface area remaining over an 11-month period indicated that the amoxicillin treatment is effective for healing individual lesions and preserving coral tissue. However, this treatment does not necessarily prevent the development of new lesions. The chlorinated epoxy treatment provided no significant benefit to corals. We used 16S amplicon sequencing to examine effects of treatments on associated microbial communities. Analyses of this sequence data will elucidate how treatment impacts the diversity and abundance of different microbial groups in the coral surface mucus layer. This integrative approach will both provide data to improve management of coral disease outbreaks as well as contribute to overall knowledge regarding coral health.

1742 Seth Shirazi, Timothy Higham

Why do fish miss? Attack strategies of threespine stickleback capturing non-evasive prey

All predators need to successfully capture prey to survive, yet failure is frequently observed. What makes a predator miss? Suction-feeding fishes must approach prey in such a way that their mouth is within the appropriate distance for suction to be effective. The prey can evade the predator, but the predator might also miscalculate the attack. We addressed the latter using threespine stickleback as predators and blood worms (non-evasive) as prey. High-speed videography of the entire attack allowed us to determine which strike tactics resulted in successful or failed strikes. We obtained over 250 feeding trials from over 50 individuals, and analyzed the relevant kinematics and behaviors observed during prey capture. Behavioral variation was considerable. Some individuals swam quickly from relatively long distances (e.g. >25 cm), whereas others would only initiate an attack when the prey was very close to its mouth (e.g. < 2 cm). Our data show clear differences between missed and successful strikes, with potential tradeoffs underlying those trends. 30% of individuals missed at least once, with failed strikes making up approximately 10% of all strikes. In addition, repeated strike experience resulted in strike success improvement, which may indicate that predators can acclimate to environmental stimuli during predator-prey interactions. A key driver of failed strikes involved incorrect timing of suction, often initiated too far for suction to be effective.

208 Caleb Short, Paul Moore

Degradation of signals in forested environments: changing habitats and songbird communication

Vocalizations are the primary mode of communication by birds and offer birds the benefit of communication over long distances without direct line-of-sight between the receiver and sender. As sound moves through an environment, the structures of the vocalizations are subject to alterations by the environment itself through reflection, absorption, and refraction. For birds calling in forested habitats, ground cover and trees are structural elements that alter vocalizations. Frequencies may shift or degrade based on the changes imposed on the environment. We tested the effects of vegetation within forested environments on frequencies used by birds to determine what vegetative structures within forests contribute most to the alteration of auditory cues. We used a digital game call to produce pure tones commonly used by songbirds, and a Zoom handheld recorder to record the produced tones. We produced and recorded pure tones in three different forested habitats; Northern Hardwood Forest, Conifer swamp, and Boreal Forest. In each habitat we recorded at different distances from the pure tone transmitter. We also measured vegetation along the transect including overstory, understory, groundcover, and leaf density. Fast Fourier Transformations were implemented to track changes in the pure tones as distance and vegetation between the transmitter and receiver increased. Our principal component analyses of the FFTs found that degradation of lower frequencies increased as basal area as well as understory density increased.

681 Bikram Dhoj Shrestha, Santhan Chandragiri, Vivek Prakash

Confinement effects on fluid flows generated by marine larvae

Many marine invertebrates are indirect developers and have ciliated larval stages with different morphologies during their development (e.g., echinoderms). It is well known that these larvae utilize ciliary beating for swimming and feeding. However, studying the fluid flow-fields generated by these larvae is challenging using standard microscopy techniques. The larvae have natural three-dimensional (3D) flow-fields that can be quite complex, and the standard microscopic imaging configuration involving a glass slide and cover slip induces a two-dimensional (2D) confinement. Here, we systematically quantify the fluid dynamical effects of 2D confinement of a 3D micro-swimmer at low Reynolds numbers using quantitative experiments. We observe changes in the vortex size and intensity with variation in confinement. Our goal is to provide guidelines and best practices for 2D confinement imaging experiments, and our results will be broadly applicable for a variety of ciliated micro-swimmers.

1472 Cassie Shriver, Dylan Scott, Isha Palakurthy, Grace Hansen, Steve Place, David Hu, Andrew Schulz

Creating Interdisciplinary Conservation Tools: A Case Study on Vaccinating Urban Wildlife

Urbanization is causing rapid growth in the density of human populations and the amount of food to be scavenged within city limits. Coupled with the loss of the surrounding natural habitat, the abundance of negative human-wildlife interactions is increasing and, consequently, the transmission of zoonotic diseases such as rabies and tuberculosis. Traditional methods to vaccinate susceptible populations often involve dropping oral vaccine biscuits from planes, but these are not feasible for urban settings. In this project, we propose a novel vaccination method for urban wildlife: an automated oral vaccine biscuit dispenser. This solution uses machine learning and object detection to enable continuous, real-time identification, monitoring, and vaccination for different target species. A motion sensor camera, image classification, and edge computing determine if the target species is in close proximity, triggering a rotating mechanism to dispense a biscuit. To demonstrate the viability of the dispenser, we targeted foxes for rabies vaccine biscuits on a university campus. These populations are prone to eradication efforts when rabies outbreaks occur, so novel tools to preventatively vaccinate them in urban settings will directly aid conservation efforts. The reproducible and robust design enables applications to a variety of urban settings for different target species and oral vaccines. However, this design would not be possible without collaborations between biologists, engineers, and computer scientists, and demonstrates the need for interdisciplinary conservation tools.

1659 Cassie Shriver, Margaret Zhang, Staci Wiech, David Hu, Young-Hui Chang, Joseph Mendelson, Andrew Schulz

Implementing a Zoo Biomechanics Day to Improve Public Outreach

Zoos are key institutions for educating the public on animal-related science and conservation initiatives. For academic researchers, effective collaborations with zoos also allow scientists to work with animals that may be otherwise difficult to access in the wild, greatly enhancing the scope of fields like comparative biomechanics. In order to better disseminate academic discoveries to the public, we implemented a biomechanics event with Zoo Atlanta. With the involvement of eight distinct labs from Georgia Tech, we created twelve distinct stations throughout the zoo each showcasing different species and themes. By partnering zoo staff and university researchers at each of these stations, the public could learn about everyday care and attributes of the animals in addition to ongoing biomechanics research, creating a comprehensive overview. To encourage complete exploration of the event, we also distributed bookmarks that could be stamped at each station. Finally, using surveys from the zoo, we measured visitors' opinions on the quality and engagement of the event to evaluate how successful the biomechanics day is for communicating science to the public.

605 Elizabeth Sibert, Monica Marion, Jacob Licht, Immanuel Bissell, Karly Cohen

Tiny Tooth Tales: A record of fish evolution from microfossil teeth preserved in deep sea sediments

Deep-sea fish have a remarkably rich microfossil record, in the form of isolated phosphatic remains: teeth from ray-finned fish and dermal denticles from sharks, together called ichthyoliths. These microfossils are present in nearly all sediment types, as they are highly resistant to dissolution, and preserve a high temporal resolution record of marine vertebrate evolution and community structure over the past 100+ million years. However, while ichthyoliths are perhaps the most numerically abundant fossil record of vertebrates, there are significant barriers to using them to study deep-sea fish evolution. A major challenge is that ichthyoliths are preserved outside of any traditionally used biological context: there are rarely body fossils of deep-sea species preserved with in-situ teeth for comparison. However, fish teeth do exhibit morphological change through time, and are a product of both fish diet and taxonomy. Thus, certain clades of fish exhibit unique tooth shapes and structures that allow their isolated microfossil components to be taxonomically identified. Here we draw on a new database of fish tooth morphology spanning the fish tree of life, to investigate the evolutionary history of several charismatic deep-sea fish clades. Further, as ichthyoliths are preserved alongside rich environmental proxy records within precisely dated sediment cores, we demonstrate that ichthyoliths can provide valuable insight into the timing of evolutionary events and their relation to changes in global climate.

1487 Amira Siddique, L Odette Herrand, Alyssa Stringer, Emily McParland, Courtney Orsbon, Peishu Li, Nicholas Gidmark

On the clinical relevance of comparative jaw joint biomechanics across mammals

Mammalian masticatory musculoskeletal anatomy is diverse and correlated with functional demands – e.g. processing various food types. One implication for such interspecific anatomical variation is that pathologies in the jaw-closing system could present differently across taxa. Disorders of the human jaw joint (termed temporomandibular disorders or TMD) afflict millions worldwide. Experimental studies of TMD utilize a wide range of model organisms (mice, rats, rabbits, sheep, pigs, and monkeys) with astounding variation in musculoskeletal form. Here we compare a wide variety of biomechanically-relevant musculoskeletal attributes across these model organisms. Specifically, we explore which of these attributes are similar and different to humans to determine which model organisms' jaw-closing system musculoskeletal anatomy most closely resemble humans'. Preliminary multivariate analyses show that TMJ skeletal anatomy of humans (e.g., fossa depth, eminence height, condylar angle, etc.) is most similar to sheep, pigs, and monkeys. Rabbit TMJ morphology deviates from that of humans via steeper and deeper articular eminences. Human jaw adductor anatomy most closely resembles monkeys and rats, with similar length and torque moments of all four main masticatory muscles. We hope these results provide clinical researchers a framework for selecting the most appropriate model organism when studying TMD.

1537 Usama Sikandar, Haritha Sigili, Simon Sponberg

A simple linear control template enables a hawkmoth's agile aerial tracking of floral targets

Hawkmoth Manduca sexta shows remarkable agility in tracking flowers oscillating up to 14 Hz. Their flower tracking response in this frequency range has been previously shown as empirically linear: the transformation between flower and moth positions obeys scaling and superposition, provided velocities are not saturated. To achieve this, the sensorimotor control of flight and the wing-body mechanics might each be either operating in a linear regime or forming a cascade of rather nonlinear dynamics that emerges as a linear system in closed loop. To test these alternatives that predict different challenges for sensorimotor and mechanical systems, we measured wing and body kinematics of 10 M. sexta specimens that were tracking robotic flowers oscillating at 0.2-9.7 Hz sum-of-sines of up to 3 cm/s. In our data, wing sweep and pitching angles show the most variation. Hence, a choice of left-right asymmetry between these kinematic parameters as the sensorimotor control signals renders both the sensorimotor system and wing-body mechanics linear. We then interpret these results through a nonlinear quasi-steady aerodynamic model to assess the effectiveness of linearization in this behavioral regime. Our findings imply that the hawkmoth's nervous system maintains the same linear control law to achieve the entire biologically achievable range of flower tracking. Although the underlying neural activity is spike-based, multimodal, and distributed over many muscles, the emergent dynamics constitute a simple control template.

1616 Gabrielle Silva, Elizabeth Borda, Jose Valdez

Species Diversity and Barcoding of Macroinvertebrate of the San Antonio River

Invertebrates are important biological indicators of health and ecological change within aquatic ecosystems. Macroinvertebrate diversity of the San Antonio (SA) River Watershed (Texas), which traverse rural and urban regions (Bexar County, TX), remains understudied compared to vertebrate counterparts of economic and conservation importance. The SA River hosts a diversity of crustaceans (crayfish), insects (beetles, dragonflies), annelids (leeches), and unidentified larvae at intermediate developmental stages. To improve ecological records of the SA River, an integrative approach will be used to establish a reference macroinvertebrate species inventory and a genetic barcoding database (mitochondrial COI and/or nuclear 18S rRNA) for the SA River Mission Reach restored site. In addition to standard barcoding approaches of individual specimens, both environmental and whole-organism community DNA extraction techniques will be employed. These data will improve the identification of (i) larva of varying developmental stages to adult forms; (ii) cryptic species; (iii) key biological indicators and (iv) macro- (and micro-) invertebrate community members. Establishing baseline data will also facilitate the identification of not easily detectable changes in macroinvertebrate diversity potentially attributed to urban disturbance and/or climate change.

1375 Claudia Silva-Rubio, Frank van-Breukelen

Tenrec ecaudatus: hypoxic and hypercapnic effects on aerobic metabolism

Common tenrecs (Tenrec ecaudatus) hibernate socially in a sealed burrow ∼1 m below the ground. We believe tenrecs may be very tolerant of hypoxia and hypercapnia. We subjected tenrecs to progressively hypoxic or hypercapnic conditions. Active tenrecs have up to a 25-fold variation in resting oxygen consumption (V?O2) with values similar to a hibernating tenrec V?O2 up to values typical for most mammals. Regardless of ambient temperature (Ta; 16 or 28°C), tenrec resting V?O2, body temperature (Tb), and heart rate (HR), normally associated physiological variables, were somewhat independent of each other. However, tenrecs constrained and depressed V?O2 at 4% O2, 7% O2, and 10% CO2 when animals were acclimated to 16°C. Subsequent recovery of V?O2 in normoxia and normocapnia was highly variable. Interestingly, this depression of V?O2 was not predictably associated with changes in HR and Tb at 16°C. Tenrecs acclimated to 28°C do not significantly alter V?O2. Numerous anatomical and physiological characteristics suggest that tenrecs may represent an ancestral placental mammal. One questions then, if the variable nature of these hypoxic and hypercapnic responses reflect poor homeostatic control in the ancestral condition.

1039 Monique Simon, Priscila Rothier, Colin Donihue, Anthony Herrel, Jason Kolbe

Can extreme climatic events induce shifts in adaptive potential?

Multivariate adaptation to climatic shifts may be limited by trait integration that causes genetic variation to be low in the direction of selection. However, strong episodes of selection induced by extreme climatic pressures may facilitate future population-wide responses if selection reduces trait integration and increases adaptive potential (i.e., evolvability). We tested this hypothesis in two populations of the lizard Anolis scriptus that experienced hurricane-induced selection on limb traits. We surveyed populations immediately before and after the hurricane as well as the offspring of post-hurricane survivors, allowing us to estimate both selection and response to selection on key functional traits: forelimb length, hindlimb length, and toepad area. Direct selection was parallel in both islands and strong in several limb traits. Even though overall limb integration did not change after the hurricane, both populations showed a non-significant tendency toward increased evolvability after the hurricane. The population with comparably lower between-limb integration showed a less constrained response to selection. Hurricane-induced selection, not aligned with the pattern of high trait correlations, likely conflicts with selection occurring during normal ecological conditions that favors functional coordination between limb traits, and would likely need to be very strong and more persistent to elicit a greater change in trait integration and evolvability. Future tests of this hypothesis should use G-matrices in a variety of wild organisms experiencing selection due to extreme climatic events.

893 Molly Simonis, Megan Rúa, Lynn Harztler

Torpid metabolic rates of Eptesicus fuscus are additive and increase following pathogen invasion

Host resistance to pathogens can alter temperature-dependent relationships of energy expenditures and cost additional energy for birds and small mammals. For small mammals that hibernate, offsetting additional energy expenditures is challenging when food is scarce in winter months. To determine how host resistance to a pathogen alters energy expenditures, we measured torpid metabolic rates across a wide range of ambient temperatures on big brown bats (Eptesicus fuscus), a North American bat species that has some degree of resistance to the invasive fungal pathogen, Pseudogymnoascus destructans (Pd). We collected big brown bats nine and ten years following the introduction of Pd to ensure long-term pathogen exposure. We compared metabolic rate data in these bats post-Pd to data published prior to Pd introduction (pre-Pd). While big brown bat torpid metabolic rates pre-Pd remained independent of ambient temperatures, torpid metabolic rates post-Pd had additive effects and were non-linear with ambient temperatures. Additionally, big brown bats had greater torpid metabolic rates post-Pd than pre-Pd at skin temperature setpoints below 37 ?. These results suggest that big brown bat torpid metabolic rates are altered with long-term Pd exposure and their resistance to Pd costs additional energy while torpid. Future research should investigate temperature-dependent regulatory mechanisms for big brown bats' resistance to Pd infections, and consequences for how additional energy expenditures may contribute to host survival with long-term pathogen exposure.

814 Lauren Simonitis, Adam Summers, Amani Webber-Schultz, Aubrey Clark

Nosy About Noses: using biovisualization techniques to study Chondricthyan nasal morphology

Cartilaginous fishes have a diversity of olfactory morphologies which will affect both the water flow and sensitivity of the olfactory organ. For instance, in hammerheads, different areas of the olfactory organ experience different water velocities: the highest velocities are found in the center with decreased water velocities at either end. Similarly, the central olfactory lamellae have a higher surface area devoted to sensitivity than the lamellae at either end. This raises an interesting possibility - perhaps patterns in sensory morphology are related to water velocity, affecting the range of sensitivity of a particular region of the rosette. A somatotopic mapping of the sensory epithelium could then transduce a wide range of stimulant dilutions. The particulars of flow are known from a computational model of the smalleye hammerhead (Sphyrna tudes). The more than 900 species of cartilaginous fishes gives us a fertile field to apply similar computational models, or less computer intensive physical models, to understand variation in flow. We use contrast-enhanced computed tomography (CT), scanning electron microscopy (SEM), and histology to build computer-aided design (CAD) models of cartilaginous fish noses. These physical models can then be used in a flow tunnel to examine the effects of speed, angle of attack, and morphology of the nares of flow through the lamellae. Our physical model can be terated across the diversity of chodrichtian noses to reveal functional implications of morphological diversity.

1068 Meagan Simons, Delbert Green

Seasonal plasticity and population specific adult brain development in monarchs

Long distance migration plays a critical role in Monarch survival, yet we lack a holistic understanding of its mechanisms. In particular, previous work has shown that adult brain development seasonally differs, depending on migratory state; within North American populations, migratory monarchs have larger sun compass neuropils than non-migratory monarchs. However, we do not know to what extent neurological plasticity exists across migratory and non-migratory populations. Investigating plasticity in adult neurological development is a powerful elucidator in how adult brain development impacts and contributes to migration, and to what extent do all monarchs have the neural capacity for this plasticity. To investigate the role of neurological plasticity during adult brain development, we reared migratory and non-migratory populations outdoors in summer and fall before analyzing 'younger', naïve and 'older', experienced brains post pupal eclosion. We use a combination of imaging techniques to obtain volumetric data on brain regions believed to be critical to migration. From these analyses, we intend to describe neurological plasticity in the development of migratory and non-migratory brains, to provide key insight into the neurodevelopmental mechanisms of migration.

1311 Sarah Simons, Heather Rice, Charles Lacy, Kriti Shukla, Dylan Barber, Samah Houmam

Investigating cell-surface binding of sAPPα mutants to GABABR1a

Amyloid precursor protein (APP) is known for its amyloidogenic derivative amlyoid beta, the aggregation of which constitutes plaques seen in patients with Alzheimer's disease. An early phase clinical trial is aimed at reducing APP levels by RNAi. Therefore, it is critical to understand the normal functions of APP in the brain. APP is also processed to release secreted APP (sAPP). sAPPα, a non-amyloidogenic product of APP processing, was identified in Rice et al. as a ligand to GABABR1a, a subunit of the GABA B receptor. GABABR1a is suggested to be involved in APP-mediated synaptic inhibition and binds to the extension domain of sAPPα. We designed alanine substitution mutations in the extension domain of APP that are predicted to disrupt sAPPα binding to GABABR1a. We tested whether these mutations disrupt binding of sAPPα to GABABR in a cell based assay. HEK293 cells were transfected to express the GABABR1a or GABABR1b ectodomain on the plasma membrane using the pDisplay vector. The cells were treated with sAPPα-Fc, sAPPα-Fc mutants, or Fc protein (as negative control), and then immunostained to detect bound protein. The cells were imaged with fluorescent microscopy to determine binding efficacy. We found a significant decrease in binding of the sAPPα mutants to GABABR1a. These findings will be used to develop a novel mouse model to study the function of APP in vivo.

1822 Julie Simpson

Mechanosensory cues contribute to the fly grooming sequence

When a fruit fly is covered in dust, it senses debris through activation of external mechanosensory bristle neurons and coordinates different leg movements to clean itself in an anterior to posterior progression using body sweeps and leg rubs. We are mapping out the neural circuits that underly grooming from sensory detection to motor control with behavioral screens, neuroanatomical data from genetically-targeted neurons imaged by confocal microscopy, and electron microscopy connectome reconstruction. We focus on circuits that compare mechanosensory stimulus intensities across body parts, since our optogenetic competition experiments showed that these computations are important for the fly to select where to clean first. Brief optogenetic activation of some mechanosensory neurons – but not all – results in sustained grooming responses. We are testing a potential role for dopaminergic neurons in this productive persistence. Limb tracking shows that grooming flies move their legs rhythmically: both central pattern generators and mechanosensory feedback loops may contribute. Connectivity and behavioral analyses reveal evidence for both. The circuits that perform sensory comparisons and modulate motor patterns may contain connectivity motifs shared with other nervous systems.

1216 Megan Sims, Emily Rose, Heather Mason

Developing a new mark-recapture field survey technique for monitoring coastal pipefish populations

The Gulf pipefish, Syngnathus scovelli, is an excellent flagship species for monitoring the impacts of coastal anthropomorphic disturbances but relatively little is known about their home ranges, site fidelity, population sizes, and sex ratios in wild populations. This mark-recapture study utilized a novel approach consisting of 4 concentric 1.5 m circular plots (20 m diameter) at two sites within a continuous seagrass bed in Tampa Bay to compare current pipefish population dynamics to previously collected data and identify adult pipefish movement patterns. A total of 2,125 pipefish per 829.36 m2 were collected in August 2022. The current study yielded a mean recapture rate of 17.2% with an average of 2.5 days between mark and recapture events. Of those recaptured, 59.5% traveled within 5 m of their center release point suggesting possible site fidelity. Although the sites with similar seagrass coverage varied in average pipefish densities (North: 0.92 fish/m2 ± 0.19, South: 1.64 fish/m2 ± 0.30), there was no difference in recapture rates between sites indicating the new methodology is repeatable. The August population had a male-biased sex ratio (0.67) with 92.8% of males captured pregnant. Continued bi-monthly recapture surveys using this novel method will provide the first accurate S. scovelli population estimation using mark-recapture techniques and elucidate seasonal patterns in recruitment and reproduction.

668 Krishma Singal, Andrew Schulz, Michael Dimitriyev, Samuel Kirschner, David Hu, Claire Higgins, Elisabetta Matsumoto

Untangling the Collagen of Elephant Skin using Knitted Mimics

Elephant trunk skin consists of folds and wrinkles that enable the trunk to mechanically adapt to grasp or stretch while maintaining strength and flexibility. There are several properties of the skin that impact its properties including its constitutive collagen orientation, the ratio of wavelength to amplitude, and its thickness. We seek to both better understand and replicate the mechanics of the elephant trunk through a model system – knitted fabric. Knitting is a vastly unexplored method to create materials that are soft, durable, elastic, and programmable. There is room to explore its potential as a building block for bio-inspired materials. The elastic properties are dependent on how the yarn is manipulated, what types of stitches are formed, and how they are patterned. Based on the observed skin properties, collagen orientation, and stitch geometry, we fabricate knitted swatches that mimic the skin's folds and wrinkles. We study the mechanical response of our knitted model of elephant skin and compare it to experiments done on humanely sourced elephant skin. Our research opens the realm for programmable biomimetic knitted fabrics.

667 Sara Siwiecki, Lauren Mellenthin, Casey Dunn, Alison Sweeney

Ultra-soft ctenophore mesoglea and bulk extracellular matrix diversity in metazoans

Metazoans showcase an impressive diversity of specialized viscoelastic materials. These materials are usually made of bulk amounts of extracellular matrix (ECM) that is biochemically and biophysically tuned to form unique biomaterials. However, the evolutionary trends that led to this diversity are unknown. To start understanding biomaterial evolution in animals, we have focused on identifying the biochemical and material properties of ctenophore mesoglea. Ctenophores are one of our most distant animal relatives and their voluminous mesoglea is made of almost entirely ECM, thus providing invaluable information about bulk ECM evolution. To investigate the ctenophore bulk ECM, we isolated mesoglea from two ctenophore species: Mnemiopsis leidyi and Pleurobrachia pileus. Then, we used rheometry to subject the mesoglea to a range of deformations to measure their elastic and viscous moduli. We found that ctenophore mesoglea is remarkably soft compared to true jellyfish mesoglea and ECMs of other common marine animals. In fact, the viscoelastic moduli of ctenophore mesoglea are lower than 1 Pa on average compared to other marine animals who typically have viscoelastic moduli ranging from 10-100+ Pa. Given that ctenophore mesoglea is so soft, many questions remain about its biochemistry and how ctenophores are so resilient despite being so fragile. We are actively delving into further biochemical and biophysical analyses of ctenophore mesoglea and bulk ECMs from other metazoans to map the evolution of diverse metazoan biomaterials.

1633 Samantha Skerlec, Stephanie Bristow, Krista Ward, Clarke Burgert, Thomas Luhring

No free refills: the costs of pond drying to growth and survival of aquatic ectotherms

Climate change is increasing drought frequency and intensity leaving ecosystems with less time in between drying events to return to pre-drought conditions. Indeed, ecosystems around the world are increasingly operating out of a state of incomplete recovery from drying events, which are thought to cause long-lasting effects such as altered resource availability, changes to water quality and temperature, microhabitat suitability, etc. Our study investigates the impacts of incomplete recovery following a drying event on the growth and development of larval anuran tadpoles. Many studies investigate how larval amphibians respond to decreasing water levels, but few if any directly assess the carryover effects of past drying events on larval growth and survival after ponds have refilled. We used a 64-mesocosm array with a 2×4 factorial design to assess the impacts of 1) drying treatment (non-dry vs. dry-rewet) and 2) tadpole density (10, 20, 40, or 80 individuals per tank) to assess the effects of prior drying on growth, development time, and survivorship across realistic starting densities. Preliminary results show strong carryover effects from past drying events on larval amphibian growth, timing of metamorphosis, and survivorship. Our results also show strong effects of drying events on invertebrate predator guilds (e.g., larval odonates). We expect thinning effects in non-dried tanks across initial larval anuran density treatments that will be largely absent in previously dried tanks.

985 Alexis Slack, Christopher Anderson

A 3D puzzle of a human skull from CT scans as a physical model for pre-medical pedagogy

As the digitization of museum specimens becomes more widespread and access to affordable 3D printing technologies increases, the use of Computed Tomography (CT) technologies in biological research of anatomical features is well positioned to contribute to the advancement of pedagogical experiences through the creation of physical models for teaching. Such complementary efforts may enhance broader impacts associated with biological research in anatomy by simultaneously boosting the education system with a more hands-on experience for students and providing an alternative to expensive taxidermy and other artificial models. We have created a 3D puzzle of the skull of a human to aid in teaching human and comparative skeletal anatomy. After segmenting all the bones from the skull and the lower jaw, each skeletal element was individually 3D printed to create a disarticulated skull that students can learn to reconstruct. These prints were individually dip-dyed to color code different bones and small magnets are inserted into the printed components to enhance the overall learning experience. We used this 3D puzzle of a human skull in an upper-level anatomy course and surveyed the students about the effectiveness of this physical model in learning the bones of the skull. Following additional refinement, this model will be broadly disseminated to educators worldwide by uploading it to an online database with instructions on preparing the 3D puzzle.

307 David Sleboda, Anja Geitmann, Reza Sharif-Naeini

Multiscale functional morphology of a plant motor organ

Pulvini are motor organs that power active and reversible leaf movements in many plants. Pulvini operate without the specialized muscle tissues ubiquitous among animals, and instead effect motion through rapid modulation of cellular turgor pressure. How do pulvini translate cellular-level turgor variations into useful motion at the macroscopic scale of whole organs? To investigate this question, we used a combination of scanning electron and confocal microscopy to visualize the morphology of pulvini from the sensitive plant Mimosa pudica. At the ultrastructural scale of individual cell walls, we observed cellulose microfibrils and primary pit fields oriented perpendicular to the pulvinus long axis. At the cellular scale, we observed bellows-like cell geometries conducive to longitudinal cell deformation. At the tissue scale, we observed transversely oriented epidermal cells conducive to the formation of expandable surface wrinkles. These multiscale structural features are well situated to guide hydraulic deformation of pulvini, ensuring that turgor-induced expansion and contraction ultimately induces physiologically useful motion at macroscopic scales. Experimental manipulations of cell turgor provide support for this hypothesis, and we employ simple physical models of pulvinus morphology to illustrate the effects of structural constraints on hydraulic deformation. While pulvini are often cited as feats of biochemical specialization, our findings suggest that structural specializations spread across multiple hierarchical levels of organization are also crucial to the mechanism of pulvinus-driven plant motion.

1688 Katherine Slenker, Haley O'Brien, Lindsey Yann

Variance of Carotid-Rete-Mediated Selective Brain Cooling Across Aridity Indices

Species-environment interactions are integral to survivorship, especially when those environments test the extremes of organismal physiology. Large-bodied (>50kg) mammals, specifically artiodactyls and feliform carnivores, possess a specialized physiology known as carotid-rete-mediated selective brain cooling (CR-SBC), which has been established to provide a selective advantage in environments where water availability is limited and risk for dehydration is high. In this study, we investigate whether CR-SBC provides a release from physiological constraint imposed by the environment, specifically aridity. We model the range of variance in water metabolism, via a proxy of tooth enamel d18O values, across 1256 individuals from species that possess a carotid rete against those without from three different environmental categories – arid, dry subhumid, and humid – using a non-parametric ANOVA. The results of the analysis indicate there is a comparatively higher, and statistically significant, amount of variance of d18O values in mammals possessing the rete than those without, especially within arid climates, that begins to equalize as environmental water availability increases. Future studies investigating the physiological capabilities of the rete should focus on three primary areas of interest: 1) the relationship between CR-SBC and other osmoregulatory physiologies that evolved concurrently in artiodactyls, such as rumination; 2) the presence of CR-SBC in the fossil record of Artiodactyla via osteological correlates; 3) CR-SBC in Carnivora, both in extant taxa and in the fossil record.

882 Christopher Smaga, Samantha Bock, Matthew Hale, Benjamin Parrott

Environmental determinants and genetic pathways responsible for reproductive disorders in alligators

Exposure to endocrine disrupting compounds (EDCs) has negative consequences for reproductive health, yet the relevance of these exposures to ecological systems is not fully resolved. The alligator population at Lake Apopka, Florida is exposed to a suite of endocrine disrupting contaminants and displays disrupted ovarian phenotypes accompanied by broad scale transcriptional changes. Many of the EDCs present at Lake Apopka can activate nuclear estrogen receptors and our previous work revealed that treating embryos from a reference site with estrogen prior to ovarian differentiation recapitulates the transcriptomic and histological perturbations observed at Lake Apopka. Findings to date suggest that disrupting the timing of estrogen signaling may be a critical event in the etiology of EDC driven reproductive disorders in nature. However, we lack a basic understanding of the molecular pathways that are differentially impacted by the timing of embryonic estrogen signaling. Here, we compare ovarian transcriptomes of alligator embryos treated with estrogen or vehicle at two developmental stages critical for gonadal differentiation. We find more differentially expressed genes resulting from earlier exposure (139 vs. 108), with only 6 genes shared between timepoints. Additional comparisons between exposure times, functional characterization of estrogen influenced genes, and relation of timepoint differences to alterations seen previously at Lake Apopka is ongoing. Our results provide insight into how timing affects the molecular pathways influenced by estrogen, which is important for understanding.

288 Dimitri Smirnoff, Mary Guzowski, William Weber, Jessica Rossi-Mastracci, Alan Love, Ruth Shaw, Mike Travisano, Mark Borrello, Gillian Roehrig, Emiliee Snell-Rood

Staying accurate while being useful: biological principles in bioinspiration

The natural world is increasingly seen as a source of inspiration for sustainable approaches to designing the built environment of human communities. To support this work, some have documented overarching biological patterns and principles for bio-inspired design. However, there is concern among biologists, philosophers of biology, and design practitioners about the biological accuracy of these patterns and principles. Alternative depictions that aim for higher accuracy with respect to biological knowledge do not always have utility for those practicing bioinspired design, such as architects, landscape architects, and engineers. In response to this situation, we seek to: (1) identify and characterize principles and patterns among those currently proposed that are both relatively accurate and simultaneously useful to those practicing bioinspired design, and (2) establish a more transparent discourse around issues within existing frameworks, their relevance for the design practice, and how they may be revised. To address these goals, we surveyed a mixed group of biologists, philosophers and professionals seeking inspiration from nature. Our survey collected respondents' evaluation of the accuracy and utility of patterns and principles from existing frameworks. We find that strategic modifications to some biological principles can yield a fruitful balance between accuracy and utility, which may foster more effective collaboration. This work also addresses the broader question of how basic biology research might be translated into applied contexts.

1032 Judith Smit, Andrew Cronin, Vera Thijssen, Wouter Halfwerk

The effects of urbanization on male-male vocal interactions and mate choice

Sexual communication is shaped by both signalers and receivers, as well as by the environmental conditions under which sexual signaling takes place. Urbanization drastically changes environmental conditions, including by introducing sensory pollutants such as artificial light at night and anthropogenic noise. Although sexual communication often involves interactions between ri-

vals, the effects of urbanization on rival interactions and their consequences for mate choice, remains understudied. Therefore, we investigated how urban sensory conditions affect vocal interactions between male túngara frogs (Engystomops pustolosus) by recording dyadic interactions and manipulating light and noise levels. Furthermore, we conducted phonotaxis experiments with females to investigate the consequences of urban altered vocal interactions on mate choice. By incorporating the social dynamics of sexual signaling, our findings provide a more comprehensive understanding of the effects of urbanization on sexual signaling and its fitness consequences.

885 Stephanie Smith, Kenneth Angielczyk, Lawrence Heaney

Multi-scale morphological effects of body size in an arboreal rodent clade (Muridae: Phloeomyini)

The relationship between vertebrate body size and skeletal morphology can manifest differently among clades, and morphological effects of body size are often difficult to extricate from effects of ecology and phylogeny. For a controlled investigation of how body size affects the mammalian vertebral column across biological scale, we quantified cortical and trabecular bone morphology in the lumbar spine of Philippine endemic "cloud rats" (Phloeomyini). This monophyletic clade spans three orders of magnitude in body size (17g-2700g), and members are all arboreal herbivores, making them an excellent choice to isolate the morphological effects of body size in a non-model group. We collected 18 linear and six trabecular bone measurements on lumbar vertebrae of 10 species, including at least one species from every genus in the clade.Trabecular architecture, especially trabecular thickness, is correlated with body size. Although bone volumetric density increases with body size among smaller species, that relationship may not be linear: Phloeomys pallidus (2500g) and two species of Carpomys (120-170g) all have vertebrae that are ~40% bone by volume. In gross (cortical) morphology, larger species have dorsoventrally deeper vertebral centra, which may relate to maintaining skeletal safety factor (ratio of failure strain to maximum functional strain) at larger body size. Future work will consider relative mechanical contributions of vertebral trabecular and cortical bone, and how that may vary at large and small body size.

1169 Samantha Smith, Steven Phelps

The Cricothyroid Muscle's Role in Frequency Modulation of Whistle-based Sounds in a Singing Mouse.

Animals that make sounds using vocal fold vibration are limited in the frequencies they can achieve based on tissue composition and their ability to stretch and compress their vocal folds. Some mice avoid these tissue-based limitations by using a self-sustained whistle mechanism to produce high frequency sounds. Models predict that respiratory and laryngeal muscles control frequency, but there has been little work directly testing the role of muscles in whistle-based sound production. We used Alston's singing mouse, Scotinomys teguina, to test the role of one laryngeal muscle, the cricothyroid (CT), in high frequency sound production. This murid rodent makes an elaborate song consisting of frequency-modulated notes that range from 43 to 10 kHz. We recorded songs from singing mice before and after laryngeal surgery. Half of the mice had their CT bilaterally ablated, while the others received a sham surgery. CT-ablated animals sang irregular songs containing frequency sweeps with reduced bandwidths and gaps. Abnormal notes could be categorized as having either a reduced bandwidth, bi-partite, or tri-partite frequency pattern and were only found in post-surgery recordings of CT-ablated mice. Our work indicates that the CT is involved in frequency modulation of whistle-produced sounds in singing mice. The note phenotypes we found suggest that cricothyroid activity is paired with other muscles, likely laryngeal and respiratory, to produce the stereotypical downward sweep of singing mouse songs.

1522 Gilbecca Rae SMITH, Claudia Silva-Rubio, Frank van-Breukelen

Controlling resting oxygen consumption using the spleen in Tenrec ecaudatus?

The canonical functions of the spleen e.g. immune function, blood filtering, and iron recyclingovershadow its known role as a blood storage organ. Boreoeutherians or modern mammals, such asrace horses and dogs, experience splenic contractions during exercise where a 30-40% increase in redblood cell availability is associated with increased oxygen consumption. Tenrec ecaudatus arebasoendothermic mammals that possess numerous ancestral features such as a cloaca. We posit thattenrecs may provide evolutionary insight into the ancestral function of the spleen. Tenrecs canexperience as much as a 25-fold variation in resting oxygen consumption as well as a 14-fold variation inspleen size. We contend that tenrecs sequester red blood cells to the spleen to control oxygenconsumption. Here, we present data that demonstrate an association of spleen size and oxygenconsumption and discuss my future plans to more directly confirm this hypothesis. We believe theboreoeutherian functions of the spleen may be a derived condition afforded by a heightened level ofendothermy/homeothermy and its associated higher level of homeostasis.

1594 Leilani Smith, Isaac Ligocki

Behavioral responses of male eastern mosquitofish following exposure to a widely used herbicide

Glyphosate and glyphosate-based herbicides are known to influence the behavior of fish and other aquatic organisms, including variation in activity and anxiety-related behaviors. Recent work has suggested that glyphosate and glyphosate-based herbicides may have endocrine disrupting properties as well. We investigated whether male eastern mosquitofish (Gambusia holbrooki) exposed to 3 ug/L glyphosate, or a solution of Roundup® Concentrate Plus containing an equivalent concentration of glyphosate displayed differences in activity level, social interactions, or courtship behavior. We exposed fish for 48 hours to simulate a runoff event, after which each fish was placed in a behavioral arena with a 5 cm grid. Once habituated, we recorded each fish's general activity level based on the number of squares entered and time spent in the center versus the edge of the arena. We then introduced an unfamiliar male or female conspecific to the arena and recorded their behavioral interactions including time the focal fish spent following the stimulus fish, as well as any agonistic interactions. Fish exposed to Roundup® Concentrate Plus spent more time on the edge of the arena than fish exposed to glyphosate, or control fish. There were no significant differences in the number of squares entered across treatments, nor were there significant differences in any behavioral interactions between the focal and stimulus fish.

166 Anthony Snead, Corey Quackenbush, Shawn Trojahn, Anna McDonald, Luana Lins, Chris Cornelius, Paula Adams, Dengke Ma, Yuying Hsu, Eric Haag, Frédéric Silvestre, Akira Kanamori, Ryan Earley, Joanna Kelley

Plastic Gene Expression in Response to Embryonic Thermal Conditions

As human-induced climate change continues, organisms will be exposed to environmental shifts in temperature. Plasticity, genotype-dependent phenotypic changes in response to the environment, can enable individuals to rapidly shift trait values in response to these novel conditions. Kryptolebias marmoratus, rivulus, is a primarily self-fertilizing hermaphroditic killifish inhabiting shallow coastal habitats that experience spatiotemporal fluctuations in temperature. After generations of self-fertilization, rivulus form isogenic lineages thereby enabling the investigation of plastic responses to temperature while controlling for genotype. After improving the rivulus genome to chromosome length scaffolds (N50 of 28.17 MB), we use RNAseq to demonstrate that temperature and the developmental stage at exposure drive plastic changes in rivulus gene expression. We find limited variation in gene expression between embryos early in development indicating that individuals are resistant to stochastic changes in gene expression in early development. Additionally, we find low gene expression variation between individuals exposed to cold temperatures throughout the thermolabile period suggesting a canalization in the plastic response under thermal stress. When comparing gene ontology terms between cold and warm eggs sampled after the critical (thermolabile) period, we find upregulation of stress and metabolic pathways with downregulation of nervous system pathways. Therefore, embryonic thermal conditions can drive plastic responses in gene expression that may be especially relevant given the current threat of anthropogenic climate change.

320 Steven Snipes, Michael Rosario

Modeling dynamic muscle-tendon interactions in interrupted movements

A vast number of our daily activities require smooth and continuous movements of different parts of our bodies. These movements are largely controlled by muscle-tendon units (MTUs), which are composed of muscle fibers connected to tendons in series. When the muscle fibers contract, they generate and transmit force to the tendons, which can cause movements of our skeletal system. While there is consensus that these joint movements should be smooth to simplify motor control, there is a lack of knowledge regarding the functional consequences of interrupting smooth, continuous movements (e.g., external forces limiting or perturbing joint movement). In other words, what happens to our muscles and tendons when joint movement is not smooth? To answer this question, we conducted a virtual study in which simulated muscles were fully activated while MTUs underwent smooth and interrupted joint movements. We then measured and compared the amount of energy that flowed between the muscle and tendon during joint motion. In our simulations, muscles generate more work in the MTU and experience higher peak power when movements are interrupted than when movements are smooth and continuous. Given that the start and end point of the MTUs are the same regardless of whether movement is interrupted, we conclude that smooth, continuous movements are important to maximizing energy efficiency and reducing injury to muscles.

399 Chelsie Snipes, Richard Carter

Vibroacoustic response of the tympanic membrane due to hyoid-borne sound during echolocation in bats

To avoid masking incoming echoes with outgoing calls, bats use a low duty cycle (LDC) or high duty cycle (HDC) echolocation strategy. Generally, LDC echolocators separate the outgoing signal and returning echo temporally, while HDC echolocators separate the outgoing signal and returning echo in the frequency domain. Despite these differences, all echolocators must hear their outgoing call and subsequent echo within a short neural time window. It has been hypothesized that a unique stylohyal – tympanic bone articulation, which completes a bony connection between the larynx and auditory bullae in laryngeally echolocators, could allow for the transfer of the initial echolocation signal directly to the ear via bone conduction. We used μCT data to generate digital 3D models of the hyoid and hearing apparatus from a variety of HDC and LDC echolocators. Models were used to run a series of finite element analyses (FEA) to test the vibroacoustic response of the eardrum due to hyoid-borne sound generated during echolocation. We found that despite variation in hyoid morphology between LDC and HDC echolocators, bone conducted sound (vibration) through the hyoid apparatus stimulated the eardrum within a range likely heard by bats. Our data further supports the hypothesis that the unique stylohyal - tympanic bone articulation found in laryngeal echolocators allows for the direct transfer of the outgoing signal directly to the ear during echolocation.

1560 Calvin So

The fossil origins of modern amphibian miniaturization: a statistical approach

Current hypotheses on the origin of modern amphibians suggest the involvement of the evolution of extreme size reduction in their Paleozoic and Mesozoic tetrapod relatives. The evolution of diminutive body size–miniaturization–is characterized by a mélange of complex structural changes due to physical and developmental constraints. However, the mode, direction, and tempo of evolution is poorly explored under a statistically testable hypothesis in a phylogenetic comparative framework.While early tetrapod diversity covers a wide range of body sizes, this range may be derived from an ancestrally "average" body size that diversified under random variation. It is important to identify if smaller body sizes evolved more than expected in lineages leading to modern amphibians, compared to the Brownian motion mode of evolution, in which random variation in size change led to the evolution of a range of body sizes from large to small. If miniaturization occurred, extremely small body size evolved more than expected under random variation from the ancestral body size condition and is accompanied by morphological changes as described in previous studies. We reconstruct body size evolution of modern amphibians and their fossil relatives using body mass data and model the evolutionary tempo and mode under Brownian motion, evolutionary stasis, driven trends, and trended random walks. Understanding these patterns in early tetrapods is key to understanding patterns in the evolutionary origin of modern amphibians.

1725 Francesca Socki, David Fox

Exploring cranial integration in geomyoid rodents

Integration describes the impact of covarying traits on phenotypic diversity and specialization. The rodent clade Geomyoidea is an ideal group for studying integration, given that the two constituent families are ecologically disparate, specialized, and exhibit unique diversification patterns. In this study, we performed morphometrics on 3D landmarks of CT-scanned crania of species from all geomyoid genera. To elucidate if patterns of integration were based on functionally specialized traits, we used PLS analyses on two alternative partitions of landmarks, determined by PCA analyses and geomyoid functional anatomy. To account for allometry, we performed the same analyses with corrections for size. We repeated analyses separately for each family to examine within-family integration differences. Geomyids display less integration between cranial partitions than heteromyids, which are more variable in their integration and closely related taxa cluster closer together. For within-family PLS analyses, geomyids display strong integration across all species. Heteromyids at the subfamily level show weaker integration between the rostrum and the rest of the cranium. Size corrected PLS analyses display a shared pattern of integration across families, with the strongest effect on the most specialized taxa. Differences in integration across and within families indicate potential alternative adaptive timings and trajectories, which will be further assessed by incorporating phylogeny in future studies.

581 Keith Sockman, Michaël Beaulieu, Brittany Mosher

Weather and survival in the mountains: how cold, rain, and snow drive songbird population-dynamics

Rapid climate change in high-elevation ecosystems is driving a need to better understand how weather affects the population dynamics of their animal inhabitants. In a subalpine population of migratory songbird, the Lincoln's sparrow (Melospiza lincolnii), we examined how pre-arrival snowpack and breeding-season precipitation and temperature affect adult survival and recruitment. We sourced data from a weather station at our Colorado study site and, over 11 annual seasons, conducted mark-recapture procedures and estimated reproductive effort, reproductive success, body condition, and seasonal habitat maturation. While accounting for imperfect detection, population modeling indicated that accumulation of pre-arrival snow and breeding-season rain were both positively correlated with apparent survival to the next year. We found no support for a role of other weather variables in predicting apparent survival nor for a role of any weather variable in predicting recruitment, which was nearly constant over the study period. Neither pre-arrival snow nor breeding-season rain was associated with reproductive effort, reproductive success, or body condition. However, late-season habitat maturation increased with pre-arrival snow, raising the question whether snowpack prior to the migrants' arrival contributes to survival through effects on summer habitat. The dynamics of a migratory bird population appear to have a complex, relationship with weather that is, in some cases, temporally dissociated. This relationship may be mediated through habitat changes, although other mechanisms merit further investigation.

855 Alexandria Soldo, Ashley Love, Sarah Knutie

Prevalence of the invasive avian pox virus in nestling Darwin's finches in the Galapagos Islands

Introduced pathogens can cause population declines and extinctions of naïve island species. For example, avian pox virus was introduced to the Galapagos Islands in the 1890s and currently infects nearly all endemic passerine bird species, including Darwin's finches and Galapagos mockingbirds. Past studies have found that the prevalence of avian pox, which is detected by the presence of skin lesions, is higher in nestling and juvenile mockingbirds compared to adults. Although pox lesions are present on infected adult Darwin's finches, lesions are not found on nestling finches in pox-infected populations. For our study, we explore whether asymptomatic nestling small ground finches (Geospiza fuliginosa; a species of Darwin's finch) are infected with avian pox.We quantified the prevalence of avian pox in finch nestlings in Puerto Baquerizo Moreno on San Cristobal Island, Galapagos, using three years of data. When nestlings were approximately 7-8 days old, blood samples were collected and preserved to determine the presence or absence of the virus. We also inspected nestlings for signs of pox lesions. We then determined the presence of pox using PCR to amplify and detect pox DNA in our blood samples.In our study, we found no evidence of pox lesions in nestling small ground finches. The prevalence of pox virus present in blood will be discussed.

952 Ummat Somjee

Energetics and the evolution of extreme sexually selected traits

Elephant tusks, deer antlers, beetle horns, and the elaborate plumage of many birds are all shaped by sexual selection. All these traits are fueled by metabolic energy, yet the energetic cost of maintaining, growing and supporting these traits does not scale 1:1 with body size. The persistence of exaggerated traits was a major puzzle for Darwin, yet the costs of these traits have been surprisingly difficult to document even with recent technological advances. How can size-dependent energetic processes shape the evolution of exaggeration? I examine insects with extreme sexually selected traits to understand the relative roles that physiology, selection and energetics play in shaping the evolution of exaggeration. An energetic perspective allows us to link morphology, behavior and life-history which are selected in concert with exaggerated structures. I find that many animals use 'physiological tricks' to reduce the costs of these exaggerated structures; understanding maintenance costs and the energetic investment in reproduction between the sexes may deepen our understanding of the evolution of exaggeration.

730 Yash Sondhi, Jamie Theobald, Rachit Pratap Singh

Exposure to high levels of artificial light at night decreases wild moth locomotion

Artificial light at Night (ALAN) is increasing rapidly worldwide, and studies show it adversely affects many animals and plants, but nocturnal phototactic insects are especially vulnerable. Laboratory experiments simulating ALAN have disrupted circadian behaviors, such as locomotion, but few studies have tested this in natural populations. To address this, we caught adult wild moths (Areas galactina (Arctiinae) and Artena dotata

(Erebinae)) in the Western Himalayas at a field site with low light pollution and used an open-source system, the Portable Locomotion Activity monitor (pLAM) to monitor their activity. We monitored moths in flight cages at two distances from a single installed solar street lamp, simulating high and low light pollution, and repeated trials on subsequent nights at the same locations without the light. In both species, high light pollution severely curailed activity at night, with more interrupted bouts of activity, while moderate light pollution slightly increased activity, compared to dark nights. These patterns were more consistent and robust over multiple trials in Areas than Artena.

1422 Mahaut Sorlin, Simon Lailvaux, Alexei Maklakov

Age-dependent selection for elite athletic performance: have world class runners gotten younger?

Over the years, competition at the highest level of athletics has been drastically changed by a number of factors ranging from diet and equipment to training methods. This has resulted in a shift in both the pool of potential competitors, as well as in the realized performance of those competitors during events. However, it is unclear how this shift has affected the optimal performance age of world-class athletes, particularly given the increase in event specialization over time. To test the hypothesis that the optimal performance age has decreased in recent history, we compiled a large dataset on both racing times and ages of runners who broke athletic world records over the last 100 years in events ranging from marathons to the 100m. In total, we were able to collect over 4000 race entries pertaining to 3226 unique athletes and their ages and 12 different events. We fit mixed-models and applied selection analysis where feasible to this dataset and consider the various factors driving age-specific performance in various athletic events.

1454 Daniel Soto, Eva Erickson, Kelimar Diaz, Tianyu Wang, Velin Kojouharov, Daniel Goldman

Novel terradynamic interactions in myriapod locomotion in obstacle-rich environments

Centipedes locomote through various environments by coordinating traveling body waves and limb flexion. Little is known about the terradynamic interactions they experience when traversing obstacle-rich heterogeneous environments. Here, we challenged S. polymorpha ($N = 8$, $L = 8.6\pm1.1$ cm, 19 leg-pairs) to negotiate model heterogeneous terrains - hexagonal and square lattices (1 to 2 cm distance between posts). The centipedes traversed the lattices at $0.30+0.17$ body lengths per second and exhibited behaviors that we hypothesize emerged from both active and passive mechanisms. We note four distinct behaviors: hooking, laddering, limb gliding, and limb dragging. Hooking consisted of limb aggregates pushing off localized obstacles; laddering occurred when the centipede fully rolled onto its side to locomote along posts. Limb gliding consisted of partial limb bending when encountering obstructions and, while similar, limb dragging was denoted by a complete folding of the limbs against the body. In dense lattices, the prominent behavior was laddering (probability (p) $= 0.67$ to 0.86), and in sparse lattices, limb gliding was more prevalent ($p = 0.94$ to 1). We posit that, since centipedes locomote in non-inertial regimes, the role of active and passive control in limb and body dynamics can be probed on a scaled robophysical model ($L = 86$cm, 7 leg-pairs). To test this, we augment previously developed myriapod robots with new compliant limbs and bilateral body actuation and test in lattices of scaled dimensions.

1768 Gabriella Sparkes, Oakleigh Wilson, Kaylah Del-Simone, Ami Fadhillah Amir-Abdul-Nasir, Ben Barth, Sean FitzGibbon, William Ellis, Robbie Wilson

The secret life of koalas: using accelerometry to quantify fine-scale behaviours in the wild

The koala (Phascolarctos cinereus) is an Australian icon, receiving millions of dollars in funding for conservation, yet the population remains severely under threat. Koalas are arboreal specialists, relying on specific trees to complete ecologically significant tasks like resting, feeding, and mating. As such, the biggest threats to koalas are dog attacks and vehicle strikes, both of which occur while traversing the ground. We currently lack a unifying ecological framework for studying the movement, habitat use, and behaviour of koalas both in trees and on the ground. Here, we used tri-axial accelerometry and machine-learning algorithms to quantify the fine-scale behaviours of koalas in the wild. We collared 14 koalas with accelerometers for an average of 8 days in the wild. Using video-training data on captive koalas and machine-learning algorithms, we matched the 'fingerprints' of fine-scale behaviours such as foraging, eating, vigilance, resting, tree-climbing, branch-walking, and on-ground movement such as walking and galloping in movement patterns logged in the accelerometers of the wild monitored koalas. We discuss results from analyses of the frequency, duration, and proportion of time spent during each activity and estimated energy budgets of koalas in the wild. This study demonstrates the use of both remote field-based and computational-based technologies to study the fine-scale behaviour of koalas—the first piece of the ecological framework puzzle dictating the movement ecology of this animal.

1780 Gabriella Sparkes, Jaime Heiniger, Nicholas Smith, Vincent Careau, Ami Fadhillah Amir-Abdul-Nasir, Skye Cameron, Robbie Wilson

War and Sex in the Tropics: Performance trade-offs in the world's largest semelparous mammal

The activities that define survival and reproductive success for all animals depend on movement. However, movement is affected by multiple underlying factors, and organisms must balance the competing demands of these factors whenever they move. In northern quolls, the morphology that increases bite force (i.e., bigger heads) can improve fighting ability, but should constrain sprinting performance by adding mass to the body. Trade-offs between fighting and escape performance might therefore be sex-specific or manifest only during particular times of the breeding season. Male northern quolls (Dasyurus hallucatus) die after a single synchronous breeding season, while females live and breed for 2-3 years. This provides a unique life history strategy in which to explore sex differences in performance trade-offs. We assessed whether sprinting and biting performance trade-off for wild male or female northern quolls before, during, or after breeding (2012-2014). We found no functional trade-off between the performance traits; bigger, heavier quolls with greater bite forces are not slower sprinters. However, we found that males sprint slower in the post-breeding season. We also assessed performance trait repeatability across days, seasons, and years. Performance was consistent within seasons, but less repeatable across seasons, highlighting the costs of the species' extreme breeding.These findings suggest that ecologically relevant tasks important for survival and reproduction—fighting capacity and locomotor performance—may evolve independently in male and female northern quolls.

748 Daniel Speiser, Alexandra Kingston, Daniel Chappell

Few Eyes, More Eyes, Fast Eyes, Slow Eyes: Metabolic Constraints on Distributed Visual Systems

The evolution of visual systems involves trade-offs in which higher performance incurs higher metabolic cost. How do these metabolic constraints influence the evolution of distributed visual systems in which animals have dozens to hundreds of eyes spread across their bodies? Distributed visual systems must be somewhat efficient because the animals that have them (e.g. bivalves, chitons, fan worms, echinoderms, and cnidarians) tend to have low metabolic rates and relatively decentralized nervous systems. Despite the apparent pressure for metabolic efficiency, distributed visual systems often demonstrate oversampling in which many separate eyes simultaneously view overlapping regions of visual space. Oversampling may be metabolically expensive because axon length is a major contributor to the cost of neural processing and distributed visual systems often include eyes whose photoreceptors have lengthy axons. This suggests that sparser sensor arrays will be advantageous from a metabolic perspective, an observation challenging to reconcile with the level of oversampling observed in many distributed visual systems. A potential solution is suggested by differences between centralized versus decentralized visual processing. Adding eyes to cephalic visual systems may be prohibitively expensive because of the numerous layers of visual processing involved; however, adding eyes to distributed visual systems may be relatively inexpensive if decentralized visual processing is sufficiently efficient. If so, adding eyes to distributed visual systems may occur at low metabolic cost relative to the benefits gained.

1313 Emily Sperou, Dan Crocker, Dan Costa, Michael Goebel, Renato Borras-Chavez, Shane Kanatous, Stephen Trumble, Sarah Kienle, Douglas Krause

Hot off the stress: Leopard seals exhibit high levels of cortisol, driven by sex, diet, and mass

Leopard seals (Hydrurga leptonyx) are Antarctic apex predators that exert top-down pressure on the structure and function of Southern Ocean food webs. However, there is a paucity of knowledge on their ecology and physiology, hindering our ability to understand the current and future health of these polar mammals. The objective of this study was to measure and validate cortisol in leopard seal blood (serum, $n = 20$) collected off the Western Antarctic Peninsula to determine the relationship between the stress biomarker (cortisol) with diet (?15N, ?13C), body condition (scaling body mass index), and sex. Our results indicate that leopard seals show sex-specific differences in cortisol. Females having significantly lower mean cortisol than males (females: 94.67 ± 3.13 ug/dL, males: 120.85 ± 6.20 ug/dL). Diet also influences cortisol levels. Leopard seals with higher ?15N values, indicative of foraging on high trophic level prey, exhibit lower cortisol concentrations. In addition, we examined leopard seal stress profiles compared to other mammals and found that leopard seals have the highest mean cortisol concentration among closely related phocids, otariids, bears, and mustelids for which comparable data exist. Our study validates and compares cortisol concentrations in leopard seals and emphasizes sex-specific and diet specific differences among the population. This information is vital to understanding the health of the population and will aid in assessing leopard seals' vulnerability to climate change.

1013 CHEYNE SPRINGBETT

Digging In: An Investigation of Burrowing Behavior in Muusoctopus leioderma

Marine sediment environments are among the most expansive on Earth, yet their inaccessibility limits our knowledge of how these ecosystems function. Burrowing, or movement through soft sediment to form structures, is a particularly impactful behavior common in marine sediment environments. Burrowing functions and mechanisms vary based on the sediment and organism. Octopus are a charismatic and intelligent group that are expanding in range and numbers. Muusoctopus leioderma is a typically inaccessible deep-water burrowing octopus with a population in Burrows Bay, WA. I explored octopus burrowing by examining M. leioderma's burrowing behavior, characterizing the species' burrows, and exploring morphological traits linked with burrowing. To accomplish this, divers recorded the octopus' burrowing in situ. This allowed for measurements of Burrowing Rate Index (BRI) a standardized protocol allowing comparison of burrowing rates with other burrowing organisms. I studied the structure of burrows formed in the lab by collected octopuses, allowing me to examine the impact the species may be having. Finally, I explored the role of a morphological trait and its role in burrowing. The lateral mantle ridge fold or "keel" is hypothesized to be involved in octopus burrowing, and this was examined by measuring burrow activity and keel prominence in captive M. leioderma, and by looking at phylogenetic associations of burrowing and keel presence across taxa.

159 Robert Srygley

Mormon cricket Diet and Immunity following Fungal Attack

Mormon crickets aggregate and march in bands containing millions of insects. Some of these migrating Mormon crickets show protein-deficiency, because they ate more protein than carbohydrates when given a choice, and slowed their migratory speed when fed protein relative to carbohydrates. In addition, they elevated their phenoloxidase (PO) titers. In the lab, protein-restricted diets caused Mormon crickets to have lower circulating PO, slower encapsulation of foreign bodies, and greater mortality from Beauveria bassiana, a ubiquitous, free-living soil fungus that also kills insects. Here, we ask: Do Mormon crickets elevate PO and consume protein in response to B. bassiana infection? B. bassiana was applied topically (day 0), and mortality began on day 5. Spontaneously-induced PO, total PO, and total protein were assayed in hemolymph on day 1 and 4. On day 1, PO titers were not different between inoculated and control insects, whereas by day 4, spontaneous PO was greater in the inoculated group. Total PO activity was unchanged. Circulating protein declined in inoculated insects relative to controls. Total dietary consumption was also less than controls, but the ratio of dietary protein to carbohydrates was not different between treatments. As predicted, PO titers are elevated as a result of fungal infection, and hemolymph protein is reduced, but the insects did not compensate behaviorally. They neither switched to a more protein-rich diet nor consumed more diet overall.

1204 Michelle St.-John, Julia Dunker, Emilie Richards, Christopher Martin

Parallel genetic changes underlie novel trophic specialization in an adaptive radiation of pupfishes

Phenotypic convergence results from changes in either the same (parallel) or different (non-parallel) genetic pathways, and factors such as divergence time, shared standing genetic variation, levels of introgression, and mutation rates can all influence the likelihood of convergence via parallel/non-parallel genetic changes. However, the frequency of parallel vs non-parallel genetic changes resulting in phenotypic convergence is poorly understood. In this study, we use a QTL mapping approach to investigate the genetic basis of adaptive scale- and snail-eating phenotypes in two independent populations of pupfish found only on San Salvador Island, Bahamas. For each population, we independently raised F2 genetic crosses of scale- and snail-eaters, estimated linkage maps, and scanned for significant QTL for 30 adaptive skeletal craniofacial and body traits. We compared the genomic regions associated with adaptive phenotypes across ponds and found that most regions were indeed reused suggesting that parallel genetic changes underlie adaptive scale- and snail-eater phenotypes. An additional 11% of the detected QTL regions were associated with different traits across ponds, signifying that pleiotropy may also influence rates of convergence. Furthermore, we found that less than 3% of adaptive genetic variation within QTL regions was due to de novo mutations. Ultimately, we suggest that parallel genetic pathways containing standing or introgressed genetic variation may have produced convergent scale- and snail-eating specialist phenotypes on San Salvador Island.

1096 Lyndsy Stacy, Ashley Teufel, Davida Smyth

Agent-Based Modeling to Establish a Protocol for Sampling DNA from the Air

It has become painfully apparent in the last two years the efficiency in which viruses can spread through aerosols. While this is not new information, we did not yet have the tools to create effective safety measures. Our team is working on a method of measuring and modeling how aerosols containing viral particles suspend and move throughout the air. We have previously used a nebulizer to simulate the spread of aerosols filled with a detectable bacteriophage and were able to observe how viable particles spread and some of the things that can affect this. The next step will be sampling the bacteriophage on plates, but also using a new air sampler to quantify DNA. We will also be introducing more variables such as airflow and movement of the source to see how these changes may affect how much the aerosols spread. An agent-based model is in progress to further explain the phenomenon of aerosol travel and to potentially use as a future guideline for social distancing or other safety guidelines. An issue with current models is that little experimental data is collected and much of the outcomes are hypothetical. With experimental data used to create the baseline for our model, we anticipate that it will be more accurate and applicable to those trying to create safety protocols while keeping aerosols in mind.

1136 Daniel Stadtmauer, Silvia Basanta, Jamie Maziarz, Mihaela Pavlicev, Gunter Wagner

Origin of a Novel Tissue from the Ancestral Live-Bearing Mammal's Uterine Cell Type Inventory

The uterine decidua orchestrates embryo implantation and regulates the immunological milieu of the uterus. Its origin was a key innovation underlying the ability of eutherian mammals to sustain extended periods of gestation. Its cardinal cell type, the decidual stromal cell, is embedded in webs of developmental dependencies with other tissue-specific cells. That raises the question: How does a highly interdependent, evolutionarily stable configuration of cell types arise through a gradual process of evolution? We present results from a phylogenetic analysis of cell type origination at the fetal-maternal interface of therian mammals, augmented by single-cell transcriptomic atlasing of key species (the nondeciduate opossum, and deciduate mouse, human, and guinea pig). Quantitative analysis of cell type species specificity confirms that the decidual stromal cell is eutherian-specific. Decidual natural killer cells seem to have arisen along the stem lineage leading to eutheria. An anti-inflamamtory tissue-resident macrophage is conserved across therian mammals, likely homologous to the cells which interface with invasive trophoblast in the human. Divergent phenotypes of syncytiotrophoblast cell types originating from independent events of retroviral gene insertion give a window into parallel cell typogenesis. Together, these findings contextualize what has become a paradigmatic evolutionary novelty – the decidual stromal cell – as part of a stepwise-assembled complex system of interacting cell types, and reconstructs the history of the most recently evolved "tissue type" in the human body.

1048 Kathryn Stanchak, David Perkel, Bingni Brunton

The avian lumbosacral organ: A spinal mechanosensor for bird balance?

Birds have evolved a variety of locomotor abilities: all modes of flight and cursoriality, swimming and diving, and exquisite balance control under extreme conditions. For instance, many species are capable of holding their head still to spot prey as their body sways with gusts of wind while hovering or perching. This ability to coordinate their head seemingly separately from their torso may be facilitated by a highly specialized lower spinal cord and column, which is hypothesized to act as a mechanosensory balance organ analogous to those present in the vertebrate inner ears. This talk will review anatomical and comparative evidence on the organ, tissue, and molecular scales that supports the mechanosensory hypothesis for the LSO, especially our recent finding of mechanosensation-related molecules that potentially link the avian LSO to mechanosensory spinal cord cells and networks known in other vertebrate systems. Direct functional experiments testing this hypothesis are still lacking, but continued cell-and molecular-scale research might enable targeted spinal cord manipulations in the near future. Both the LSO and its influence on avian evolution are understudied. The LSO might permit anatomical regional specialization and multifunctionality, enabling avian diversification. Thus, the avian LSO is a choice anatomical study system from multiple perspectives, including sensory biology and locomotor control, organismal ecology, and macroevolution.

1831 Kathryn Stanchak, Hilary Katz

Symposium Introduction: The role of mechanosensation in robust movement control

Many animals exhibit extraordinarily robust behaviors even in the face of extreme external disturbances. It is becoming increasingly clear that mechanosensation is integral to completing patterned and repeatable maneuvers. This symposium will explore how mechanosensors are incorporated into behavioral movement control systems and their impact on behavioral performance. The speakers will discuss a variety of mechanosensing mechanisms in vertebrate, invertebrate, and robotic systems. Our goals for the symposium include (1) encouraging a comparative approach to understanding how mechanosensors are incorporated in organismal control systems and (2) developing an evolutionary approach to understanding the basic biology of mechanosensors, considering the potential for analogous (or homologous) sensor structure and function across taxa. Research on mechanosensation has recently rapidly progressed, and now is an excellent time to bring together researchers to compare and contrast their different systems (at cellular, organ, and organismal-levels); share experimental advice and methods; and inspire collaborative, cross-species approaches to understanding the role of mechanosensation in movement control systems.

908 Keegan Stansberry, Kaitlin Couvillion, Tosha Kelly, Allison Cannon, Melanie Kimball, Christine Lattin

Compensatory growth tradeoffs of experimentally induced asynchronous hatching in a songbird

Many songbirds begin active incubation after laying their penultimate egg, resulting in synchronous hatching of the clutch. However, later in the breeding season, environmental incubation may begin as soon as eggs are laid, causing asynchronous hatching and distinct size hierarchies among siblings. Late-hatched individuals may compensate for this initial size deficit by allocating more resources toward skeletal growth at a cost to growth in other tissues. To test for compensatory growth-related tradeoffs, we manipulated incubation temperature in nest boxes of free-living European starlings (Sturnus vulgaris) using heating packs that successfully induced asynchronous hatching ($n = 10$) or no manipulation for control nests ($n = 10$). We collected nestling morphological measurements at days 3, 6, 9, and 12 post-hatch, and on day 14 euthanized the largest and smallest nestling in each brood and collected spleen, liver, and bursa to measure the mass of each tissue. By day 12, morphological measurements of the smallest nestlings in heated and control nests were not different, demonstrating compensatory growth. We found that immune tissue mass was more strongly correlated with skeletal growth in the control group. Unexpectedly, relative to tarsus length, the spleen was heavier in the smallest nestlings in the heated group. These results suggest that, in our population, compensatory growth may uncouple allometric relationships among different tissue types, but there may not be tradeoffs between somatic and immune tissue growth.

110 Gavin Stark, Wei-guo Du, Zhi-Gao Zeng, Liang Ma, Ofir Levy

Cool shade and not-so-cool shade: the importance of microclimate diversity in a changing world

As habitat loss and climate change threaten global biodiversity, we need a theoretical framework for predicting the combined impacts of these two threats on the performance of organisms. However, current models simplify microhabitats' diversity of natural landscapes and are prone to biased predictions. By combining empirical and modeling approaches, we show the cascading effect of habitat loss and climate change on activity time and thermoregulatory accuracy in a diurnal desert lizard. Our model predicted a severe loss of summer activity in the absence of medium and large rocks. Future warming will gradually decrease summer activity as even large rocks become thermally stressful. Warmer winters will enable more activity and require bushes and small rocks as shade retreats. Hence, microhabitats that may seem unimportant today may become important under climate change. Such modeling frameworks may be crucial to understanding species' microhabitat requirements and developing conservation programs.

1054 Alyssa Stark, Austin Garner, Stephen Yanoviak

Adhesive performance of arboreal ants as a function of substrate surface temperature and shear rate

Arboreal ant workers are wingless, cursorial organisms that rely on a fluid-based adhesive system to attach to substrates they traverse. On average, the surface temperature of an exposed canopy tree branch in the tropics is 35°C, however surface temperatures can exceed 50°C. Although ants forage on these superheated substrates, adhesive performance decreases as surface temperature increases in some species, reducing their safety factor. Conversely, adhesion peaks around 35°C and reduces only slightly at higher temperatures in other species. The reason for species-level differences is unknown but could be related to the adhesive fluid. To test for differences in adhesive fluid behavior, we measured shear adhesion of two species of ant, that vary in adhesive performance at two temperatures (22 and 40°C) and two shear rates (6 and 21 mm s-1). We found adhesion varied as a function of surface temperature and shear rate independently, where the more temperature-adapted species (Cephalotes atratus) only experienced a slight drop in adhesion as temperature increased compared to the temperature-sensitive species (Atta colombica). Conversely, only A. colombica experienced variation in adhesive performance as a function of shear adhesion rate. Taken together, these results suggest that the adhesive fluid, or some other component of the adhesive system, varies among species, making some species of ant better adapted to high temperature conditions.

1466 Jeremy Starkey, David Delehanty, Melissa Rivas, Devaleena Pradhan

Testosterone and Estradiol are Tightly Linked Across Different Regions of the Avian Brain

In vertebrates, crosstalk between peripheral and neuroendocrine systems can initiate precise downstream processes in cellular targets. For example, one hypothesis is that testosterone (T), produced primarily by the Leydig cells of the testes, can signal reproductive readiness to neurohormone regulatory systems in the brain to coordinate the onset of reproductive behavior. In several species, T and other androgens in extra-gonadal tissues serve as prohormones that are locally converted to estrogens by the enzyme aromatase. We used a comparative approach to examine the bioavailability and stochastic relationship between brain T and estradiol (E2) in four non-model avian species: cinnamon teal (Spatula cyanoptera), mallard (Anas platyrhynchos), chukar (Alectoris chukar), and Eurasian collared-dove (Steptopelia decaocto). We used solid-phase extraction and enzyme immunoassays to measure T and E2 concentrations within the rostral telencephalon, hippocampus, hypothalamus, and cerebellum of breeding males. Testosterone concentrations were higher than E2 concentrations in the rostral telencephalon, hippocampus, and cerebellum of chukar. Both T and E2 concentrations were similar throughout all brain regions in cinnamon teal, mallard, and Eurasian collared-dove. Testosterone and E2 were positively correlated within the rostral telencephalon and hippocampus and a strong trend existed within the hypothalamus and cerebellum. These relationships indicate that there are adequate T concentrations present in these four regions to act as a prohormone for aromatization to E2 within the avian brain.

874 Katherine Starr, Emma Sherratt, Thomas Sanger

Evolutionary Patterns of Anolis Skull Shape Diversity

Adaptive radiations are characterized by an increase in species and phenotypic diversity as organisms fill open ecological niches. Anolis lizards are an oft-used model for investigating the tempo and mode of adaptive radiations. Most of the prior research on the adaptive diversification of Anolis lizard morphology has focused on the post-cranium, developing an understanding that anoles have higher speciation rates and more variation in body forms than their closest relatives. But, like the post-cranium, there is also a remarkable range of skull diversity in anoles. How the diversity in anole skull shape compares to that of closely-related families has not been previously investigated. It remains unknown whether anoles have unique head shapes or whether their skull shapes diversified as they radiated among arboreal microhabitats. We performed geometric morphometric analysis of skull shape of anoles and their Iguanian relatives. This revealed that the main axis of variation is skull length, specifically face length. Anoles occupy a unique region of morphospace because of their longer faces. The non-anoline iguanian families generally have relatively short faces, with the Phynosoma having the shortest in the clade. Across all axes of variation, the Iguanian relatives of anoles exhibited a higher degree of morphological disparity compared to anoles. Despite anoles' radiation, their skulls have not become more diverse than their relatives, but they have gotten longer.

1034 Nancy Staub, Stephen Hayes, Mary Mendonca

Androgen levels in species of the plethodontid genus Aneides.

The plethodontid genus Aneides is striking for its morphological variation, both within and between species, especially when compared to other plethodontid genera. What is also intriguing is the variation in degree of sexual dimorphism among species. Aneides hardii is dramatically dimorphic in head and body size (for a salamander) and the other species are less dimorphic because females of these other species express derived traits. The expression of these secondary sexual traits in females results in them appearing phenotypically more similar to males than to female A. hardii. Our study examines a potential mechanism for the expression of these derived secondary sexual traits in females, as well as in males. We analyzed log-transformed serum steroid levels in several species of Aneides (A. lugubris, A. ferreus, A. flavipunctatus, A. hardii) using R. All species show sexual dimorphism in testosterone levels and A. lugubris and A. ferreus are dimorphic for DHT. Male and female Aneides lugubris, the most robust member of the genus, have high levels of androgens relative to the other species of Aneides studied. While androgen levels in females are high relative to other amphibian species, more experimental work and gene expression analyses would be valuable to further explore the relationship between androgens, morphological variation, and sexual dimorphism in this group.

1045 Nicholas Steichmann, Daniel Speiser, Jenna Mazza

The Function of Crustacean Accessory Eyes: A Behavioral and Physiological Approach

Eyes are physiologically costly to produce and maintain, making the evolution of secondary eyes where primary eyes are already present particularly intriguing. Most decapod crustaceans have primary compound eyes with superposition optics, but some species (spread across fourteen families) have an additional pair of compound eyes with apposition optics, henceforth referred to as accessory eyes. The function of accessory eyes is unknown, but they may help regulate behavioral and physiological rhythms. Associations identified between accessory eyes and endocrine organs within eyestalks have led to the hypothesis that accessory eyes contribute to hormonal control of integumentary pigment cells called chromatophores. We are using electrophysiological and behavioral experiments to ask how the evolution of accessory eyes may be linked to dynamic color change in caridean shrimp. Using electroretinography (ERG), we tested the spectral sensitivity and temporal resolution of both sets of eyes of the shrimp Saron marmoratus. We found that accessory eyes have a broader range of spectral responses than primary eyes across the visible range (380-700 nm). We also assessed whether color change in S. marmoratus is influenced by background and illumination. We found dynamic color change in S. marmoratus involves distinct pattern components in regions of the exoskeleton characterized by different sets of chromatophores. We propose accessory eyes may have evolved to assess light conditions independently of the primary eyes to regulate dynamic color change.

871 Laura Stein, Faith Leri

Disentangling mechanisms of predator-induced parental effects in Poecilia reticulata

Organisms rely on evolutionary history, personal experience, and parental experience to gather information about their environment and produce an integrated phenotype. Parental cues can serve as a catalyst for adaptive responses in offspring. What remains unclear is whether/how direct versus indirect cue reception influences molecular mechanisms underpinning developmental changes, and indeed, whether these different sources result in different phenotypes. Two non-mutually exclusive forms of parental information transmission, intergenerational (potentially direct) and transgenerational (indirect), can begin to be teased apart to better understand how cues are integrated during development and ultimately alter phenotypic outcomes. Understanding these mechanisms will provide a foundation for investigating how and why organisms attend to different informational sources. Here we examine whether transgenerational or intergenerational plasticity results in offspring response to parental predation risk using Trinidadian guppies (Poecilia reticulata) as a model. We found evidence for complex interactions between parental information transmission and offspring sex in life history, growth rate, morphology, and behavior that persisted across the lifetime of individuals. Our results suggest multiple interacting mechanisms of information integration in this system, with implications for evolutionary and ecological processes.

990 Natalie Steinel, Ahmed Attaya, Lohman Brian

Threespine stickleback immune atlas: baseline immune composition and response to immunization

Studies of immunity in diverse taxa are often limited as these they require 1) prior knowledge of surface markers expression patterns of immune populations and 2) the availability of species-specific reagents to identify those markers. Single-cell RNA sequencing (scRNA-seq), conversely, can be a powerful tool for ecoimmunology and comparative immunology studies as it is not limited by reagent availability and can produce a comprehensive immunologic snapshot based on cells' unique transcriptional profiles. To characterize the immune landscape of threespine stickleback (Gasterosteus aculeatus), an emerging immunologic model, we performed scRNA-seq of whole spleen. We detected 18 cell clusters, encompassing major leukocyte populations (B cells, macrophages, neutrophils, etc..), and defining the baseline splenic immune profile for this species. Within each population we resolved several subpopulations with discrete expression profiles, indicative of functional subsets or different activation statuses. To define the cell populations and expression profiles associated with stickleback immune activation, we compared single-cell profiles of immunized fish to those of both carrier-injected and unimmunized controls. We found that splenic immune composition changed upon immunization, notably there was a marked expansion of several myeloid and B cell subsets, with expression profiles of the latter consistent with activated B cells and plasma cells. This single-cell resolution atlas of stickleback spleen established both baseline and activated immune profiles and will benefit future immunology and host-pathogen interaction studies in this species.

807 Katherine Steinfield, Andrew Knapp, Ryan Felice

What a carrion: morphological convergence in vulture skull shape is driven by feeding ecology

Among tetrapods, obligate scavenging has evolved twice, in American and Afro-Eurasian vultures (Cathartidae and Accipitridae). Morphological and ecological studies that incorporate dietary information have tended to group these taxa under the umbrella term 'scavenger,' but there is evidence that species in both groups have evolved to exploit different niches when scavenging based on distinct feeding styles. We used three-dimensional geometric morphometrics to quantify skull morphology across 23 extant and 1 extinct species of vulture, incorporating 8 non-vulture raptors. A PCA of shape data shows that the two vulture families, Accipitridae and Cathartidae, are clearly separated in morphospace, but feeding groups show distinct clusters, and a MANOVA performed on the shape data shows that there is a strong and significant correlation between skull shape and feeding group ($Rsq = 0.43$, $p = 0.001$). There is a moderate phylogenetic signal in shape ($Kmult = 0.47$, $p = 0.001$), suggesting some convergence in skull morphology between the two taxonomic groups. Our results suggest that feeding style has an important influence on skull morphology, and that there is clear shape convergence between the two families. Given the critical conservation status of many vultures, a better understanding of feeding ecology and its effect on morphology can help inform conservation efforts.

1704 Bernd Steklis, Todd Blackledge

Comparing Semi-Aquatic and Terrestrial Spiders Attachment Disc Adhesion in Wet Conditions

Terrestrial spiders produce small, quick-curing glue structures called attachment discs that are used to either secure webs to a substrate, or anchor trailing dragline silk as a "safety line" while traversing the environment. Spiders that primarily live or hunt in semi-aquatic environments, such as on the surface of ponds, also produce and use attachment discs similar to their terrestrial counterparts. However, semi-aquatic spiders face the challenge of using attachment discs in aquatic environments where substrates are often wet, making adhesion using standard methods very difficult. This study compares the performance of attachment discs produced by two semi-aquatic spider species (Dolomedes triton and Tetragnatha laboriosa) and several terrestrial species, in order to examine the hypothesis that semi-aquatic spiders have modified their attachment discs in order to adhere better in wet environments than their terrestrial relatives. The peak adhesive forces of the attachment discs were measured following their application to wet and dry surfaces. The semi-aquatic species have similar peak pull off forces on both dry and wet surfaces, while the terrestrial species adhere more strongly to dry surfaces while losing significant adhesion when applied to wet surfaces. This lays the groundwork for using semi-aquatic spiders as biomimetic models to develop novel bio-inspired wet adhesives with a broad range of applications such as medical or industrial adhesives.

1061 Raedan Stephens, Keegan Stansberry, Christine Lattin

Bird DIY: Building an RFID system to study behavior in free-living starlings

Radio Frequency Identification (RFID) technology can be effectively utilized to gain insights into animal behavior, such as avian responses to environmental change. In our established field system of free-living European starlings (Sturnus vulgaris), we sought to implement a new system of RFID readers with antennas encircling the entrances of bird boxes and RFID leg bands with unique identifiers that record when birds pass through the antennas. To limit costs, we used Arduino RFID readers built by Eli Bridge and Jay Wilhelm and constructed the rest of the system components ourselves. We designed and 3D printed a new device to efficiently coil copper wire antennas of the right diameter, which we weatherproofed using Plastidip. We constructed custom RFID bands out of passive integrated transponder tags and heat-shrink tubing. In our first pilot year of data collection, we outfitted $n = 41$ adults and $n = 40$ chicks with RFID leg bands and collected data from 13 different nest boxes. These data demonstrate that the system can be used effectively to gather data on parental provisioning behavior and nestling fledge dates, but further optimization is needed to provide more consistent results. Necessary improvements include optimizing battery usage and increasing component durability. Moving forward, we plan to continue improving the system while maintaining its affordability and are currently exploring how to convert RFID readers to run on a cost-effective solar power source.

319 Jess Sterling, Justin Havird

The Forming of a New Kingdom: Primary Microbial Succession in Anchialine Ecosystems

The creation of a new ecosystem is akin to the creation of a kingdom. Undiscovered land, untouched and unconquered, and destined to be plagued by war and colonization. The first organisms to lay siege to new territory are microbial life forms. They undergo unseen wars to establish which species will dominate the space in a process known as primary microbial succession. This initial colonization by microbial communities lays the foundation for further ecological succession of plants and animals. The anchialine ecosystem offers a unique opportunity to examine this process. Here, we characterized microbial communities of anchialine habitats in Hawaii that were created during the eruptions of the Kilauea volcano in 2018. Samples from three anchialine ponds were collected ~2 years after their formation and at later time points spanning ~1 year. Sequence profiling of prokaryotic and eukaryotic communities was used to test whether communities were similar to those from older, established anchialine habitats, and if community structure changed over time. Results show that microbial communities from the new habitats were unlike any from established anchialine microbial communities and each new habitat harbored its own unique community relative to other habitats. While community composition in each habitat underwent statistically significant changes over time, they remained distinctive from established anchialine habitats. These results suggest idiosyncratic microbial consortia form during the early succession of Hawaiian anchialine habitats.

754 Phillip Sternes, Lars Schmitz, Timothy Higham

Cretaceous origin of pelagic sharks coincides with major shifts in pectoral fin morphology

Sharks (Selachimorpha) are among the oldest and most successful vertebrate lineages. They occupy almost every part of the marine ecosystem. However, when and how sharks evolved this high ecological diversity is poorly understood.The shape and size of the pectoral fins may help explain the success of sharks, as they are critical for maintaining high levels of swimming performance. We therefore examined the evolution of pectoral fin morphology of nearly every known shark species in the context of their preferred habitat spanning the benthic-pelagic axis.Our phylogenetic comparative methods identify the Cretaceous as a critical phase in shark habitat evolution. Stochastic character mapping reveals a benthic origin of sharks, but the initial transition to pelagic habitats already occurred in the Early Cretaceous. This transition coincided with a selective regime shift to higher pectoral fin aspect ratios. Evolutionary model fitting provides robust evidence that pelagic sharks have considerably higher pectoral fin aspect ratios compared to other sharks. We also discovered high morphological differentiation within clades beginning in the early Late Cretaceous. We conclude that the enormous diversity of shark habitats originated in the Cretaceous. Higher aspect ratios of the pectoral fins likely reduced the cost of transport, enabling sharks to cruise at faster speeds. Warm Cretaceous waters likely resulted in elevated swimming performance due to the tight relationships between temperature and muscle performance.

1478 Dale Stevens, Anna Gilmartin, Sydney Macedo, Isabella Reichel, Matthew Wund, Kaitlyn Mathis

Testing for evolved morphological plasticity in stickleback fish following northern pike invasion

Biological invasions are one of many ways that humans are facilitating rapid environmental change across the globe. The introduction of invasive predators can impose harsh selective pressures on prey populations, and can lead to their local extinction. In Southcentral Alaska, Northern pike (Esox lucius) have been invading freshwater lakes for approximately 70 years, and have been interacting with native populations of threespine stickleback (Gasterosteus aculeatus) in the process. Previous research has found the effects of northern pike effects on local stickleback populations to be inconsistent. Some studies indicate that northern pike may impose harsh selective pressure on stickleback reproductive life history, and lead to the local extinction of stickleback populations entirely. However, other studies suggest that plastic behavioral phenotypes are not under selective pressure following northern pike invasion, and the effects of pike predation on morphology are poorly understood. Here, we asked how the morphological plasticity in threespine stickleback populations has evolved by exposing 6 populations of stickleback (3 with and 3 without northern pike) to simulated predation attacks during the course of their first year of development. In this presentation, we discuss the results of this work, and consider their implications in the broader framework of studying evolution in an increasingly human-dominated landscape.

862 Josef Stiegler, Andrew Moore, Shuo Wang, Elena Cuesta, John Scannella, Xing Xu, James Clark

Exceptional fossils and juvenile birds resolve dinosaurian digit dilemma

The reduction and integration of the dinosaurian carpus and manus from an ancestral 9 carpal ossifications and 5 digits to 4 carpal ossifications and 3 digits represents a classic homology problem, and historical discrepancies between prevailing developmental and paleontological hypotheses have invited denial of the dinosaurian origin of birds. Though homologies for some problematic elements of the extant avian autopod have now been established, a comprehensive understanding of the transition to the modern arrangement has remained elusive, as evidence from paleontology, development, and transcriptomics are seemingly in conflict. Here, we reconcile paleontological evidence with other disciplines using CT scans of the carpus and manus from key fossil specimens, a revised phylogenetic hypothesis for non-avian theropods based on a novel character matrix, and a phylogenetically broad survey of the autopodial ossifications in juvenile extant birds prior to fusion of the carpometacarpus. We document the repeated homoplastic ossification of a rudimentary digit V throughout theropod dinosaurs. Using digit V as an anchor for homology assessment, we have identified the likely phylogenetic locations on the non-avian theropod stem for the losses of autopodial elements and transitions from retained ancestral morphologies towards the modern avian arrangement. Our analysis shows that hypotheses that necessitate a complete and comparatively rapid homeotic frameshift in digit identities are oversimplifications.

1514 Kelsey Stilson, Zhe-Xi Luo, Callum Ross

Hemimandibular Mastication in Didelphis virginiana: bilateral control through periodontal feedback

Mammal teeth are subjected to periodic, high bite forces during mastication. Bite force orientation and magnitude are transduced into neural signals via tension and compression of the periodontal ligaments. This neurofeedback is used to elicit and modulate oral reflex arcs, muscle activity, jaw kinematics, and to protect the teeth during biting. However, the precise contribution of these afferents to chewing kinematics has not been examined. The hemimandibles of Didelphis virginiana (the Virginian opossum) are joined at the midline by an unfused, fairly mobile symphysis. We hypothesized that periodontal feedback in this system primarily impacts kinematics of the ipsilateral hemimandible. To address this question, we used biplanar videoradiography and the X-Ray Reconstruction of Moving Morphology pipeline to measure bilateral hemimandibular kinematics in five D. virginiana individuals before and after transection of the left inferior alveolar nerve (IAN). Results in non-transected individuals show that, during occlusion, there is limited hemimandibular movement anteriorly due to the interlocking canines. However, the temporomandibular joint is highly mobile. We hypothesize that this mobility allows for the complex occlusal movements necessary for an interlocking molar system. Left IAN transection impacted rotation and translation of both and left and right hemimandibles during the occlusal phases of the gape cycle. Importantly, this demonstrates that a one-sided nerve transection changes the kinematics of both hemimandibles, suggesting that bilateral periodontal afferent feedback is integrated in the.

970 Kelly Stiver, Jennifer Hellmann, Susan Marsh-Rollo, Suzanne Alonzo

Examining the stability of newly formed nesting male and satellite alliances in Symphodus ocellatus

Increased research on short-term cooperative alliances, including those involving non-relatives, will lead to a broader understanding of how cooperation evolves and the dynamics underlying more and less successful alliances. In Symphodus ocellatus, few individuals survive to adulthood and relatedness among adults is low. Males engage in one of three reproductive strategies that involve cooperation and competition with other males. Dominant nesting males provide parental care, while satellite and sneaker males sneak-spawn with mating nesting males and females. Nesting and satellite males engage in short-term partnerships characterized by nesting male tolerance of the satellite, and satellite defense against sneakers and courtship of females. In a pair of studies examining partnership formation via removal of one established partner, stability of the newly formed alliances was highly variable. We looked at how reproductive behaviors of the nesting male and satellite, as well as social factors at the nest, predicted stability of the new partnership. Satellite attention to females appears critical to stability in some circumstances. We also consider how stability is affected by which individual is new to the alliance (nesting male versus satellite), how contested the vacancy was, and whether the new partnership was a result of natural versus induced partner change.

702 Alberto Stolfi, Billie Swalla, Sydney Popsuj

Evolution of swimming behavior (or lack thereof) in tunicate larvae

The dispersal of sessile tunicates is usually carried out by their small, motile larvae. The larva does not feed during this brief dispersal phase (∼24 hours), and therefore contains a minimal nervous system that drives swimming and settlement behavior. For instance, the larva of the laboratory model species Ciona robusta has only 177 neurons in their central nervous system and 54 peripheral sensory cells. This nervous system is modulated by sensory cues and drives the simple left/right alternating contractions of the tail muscles on either side of the notochord. However, several species have diverged from this biphasic life cycle and have independently lost the swimming larval phase. These tail-less, non-swimming larvae provide an interesting look into how genes or gene activity can be evolutionarily lost from marine organisms. Here we report our studies on the patterning of the MG in species with tailed larvae as well as in Molgula occulta, a species whose tail-less larvae have lost the ability to swim.

1295 Marie Strader

Legacy effects of marine heatwaves on reef-building corals

While mass thermal bleaching events threaten coral reefs globally, survivors persist that ideally contribute to the maintenance of these populations into the future. However, contributions of these surviving colonies to future populations relies on unknown sub-lethal and legacy effects of these stress events that can impact reproduction and physiology. Further, while specific genes are associated in heat tolerance, the regulation of genes underlying this trait and mechanisms that contribute to environmental memory are not well understood. The French Polynesian island of Mo'orea experienced a severe mass bleaching event in 2019. Despite widespread coral mortality, some Acropora hyacinthus colonies monitored in the field were resistant to bleaching, alongside others that bleached but showed signs of symbiont recovery after the bleaching event. We examined DNA methylation profiles and symbiont communities of Acropora hyacinthus colonies during the stress event and 3-6 months later once they had either died or fully recovered. We additionally investigated differences in fatty acid profiles and stable isotopes between recovered and resistant colonies. While DNA methylation and symbiont communities were generally stable within a genotype throughout this period of extreme stress and recovery, we observed broader population wide shifts and significant differences between colonies with different responses to thermal stress. This dataset reveals complex legacy effects of extreme stress events on survivors of mass bleaching events.

427 Nicholas Strasser, Maya Makhtin, John Hatle

Dietary protein quality does not alter P:C intake target in grasshoppers

Adequate consumption of essential amino acids (EAAs) is needed to facilitate development and reproduction. However, overconsumption of some (e.g., BCAAs) can spur disease, while low protein consumption can extend lifespan. When offered multiple foods, most animals self-select their dietary protein:carbohydrate (P:C), called intake target. We sought to elucidate the effect of dietary protein quality on intake targets of female grasshoppers. We predicted that consuming a low-quality diet will shift intake targets to a higher P:C ratio, to acquire sufficient EAAs. Here, each individual was offered both a high- and a low-protein version of one of four artificial diets (a high-quality diet; a low-quality diet; a diet known to positively P:C [positive control]; a negative control). Each grasshopper was tested on all diets, and sequences were randomized. Intake targets for each diet group were: high-quality 0.42 ± 0.04, low-quality 0.42 ± 0.04, positive control 2.15 ± 0.14, and negative control 0.76 ± 0.10. High- and low-quality diets were not significantly different (t-test; $P = 0.44$). In contrast, consumption of the positive control diet increased intake target (ANOVA; $P < 0\ .0001$), showing these grasshoppers can alter intake target. Low-quality diets may not lead grasshoppers to increased protein feeding. Animals that consume lower quality protein may experience impaired reproduction. In future work, we seek to bridge the gap between the preference to feed on higher quality diet and the lack of altered feeding behavior on a lower quality diet.

1395 Samuel Stratton, Delbert Green

Decoupling the induction mechanisms of migratory orientation and reproductive diapause in monarchs

Research on the inductive mechanisms of seasonally expressed migratory traits have led to deep understandings of individual component traits, such as delayed reproduction, yet less understood is how the induction of the migratory syndrome, which is the sum of these multiple individual migratory traits, is coordinated. Further, whether the key component traits of delayed reproduction and oriented movement are induced by the same or independent biological mechanisms remains an open question. The monarch butterfly in eastern North America is an iconic trans-generational migrant. Here, individuals produced in the summer generation are reproductively active and non-migratory, whereas the fall produces a distinct migratory generation who enters reproductive diapause and journeys from northern US and Canada to central Mexico. We test whether fall conditions experienced during larval, pupal, or adult stages are sufficient and necessary to induce and maintain diapause and orientation. We reared individuals in both outdoor natural fall and indoor summer conditions and transferred individuals between locations at the end of each stage to restrict fall cues to specific stages. This design enables us to determine the interdependency of induction of these traits. These results provide important insights into how the induction of separate polyphenic traits, that work synergistically for the same life history strategy of migration, are coordinated across the life of an individual in response to changing environmental conditions.

1329 Margaret Streeter, Nathalie Le-François, Thomas Desvigne, Jacob Grondin, John Postlethwait, H. William Detrich, Jacob Daane

Examining the impact of climate change at a critical life history stage using Antarctic fishes

Rising temperatures caused by climate change pose serious challenges for ectotherms. The developing embryos of fishes are particularly sensitive to fluctuating temperature and have reduced thermal tolerance compared to juvenile or adult life history stages. This thermal sensitivity creates an embryonic bottleneck that may limit the ability of fish species to adapt to rapidly changing aquatic environments. Stenothermal Antarctic notothenioid fishes are important models for exploring thermal sensitivity to climate change due to their adaptations to the thermally stable, freezing temperatures of the Southern Ocean (SO). While many studies have assessed the impact of thermal stress on notothenioid adults, few have investigated thermal stress during embryonic development. At Palmer Station, Antarctica, we raised thousands of Notothenia coriiceps embryos from fertilization to hatching at ambient (0°C) and at elevated temperatures (4°C) modeled after projections for SO warming over the next one to two centuries. We found that development was significantly accelerated at 4°C, with hatching occurring 65 days earlier compared to controls (135 vs. 190 dpf), likely disrupting the evolved phenology between hatching and SO spring. To investigate the molecular impact of elevated temperatures on notothenioid embryos, RNA and DNA from stage matched samples were sequenced to compare gene expression and genome integrity. Together, these data will uncover molecular mechanisms underlying thermal acclimation and bottlenecks in notothenioid embryos. Supported by NSF grant OPP-1955368 (JMD, HWD).

1321 Jeffrey Streicher, Anjali Goswami, Ashwini Venkatanarayana-Mohan

How does chromosome evolution influence landmark-based estimates of genomic disparity?

Many genomic regions are highly conserved among species and offer important opportunities for comparative genomics. We have been using conserved genomic elements as homologous landmarks to explore the evolution of genome structure across diverse species. Our method, which can be applied to whole chromosome sequences or large homologous synteny blocks, generates estimates of genomic disparity that quantify variation in the spacing, order, and orientation of landmarks among focal taxa. To realistically interpret what genomic disparity values represent, we needed to understand how genome evolution influences this quantification. Most importantly, relating to the phenomena of chromosome inversions, chromosome fission/fusion events, and insertion/deletion events. Using theoretical and empirical simulations, we explored how different types of chromosome evolution impact disparity scores. Empirical simulations were performed using chromosome-level genome assemblies from tetrapod animals that were previously landmarked for homologous ultraconserved elements (UCEs). Our results suggest that disparity score is correlated with increasing chromosomal divergence across species, both in relation to landmark spacing and order. We also compared landmark-based disparity scores with sequence alignment-based divergence levels, a different but commonly used method for quantifying genomic variation.

688 Lynette Strickland

The genomic basis of color variation in a polymorphic Neotropical tortoise beetle

In our pursuit to understand how life's diversity is shaped and maintained, color polymorphisms serve as a powerful tool to connect phenotypic variation with the ecological processes that influence them and the genomic factors that maintain them. This work focuses on a color polymorphic species within a unique and striking group of beetles, the tortoise beetles (Cassidinae). Previous research with this species, Chelymorpha alternans, has shown the distribution of color pattern phenotypes across the Isthmus of Panama and revealed how these phenotypes are inherited using a series of targeted crossing studies. Here, we use pool-sequencing approach with two of the most widely distributed phenotypes, sampled from three different geographic populations to identify the underlying genomic basis of color pattern variation in this species. Using FST measurements, we see a highly differentiated area of the genome that is significantly associated with color pattern. This is then compared to other insect species for which a genomic basis of color has been investigated.

1499 Christopher Strickland, Laura Miller, Nick Battista

Planktos: An agent-based framework for small organisms in fluid and around structures at the m scale

Most fluid-based studies on organismal locomotion and dispersal at the meter scale have considered cases where either one organism actively locomotes in a quiescent fluid or many organisms passively drift with the fluid. Theoretical, computational, and experimental studies that consider both methods of transport are often limited to a small number of organisms across small scales or focus on fluid dynamic interactions between many microscopic individuals with simplified behavior. Agent-based simulations reveal complex emergent phenomena and collective behavior, but nearly all studies at this scale neglect background flows. Understanding the complex interactions between dynamic flows and small organism behavior for navigation, settlement, and dispersal has been a long-standing challenge.In this talk, I will introduce an open-source, computational framework for modeling the collective motion of microscopic organisms in 2D or 3D fluid flow near immersed structures. This Python library, Planktos, provides a complete agent-based environment in which to conduct and visualize simulations. Applications will be presented, including collective motion around filter feeders such as sea fans.

1547 Mason Strickland, Michael Sandel

Conservation Genetics and Environmental DNA of the Bridled Darter

The Bridled Darter is a small, ray-finned fish native to the Mobile Basin in the Upper Coosa River watershed throughout Georgia and Tennessee. Prior to 2021, the Bridled Darter was thought to be one species. But recent genetic and morphological studies have now split the fishes into two distinct species, the Etowah Bridled Darter, Percina freemanorum, endemic to the Etowah River System in Georgia, and the Bridled Darter, Percina kusha, endemic to the Conasauga River System in Georgia and Tennessee. Recent range decline and declines in population sizes has raised concern to list them as threatened species to undergo protection from further decline. A full population genetic study is being conducted to understand the current genetic variability within and between the two Bridled Darter species. This is done through collection of fin clip tissues from all known Bridled Darter populations, totaling eight sample sites. The DNA extracted from these tissues is being used to generate a molecular phylogeny. Environmental DNA (eDNA) is also being used to detect Bridled Darters at sites where their presence is below detectable limits by snorkeling or seining methods. The sites for eDNA include all known and historical Bridled Darter populations. The outcome of this study is to fully understand the population status of Bridled Darters to be able to properly manage the remaining populations and recovery of the extirpated populations.

453 Sarah McKay Strobel, Molly Womack

Evolution of signaller and receiver: assessing matched filters in anuran acoustic communication

Acoustic communication originated independently across major tetrapod clades, including birds, crocodilians, frogs, and mammals. Selection for consistency between signal characteristics and auditory sensitivity–termed the matched filter hypothesis–may maintain efficient detection of conspecific signals, but evidence so far has been equivocal. Anurans are a speciose group with the oldest known evolutionary origins of acoustic communication, which they use to locate and attract mates. Anurans provide an excellent system to explore how signaller and receiver may be coupled or decoupled in response to selection. Although anuran calling has received significant attention in the literature, anuran hearing studies have been sparser, limiting our ability to test the matched filter hypothesis. To address this data gap, we used consistent neurophysiological methods in 22 species to assess broad patterns in hearing sensitivity evolution across seven families. We combine these new data with decades of published data to evaluate evidence for the matched filter hypothesis, while accounting for phylogeny and body size. We consider future directions to identify how ecology, breeding strategy, and sexual dimorphism may explain deviations from the matched filter hypothesis and contribute to variation in the degree of coupling between sound production and reception in acoustic communication.

1765 Mikayla Struble

Terrestrial to Aquatic Locomotor Transitions in Notophthalmus viridescens

The diversity of locomotor behaviors in complex natural settings remains largely undescribed. Many amphibious tetrapods live in habitats neither fully terrestrial nor entirely aquatic. To investigate locomotor behaviors of aquatic tetrapods in aquatic ecosystem boundaries, we measured kinematic patterns across different water-depths in eastern newts (Notophthalmus viridescens, n = 6). In terrestrial environments, Notophthalmus walks; forward propulsion is driven almost exclusively by the limbs and axial bending in the form of a standing wave, but the axial body frequently collapses onto the ground during limb swing phases (similar to patterns reported in mudskippers). In aquatic environments, Notophthalmus typically adopts "walking-like" limb-driven locomotion at slow speeds, axial swimming at fast speeds where forward propulsion is driven almost exclusively by lateral undulations of the axial body forming traveling waves (previously reported in crocodilians, salamanders, and aquatic fishes), and intermediate patterns at moderate speeds where lateral undulations of the spine and limb cycling frequencies are both present but unsynchronized (previously reported in lungfishes). In semi-aquatic environments, Notophthalmus produces a walking-like footfall pattern, but also slides continuously along on its belly (similar to patterns reported in crocodilians). This wide repertoire of locomotor capabilities suggests that locomotion in Notophthalmus is modulated in response to both varying environmental conditions and speed. This supports the overarching hypothesis that locomotor behaviors in smaller ectotherms are not characterized by abrupt gait transitions, but instead vary along a continuum.

700 Joshua Stueckle, Asher Marvy, Suzy Renn

Social dynamics of infanticide in a mouthbrooding chiclid fish

Parental care is critical for offspring survival in many species, yet parenting is energetically costly and balanced against future reproductive potential. Mouthbrooding, a costly parenting method sometimes resulting in infanticide, provides an interesting system to address this decision. We use the maternal mouthbrooding species, Astatotilapia burtoni. Females brood young in the buccal cavity for 1–3 weeks, where they cannot eat, losing mass. Nevertheless, mothers shelter fry in their mouths at night post-release. My hypothesis was that if social dominance impacts parental care, the dominant female would be less likely to consume her fry. We used 24/7 recording to quantify care from early spawning until the female consumed or consistently ignored their fry. Females were housed in 15 gallon divided tanks, which allowed visual interaction with another female of matched brooding stage. Behavioral observations were made every 1–2 days for 10 minutes to quantify aggression, which increased in the week before release. Following release the mothers accepted fry into their mouths at night for 6–12 days before ignoring or consuming them, over which time they typically accepted fry later at night and (not statistically significantly) released them earlier in the morning, suggesting reducing investment. Contrary to my hypothesis there wasn't evidence that the other fish's aggression impacted whether the fish consumed or ignored fry. Future experiments should allow physical contact, better matching natural social situations.

546 Yunxing Su, Rose Weinbaum, Eckart Meiburg, Darcy Taniguchi, Dustin Carroll, Tihomir Kostadinov, Monica Wilhelmus

Quantifying large-scale transport by diel vertical migrations of mesozooplankton

Diel Vertical Migrations (DVM) of mesozooplankton aggregations are the largest animal movement on Earth. While DVM have been hypothesized to trigger large-scale vertical nutrient transport in the upper ocean, much of the discussion has focused on the length scales at which kinetic energy is introduced into the system by a vertically migrating organism swarm. However, we still lack methods for scaling lab results to inform the physics in complex marine environments. Here, we outline a new approach for assessing the effect of DVM on the global ocean by: (1) characterizing DVM from active and passive ocean-color satellite observations; (2) developing a lab-based, continuum model of fluid transport; and (3) implementing the acquired DVM characteristics and swimmer parameterization in a global-ocean biogeochemistry model. In this talk, we focus on point (2) where flow field measurements of relevant copepod species for both an individual swimmer (bright-field microPIV) and organism swarms (2-D PIV) inform the discretization of a continuum swimmer model as a function of aggregation density and migrating direction in fluids with and without density stratification. The energy length scales of the organism-induced flow fields will be characterized to assess the associated fluid transport. Our study will set an important new baseline for incorporating organism behavior and biological processes into state-of-the-art ocean circulation models to quantify the effects of environmental changes on the structure of marine ecosystems.

1842 Banu Subramaniam

Linnaean libertines: the queer possibilities of plants

How did plant sexuality come to so hauntingly resemble (colonial) human sexual formations? Why do we have binary frameworks of male/female and selfing/outcrossing, active male and passive females – all of which resemble (western) categories of sex, gender, and sexuality? Tracing extant language of sex and sexuality in plant reproductive biology, I examine the histories of science to explore how plant reproductive biology emerged historically from formations of colonial racial and sexual politics, and how evolutionary biology was premised on the imaginations of race(d) heterosexual romance. Drawing on key examples, the paper aims to (un)read plant sexuality, and sexual anatomy and bodies to imagine new possibilities of plant sex, and sexualities, and their relationalities. If plant sexuality was modelled on human sexual formations, might a re-imagination of plant sexuality open up new vistas for the human?

552 Madeline Sudnick, Erin Sauer, Sarah DuRant

Influence of a previous infection on Mycoplasma gallisepticum transmission in canaries.

Physiological processes of hosts govern how pathogens can establish infection. In diseases that remain common in the environment, physiological differences between first infection and reinfection can influence disease patterns by altering transmission dynamics. The bacterium Mycoplasma gallisepticum (MG) causes severe conjunctivitis in House Finches and the likelihood of birds encountering the pathogen multiple times is high. Birds infected with the same MG strain maintain partial resistance to reinfection and have milder eye lesions. Therefore, re-infected birds could be less likely to spread the disease due to reduced bacterial depositions. To determine if previous infection with MG alters the likelihood of transmission during a subsequent MG infection event we placed birds into flocks of four individuals either completely naïve to MG or previously exposed to MG once. One index bird in each flock was inoculated with MG. MG was considered transmitted within a flock when a non-index bird showed an eye score above zero or tested positive for MG through qPCR. Preliminary data indicate that MG is more likely to transmit in flocks experiencing first infection ($n = 3$ of 5) than in flocks experiencing second infections ($n = 0$ of 5). Determining differences in the proportion of flocks with transmission and time until first transmission between naïve and previously infected birds will lead to a better understanding of disease dynamics in wild birds.

1442 Lisa Surber, Eva Fischer

Behavioral, morphological, and hormonal plasticity in cannibalistic poison frog tadpoles

An essential challenge for all animals is to detect and respond appropriately to environmental cues. The tadpoles of dyeing poison frogs (Dendrobates tinctorius) are aggressive and cannibalistic, thus conspecific cues present a unique conflict at the intersection of predation, competition, and resource acquisition. Given the unique importance of these cues, we hypothesized that these cannibalistic tadpoles are phenotypically plastic in response to conspecific chemical cues. To test this, we raised tadpoles in the presence or absence of conspecific chemical cues and analyzed patterns of morphological, behavioral, and hormonal plasticity. Tadpoles reared in the absence of conspecific cues grew faster and were more aggressive than those raised in the presence of conspecific cues. This indicates there could be differences in optimal phenotypic strategy dependent on conspecific density. Given the importance of corticosterone and thyroid hormone in tadpole development and metamorphosis, we also characterized differences in hormone levels between treatment groups, as well as correlations between hormone levels and behavior. Overall, our study informed that cannibalistic tadpoles modify their phenotype in response to conspecific cues and from this we can make predictions about the evolution of traits and their trajectories.

1745 Diego Sustaita, Arianna Ramirez

The mouse's tale: the role of the tail during swimming in the salt marsh harvest mouse

The endangered salt marsh harvest mouse occupies the brackish marshes of the San Francisco Bay estuary, where it is subjected to natural tidal and managed flooding regimes. Previous radiotelemetry work has indicated that mice tend to remain in their habitats despite flooding. Of particular interest is whether salt marsh harvest mice possess specialized swimming capabilities that allow them to tolerate such periods of tidal inundation. We conducted controlled swimming trials to compare the swimming performance of salt marsh harvest mice to other co-occurring rodents in the Suisun Marsh. We digitized high-speed videos of voluntary swimming behavior to obtain estimates of a range of kinematic variables typically used to evaluate swimming performance in aquatic and marine mammals, focusing on the use of the tail, to uncover the functional significance of their relatively long tails compared to coexisting congeneric western harvest mice. Our preliminary results reveal kinematic differences among species, primarily in body pitch angle, tail tip cycle frequency, tail wave amplitude, trailing edge lateral velocity, and wave speed, reflecting differences in their efficiencies for moving through the water. Furthermore, tail trailing edge velocity increases with increasing tail length across species, suggesting a functional link between tail length and speed. These data may help explain differences in microhabitat use among species, based on differences in their locomotor capabilities.

1174 Donald Swiderski, Miriam Zelditch

Modularity of mandible shape, part II: Empirical analyses of squirrels

Variational modularity (higher covariances within subsets of traits than between subsets) is an important feature of intraspecific variation that may cause traits to covary in a pattern that optimizes fitness. Variational modularity may also restrict evolutionary divergence unless the pattern of modularity can evolve. Evolutionary modularity refers to the pattern of evolutionary correlations between subsets of traits, that could be shaped by the adaptive topography and its dynamics or by random genetic drift as well as by the structure of variation. In this study, we analyze mandibular shape variation in squirrels, which diverge in multiple functional and ecological directions. We evaluated the relative fit of modularity hypotheses based on development, genetics and function, using the covariance ratio statistic (CR). For six of seven species, the best fitting models of variational modularity had at least four modules, with the condyloid process, molar and incisor regions in separate modules. In most of these species, three or four such models fit equally well and significantly better than any of the two-part models that were tested. In analyses of evolutionary modularity in both tree squirrels and ground squirrel lineages, no model fit significantly better than any other. The lack of a clear signal of evolutionary modularity may be the result of divergence in multiple directions obscuring multiple patterns coordinated changes.

139 Caitlyn Swiston, Frank Fish, Megan Leftwich

On the flip side: Hydrodynamic function of the hind flippers of three otariids

Importance of the hindflippers of otariids for swimming has been largely overlooked. Otariids are highly maneuverable in water. Hindflippers play a crucial role in making quick turns with small radii. Hindflippers of three otariids were examined, California sea lion (Zalophus californianus; CSL), Guadalupe fur seal (Arctocephalus townsendi; GFS), and Northern fur seal (Callorhinus ursinus; NFS). The three hindflippers were morphologically different. CSL exhibited the largest span while NFS had a relatively smaller span. Though different in size, the aspect ratios of the hindflippers were similar, ranging from 0.111-0.117. Location of the claws differed. For NFS, the claws were farthest from the flipper tip, whereas for GFS, they were close to the tip. Hindflipper sweep angles for CSL, GFS, and NFS were 8°, 10.4°, and 4.3°, respectively, giving a delta wing appearance. Each hindflipper was 3D scanned to build 3D models for hydrodynamic testing in a flow tank at 1 m/s. A force transducer was used to measure the forces on each flipper at angles of attack (AOA) ranging from -10° to 32o. Lift coefficients for the three otariids hindflippers ranged from 0.8-1.0 without stalling. Lift/Drag ratio was highest for GFS at 2.5 at 12o AOA while CSL and NFS showed maximum values at 14o AOA. Despite morphological differences, hydrodynamic performance of the hindflippers was remarkably similar.

911 Santi Tabares-Erices, Grace Guo, Irby Lovette, Anusha Shankar

Reassessing torpor use across mammals: does diet influence torpor?

Torpor is a physiological strategy some animals use to save energy in response to low-energy environmental conditions. By lowering metabolic rate and allowing body temperature to passively approach ambient temperature, organisms can reduce energy use. Animals using this strategy can be categorized into two main groups, 'daily torpor' users and multi-day or multi-week 'hibernators'. Both birds and mammals are capable of using torpor, but whether this is due to convergent evolution or to a deeply conserved trait remains unknown. Yet not all birds and mammals have been observed to use torpor, due to lack of data, negative effects, or lack the ability to do so. Ruf & Geiser's 2015 phylogeny of endothermic torpor users revealed patterns across just 215 species. We expand upon this work with an additional ∼80 species and how diet and habitat influence torpor use. While this is a small subset of the roughly 15000 species of vertebrate endotherms, there are various representatives from across the board enabling wider inferences about torpor use. I will present on this updated mammal phylogeny, and specifically assess whether diet is correlated with the use of hibernation vs. daily torpor. With this global dataset, we hope to link ecological parameters with torpor use across vertebrate endotherms.

1148 Nils Tack, Monica Wilhelmus

Hot and cold: physiological and physical effects of temperature on metachronal swimming

Metachronal swimming is characterized by the sequential beating of phase-shifted swimming legs (pleopods). It is widespread in crustacean groups, like shrimps, inhabiting the transitional flow regime in which both viscous and inertial effects are significant. At this scale, environmental factors such as sea surface warming or phytoplankton blooms could affect the performance of organisms by altering metabolic functions and fluid properties. However, current theories do not establish a link between the environment and pleopod kinematics. Using Marsh Grass shrimp (Palaemon vulgaris), we independently manipulated temperature and viscosity matching natural extremes to separate physiological from physical effects. We performed a multivariate analysis to explore several kinematics parameters. As expected, reducing the water temperature from standard coastal conditions (while keeping viscosity constant) induced a physiological response of the swimming muscles, quantified as a reduction of the pleopod beat frequency. The less intuitive case of increasing the fluid viscosity from the mean value encountered in the ocean (without varying temperature) reduced the phase lag between adjacent pleopods. Interpleopod interactions were thus observed to mitigate the increase in viscous drag. Interestingly, this response was observed to be independent of temperature suggesting metachronal swimmers can maintain performance even in the presence of high viscous forces while having a low metabolic function (due to low temperature). We will leverage these new insights to develop new bio-inspired solutions for underwater locomotion.

1814 Natalia Taft, Noah Bressman, Thaddaeus Buser, Benjamin Taft, Adam Summers

Functional trade-offs in the pectoral fin rays of intertidal versus subtidal sculpins

Sculpins that live in the intertidal zone experience greater physical forces from waves and currents than sculpins in the subtidal zone. Here, we examine variation in the cross-sectional shape, ossification, and estimated flexural stiffness if the pectoral fin rays in intertidal versus subtidal sculpins. Flexural stiffness is the result of the material properties and shape of a structure. We collected cross-sectional shape data from CT scans of the pectoral fins from intertidal and subtidal species. Our analysis of the size-corrected second moment of area predicts that intertidal species should have more flexible fin rays than subtidal species, even though they are also more highly ossified. This is true for the ventral fin rays that routinely contact the substrate in these species, and for the dorsal fin rays that do not. Subtidal species have pectoral fin skeletons that are not as well ossified, but have fin rays we predict should be more stiff, based on their shape. We hypothesize that there is a trade-off in toughness and flexibility, and that the two components of flexural stiffness, material and shape, will vary based on the functional demands on fin rays of fishes in different environments.

224 Cheyenne Tait, Paul Katz

Sensory integration occurs at multiple levels in a nudibranch brain

In mammals and insects, multisensory integration occurs in dedicated synaptic regions of the central nervous system (CNS). In molluscan chemosensory systems, second-order neurons are found in the periphery, a major divergence from other taxa. Here, we used axon tracing techniques and immunohistochemistry to determine where higher-order multimodal integration may be occurring in the nudibranch mollusc Berghia stephanieae. Neurobiotin fills of the nerves leaving the chemosensory rhinophore labeled projections to three-dimensional glomerular structures in both the cerebral and rhinophore ganglia. Simultaneous fills of the left and right rhinophore nerves revealed locations of bilateral integration. Immunohistochemical labeling for serotonin, histamine, and octopamine as well as Small Cardioactive Peptide labeled axon terminals in the densest neuropil structure in the CNS that the rhinophore nerves project to. The presence of these neurotransmitters in specific fields is reminiscent of insect mushroom body neuroanatomy, suggesting that it might serve a processing function. Filling nerves associated with the eye and the chemotactile oral tentacle labeled subdivisions of neuropil associated with different sensory modalities, as well as some zones of convergence. In summary, structured neuropil regions the central cerebral ganglion and the more peripheral rhinophore ganglion are sites of multisensory, bilateral convergence. Thus, in contrast to mammals and arthropods, higher-order processing seems to occur in various areas of the CNS as well as the periphery of this mollusc.

993 Katie Talbott, Ellen Ketterson

Investigating the roles of tolerance, resistance in functional responses to Plasmodium inoculation

Parasitism is ubiquitous among animals, yet the factors driving heterogeneity in host functional responses to parasitism remain understudied. Our earlier work showed that male songbirds (Junco hyemalis) with long-term (i.e., 'chronic') infections with Plasmodium, the causative agent of avian malaria, tend to be heavier, have higher hematocrit, and have larger cloacal protuberances (i.e., sperm storage capacity) than males without chronic infections. This pattern persisted following experimental inoculation with Plasmodium, but we did not observe an effect of chronic infection on GnRH-induced testosterone levels ('max T'), sperm count, or proportion of non-deformed sperm. In this presentation we ask whether the effect of experimental Plasmodium inoculation varied between males with and without chronic infections in relation peak parasite load. Parasite load reflects the interaction between the host's immune response and the parasite's ability to reproduce. Low peak loads could indicate a strong host immune response, which is predicted to be energetically costly to the host (i.e., resistance). Conversely, high loads might reflect a reduced host immune response, presumably to prioritize allocating energy to self-maintenance and/or breeding (i.e., tolerance). We also ask whether host tolerance and/or resistance explained variation in functional responses (mass, hematocrit, cloacal protuberance volume, max T, etc.) to experimental Plasmodium inoculation. Additionally, we will discuss whether the phenomena of tolerance and resistance are mutually exclusive in this host-parasite system.

1629 Princely Tamfu, Justin Andries, Ioulia Bespalova, Heather Axen, James Waters

Testing hypotheses about metabolic compensation and the ecophysiology of phenotypic plasticity

Phenotypic plasticity encapsulates diverse mechanisms by which organisms can alter their own trajectory in response to environmental variation. One of the major drivers of phenotypic plasticity is an organism's response to temperature. Exposure to different thermal climates over acute or longer time scales can induce beneficial acclimation and shifts in their critical upper and/or lower thermal limits. Are there costs to being this flexible? To answer this question, we are studying the metabolic phenotype and thermal sensitivity in Drosophila pseudoobscura. A species known for its induced allopatric speciation, that has yielded genetic differences in populations gathered from place to place. Flies from four locations include pairs at similar average yearly temperatures but with different annual temperature variation (two colder sites, and two hotter sites respectively). We measured the metabolic rate of flies from these four populations in a factorial design so that each is reared at 15, 20, and 25 degrees C and subsequently measured across a thermal cycle consisting of altering high and low temperatures. High-throughput metabolic phenotyping failed to support consistently reliable respirometry baselines, but single-throughput measurements were successful. This project was supported by funding from NSF EPSCOR RII Track 2 FEC (OIA 1826689).

956 Hails Tanaka, Robert Podolsky

Can parasites guard their investment by protecting host structures on which they depend?

Parasites have widespread effects on their hosts, including changes in growth, resource allocation, behavior, reproduction, and mechanical properties. A number of decapod crustaceans are parasitized by rhizocephalans, a strictly parasitic clade related to barnacles. As in other cirripedes, the life cycle includes a cyprid larval stage, which in the case of rhizocephalans locates a host and injects cells into the body. The female parasite then ramifies throughout the host body to produce an interna, which derives its nutrition from host tissue. Ultimately the parasite castrates the host, stops its molting, and produces on the host abdomen an externa, which includes the ovary. Given that the parasite depends entirely on host feeding, we examined two hypotheses related to loss of chelae used in host feeding, with the host xanthid Eurypanopeus depressus and its cirrepede parasite Loxothylacus panopaei. First, we looked at the force needed to induce autotomy in the chelae, hypothesizing that parasites would benefit from somehow increasing the tenacity of feeding limbs. Second, we examined the hypothesis that loss of both limbs would lead to release of the host from the inhibition on molting imposed by the parasite, which would allow the host to regrow chelae. Our results did not support either hypothesis, suggesting there are important limitations on the ability of these parasites to adaptively control the biology of their hosts.

348 Daniel Tanis, Brian Beatty, Edwin Dickinson, Michael Granatosky, Melody Young

What drives tetrapod gait choices? Cost landscapes and optimization criteria during walking

While the rules and trends driving tetrapod gait choice are considered well-established, there remains considerable uncertainty as to why certain lineages adopt specific locomotor patterns. Moreover, some gait patterns (i.e., diagonal sequence lateral couplet) have never been observed in nature. We developed a computational model to simulate stability, limb forging, and energetic costs across all possible combinations of phase and duty factor during quadrupedal walking. We then overlaid these cost landscapes with verified gait patterns from >250 species of quadrupeds. From these simulations, we demonstrate that the diagonal sequence lateral couplet gait has very high energetic costs and subjects the animal to an inherently unstable stride in which the center of mass is frequently outside the triangle of support. This model was then used to assess optimization criteria underlying tetrapod gaits. We show that while reptiles, amphibians, and crocodilians preferentially select gait patterns to maximize stability, mammals optimize gaits that minimize energetic costs. Arboreal specialists use gaits that minimize torque and vertical forces, serving to reduce substrate oscillations. Our data provide a mechanistic explanation as to why quadrupeds select particular gait sequences and why the diagonal sequence lateral couplet gait represents a locomotor "no man's land". Overall, we provide a biomechanical framework within which to assess locomotor behaviors and the selective criteria underlying tetrapod gaits.

187 Abigail Tarleton, Katie Statile, Andrea Frías-Vellón, Jason Macrander

Is 'Reef Safe' Sunscreen Really Safe?

The most common active ingredient in sunscreens are chemical UV blockers (i.e., octocrylene and oxybenzone), which are known to be harmful to sea anemones and corals. This has led to the creation of "reef safe" sunscreens. These sunscreens currently use physical blockers such as metals (e.g., Zinc Oxide) which are believed to be harmless. To examine these claims, our study quantified differences in the biochemical response of sea anemones when exposed to sunscreens with different types of active ingredients. We used Exaiptasia pallida to study the impacts of various sunscreens on survivorship and stress response. Over a two-week period, we exposed E. pallida to one octocrylene sunscreen and three different Zinc-based sunscreens. When compared with the octocrylene sunscreen, one Zinc-based sunscreen resulted in higher phenotypic signs of stress (i.e., tentacle retraction) and an increased mortality rate. We observed similar results in juvenile life stages of Nematostella vectensis and with adult tube anemones (Ceriantheopsis americana). Using an RNAseq approach, we evaluated the differential gene expression profiles of E. pallida after exposing them to different types of sunscreens. Our differential gene expression analysis recovered a significant upregulation in stress response genes and programmed cell death. Overall, our results indicate that unregulated and untested "reef safe" labels may be less reliable than previously thought because these brands could include other ingredients or unknowns which could be more harmful.

33 Liam Taylor, Richard Prum

There are no invariants in the phylogenetic natural history of avian delayed reproduction

Both classic life history theory and classic phylogenetic comparative methods make special attempts to identify strict relationships among phenotypic characters across large clades. Here, we argue that the life histories of birds undermine this reductive goal. We present the first phylogenetic study of age at first reproduction in birds. We start by showing the diversity of behavioral, social, and sexual development (as opposed to somatic development) that underlies avian adolescence. As a case study, we select three developmental characters important for adolescent birds: coloniality, lekking, and cooperative breeding. We show that a good phylogenetic model of delayed reproduction in birds would incorporate information about all of these characters. However, because our chosen characters are neither analogous nor homologous with one another, the phylogenetic history of delayed reproduction in birds becomes irreducible to a single causal narrative. We then investigate how developmental evolutionary dynamics in birds restructure the causal ties between traits. First, we find a statistically significant relationship between body mass and age at first reproduction in our overall dataset. Second, we trace how this relationship shifts, and even disappears, as evolutionary innovations such as lekking reknit the material relationships between development and reproduction. In sum, we find that birds resist a generalized view of life history evolution, even when we "account for the phylogeny."

1271 Danielle Taylor, Daisy Dan, Gavin Svenson, Joshua Martin

Comparative morphology and mechanics of the predatory foreleg of praying mantis species (Mantodea).

Praying mantises (Mantodea) are a relatively small but diverse order of insects. They all share a crucial characteristic: they are all predators that use their forelegs to capture prey. This common task is accomplished by a variety of ecomorphs specialized for a substrate (grasses, soil, bark, etc.), hunting strategy (ambush vs pursuit), or mode of movement (climbing vs running). Here, we describe the morphological variation among forelegs, and compare the biomechanical properties across the phylogeny of mantis species. We have adapted a machine-learning algorithm (DeepLabCut) to identify 24 landmarks on the femur and tibia of over 500 species of mantises. We describe the variability of the shape space across the phylogeny, and identify subgroups with extreme forms. Using a geometric relationship between the shape of the foreleg and the optimal size of prey, we find that the majority of species occupies a narrow range in this space. A small number of species with adaptations for camouflage are limited to smaller prey, and a larger group that specialize in pursuing prey on a flat substrate can capture larger prey. We then use micro-CT to capture the internal morphology of the foreleg in a subset of species, particularly the volume of flexor muscle and the arrangement of the tendon. These are used to construct a biomechanical model of the closing force these species can generate.

1603 Kari Taylor-Burt, Joseph Thompson, William Kier

A superelongating obliquely striated muscle in the bloodworm, Glycera

Without the limitations imposed by rigid skeletal elements, shape changes in soft-bodied invertebrates sometimes require large muscle operating ranges. The obliquely striated mesentery muscles of glycerid polychaete worms, for example, likely experience large length changes in vivo as the proboscis of these worms is extended during burrowing and prey capture behaviors. Although their function is unknown, the muscles are positioned appropriately to aid in proboscis retraction and positioning of the digestive tract following proboscis extension. We measured the length-force relationships for bloodworm anterior mesentery muscles (7th-16th muscles, $n = 5$). They exhibited very broad length-force relationships, with 90% of the maximum force being produced over a length range of $\sim$0.49L0, where L0 is the length at which maximum force is produced. This range, which is broader than at least some vertebrate smooth muscles, is consistent with superelongation (i.e., the ability of a muscle to produce high force over extreme length ranges), and is comparable to the range observed for the only two known superelongating obliquely striated muscles. Whether the mesentary muscles' ability to superelongate in vitro reflects their in vivo operating range remains to be determined. Comparison of obliquely striated muscles capable of superelongation with those that are not may shed light on the physiological mechanism(s) of superelongation.

1431 Rory Telemeco, Cha kong Thao, Kira Gangbin, Nicole Gaudenti, Devon Mitchell, Keyanna Pinto, Kathryn Ramirez, Emily Taylor, Vanessa Valencia, Michael Westphal

Plant Communities Determine Thermal Exposure of Endangered Blunt-nosed Leopard Lizards

Desert-dwelling species are thought to be at risk of climate-change induced decline because of their low thermal-safety margins. In such cases, the availability of thermal refugia could determine population persistence. Blunt-nosed leopard lizards (Gambelia sila) occur in harsh, San Joaquin Desert habitats with and without the presence of shade-providing shrubs. We hypothesized that lizards without access to shrubs are less able to maintain suitable body temperatures, especially at low latitudes. We used temperature-sensitive radio telemetry to collect field body-temperature data from four populations throughout the active season: one site with shrubs and one without shrubs at both the southern and northern extents of the range. We also used physical models to describe the availability of operative body temperatures at each site. As predicted, lizards cooccurring with shrubs were active for more hours per day. However, lizards cooccurring with shrubs displayed lower thermoregulatory accuracy. This resulted from inactive lizards at the shrubless sites remaining in thermally ideal refugia for much of the day whereas active lizards on landscapes with shrubs allowed their bodies to approach dangerously high temperatures during afternoon activity. Sites at different latitudes were broadly similar. Our results confirm the importance of thermally-complex habitats for successful thermoregulation and the role of plant communities in providing such habitats.

1189 Yiting Ter, Erica Westerman

Dynamic gene expression during a social learning event in a butterfly

In many animals individuals learn to change their mating preferences after exposure to a new phenotype. In the butterfly Bicyclus anynana, both sexes learn visual preferences for wing patterns after a three-hour exposure to a new phenotype, and exhibit changes in brain gene expression after this three-hour exposure. However, gene expression associated with learning and memory can be dynamic, with both immediate early and late responses to stimuli. Therefore, genes critical to learning could be expressed at timepoints other than three hours. To identify both immediate early and late transcriptomic responses during learning, we conducted a RNA-Seq time series by exposing female B. anynana to an unfamiliar male phenotype for different exposure periods, from 30 minutes to three hours, and pairing those with naïve females isolated for the same amount of time. By comparing the transcriptomic profiles between trained and naïve females, we found a peak of differentially expressed genes (DEGs) at one hour of exposure. Of these DEGs, 40 are associated with learning and memory, including synapsin, which is known to influence neural activity. We also found one gene (TFIID subunit 6) which plays a role in initiating transcription, differentially expressed at all time points. Our results suggest that peak transcriptional response to social learning may occur during and not after training, and offer new insights into the dynamic genetic underpinnings of social learning.

545 Emily Terrill, Eva Fischer, Jesse Delia

Disentangling the cue for parental water provisioning in glassfrogs (H. fleischmanni)

Parental behavior has a major effect on offspring survival and fitness and is thereby a prominent force in social evolution. While the significance of parental care is clear, we understand little about the mechanisms by which parental care initially evolves. This study leads a series of integrative investigations that test the central hypothesis that novel behaviors evolve via co-option of existing mechanisms. To test our hypothesis, we focus on the co-option of water-balance pathways in the evolution of parental water provisioning in glassfrogs (H. fleischmanni). Glassfrogs are a unique and optimal system in which to explore parenting and water balance due to their consistent care behavior (involving water provisioning) and their specialized osmoregulatory physiology. As a first step, we disentangle the source of the cue that triggers parental water provisioning by considering the organism, its environment, and its physiology. Caring frogs were randomly assigned to one of three treatment groups in which we manipulated (1) environmental humidity, (2) parental hydration level independent of environmental conditions, and (3) clutch hydration level independent of parental or environmental conditions. We quantified the behavioral response to each manipulation by documenting care bouts and duration and the amount of water provisioned. These findings will further our understanding of the mechanisms underlying water-balance and care behaviors and the role of behavioral and mechanistic co-option in the transition to parental water provisioning.

106 Jennifer Terry, Lorin Neuman-Lee, Emily Letner, Alexia Vanoven

Innate immune component tradeoffs in a wild freshwater turtle

The innate immune system is comprised of multiple components that provide non-specific protection against potential pathogens. These components (e.g., non-specific leukocytes, complement, antimicrobial peptides, and natural antibodies) have different roles and mechanisms of action. Mounting an immune response is costly, and it is likely beneficial for organisms to prioritize investment toward specific components in a non-uniform manner. We aimed to investigate the presence of innate immune component prioritization and thus tradeoffs in a wild freshwater turtle. We captured 87 (N; females = 45, males = 42) adult red-eared sliders (Trachemys scripta) in May 2022 in Arkansas, USA. We collected blood samples within 0-3 min, 120 min, and 240 min post-capture or disturbance of net. We used fresh, frozen-thawed, and frozen thawed + heat-treated plasma in bacterial killing assays and hemagglutination-hemolysis assays to assess function of immune components. Our results suggest that while red-eared sliders do not depend on antimicrobial peptides, investment in non-specific leukocytes and complement varies by context (e.g., stress-state). This study provides evidence that tradeoffs occur within the innate immune system, component prioritization is context-dependent, and individuals within populations vary with immune component prioritization. By understanding how these abundant reptiles modulate innate immune function, we can better understand vertebrate immunology and ecophysiology.

1297 Caroline Terry, Kyle Hulse, Wes Dowd

The prevalence and significance of temporal environmental variation in marine biology experiments

Temporal environmental variation is ubiquitous in nature and is increasingly recognized as influencing organismal function. Additionally, the frequency and magnitude of environmental extremes are increasing under climate change, highlighting the importance of explicitly considering temporal variation when predicting organismal responses. Despite increased recognition of temporal environmental variation's biological effects, it remains unclear how it is incorporated into experimental designs. Here, we evaluate the extent of inclusion and significance of temporally varying factors in marine biology research. We compiled 2,364 publications citing at least one of 10 foundational publications discussing the importance of temporal environmental variation. We then explored whether concepts presented in the foundational papers influenced the field of marine biology by determining how frequently temporal variation was included in empirical study designs over time. For those studies that included temporally varying conditions, we evaluated the extent to which various taxa and environmental factors have been over- or under-represented, and whether including varying conditions led to differential outcomes compared to static conditions. Of the 221 marine empirical publications identified, only 18% included temporally varying environmental treatments. Consideration of temporal variation in experimental design increased over time and nearly all studies including it found significant effects. Thus, we conclude that including realistically varying environmental variables in marine studies – though still relatively rare – is essential for predicting responses to future scenarios under climate change.

1827 Kristin Tessmar-Raible

Timing physiology and behavior by moon and sun: molecular insight from the annelid Platynereis

While sun(light)-dependent chronobiology has been studied in great detail, moonlight has been largely neglected for its role on animal physiology and behavior. This is largely due to the lack of suitable model systems whose biology is prominently influenced by the moon. This is the case for the nocturnal bristle worm Platynereis dumerilii, for both its monthly and daily inner oscillators. We thus used this species to unravel molecular mechanisms for sun- versus moonlight discrimination and for moonphase detection.However, any organism that uses light as a synchronization cue for its inner oscillators actually faces the challenge to discriminate between sun- and moonlight. In many species moonlight (and even specific moonphases) should impact on the endogenous oscillators. Other species, like the diurnal fruit fly Drosophila melanogaster, need to prevent moonlight from shifting their endogenous circadian clock under naturalistic conditions. Thus, the molecular mechanisms unraveled in a marine annelid might even help us to understand recently uncovered, as well as classically reported plasticity in human daily behaviors that – enigmatically- sometimes can co-vary with the lunar cycle.

775 Dimitri Theuerkauff, Nine Doutreloux, Michela Patrissi, Michel Marengo

Reproductive biology of a spiny lobster: variations after more than forty years under pressure

The spiny lobster Palinurus elephas is an iconic species widely distributed through the Northeast Atlantic and the Mediterranean Sea. It is an important economic marine resources but also an endangered species due to fishing pressure. In order to better understand its reproductive biology, 492 individuals were collected throughout the annual reproductive cycle in 2020-2021. The gonadosomatic index (GI), maturity status (morphological and physiological) and fecundity of females were assessed and compared with first estimates from the 1980's around Corsica (France). GI was also assessed in males as well as new characters of morphological maturity. Our results give a better description of the reproductive cycle of P. elephas. Moreover, they also showed a reduced size at physiological maturity and an increased size-fecundity relationship in Corsican waters. Reasons for these variations are discussed and may be attributed to different factors such as densities or environmental variations induced by fishing pressure or global changes. These results highlight the need to monitor key life cycle parameters in the context of the Anthropocene.

1337 Dimitri Theuerkauff, Rémy Agniel, Claire Varlet, Nine Doutreloux, Michel Marengo, Cédric Picot

Senescence in crustaceans: a new insight from the spiny lobster Palinurus elephas

Age estimation is a major challenge in crustaceans. Unless other species, the loss of hard structures during periodic moult prevents a direct and accurate estimation of aging. Some metabolic biomarkers are used to estimate the crustaceans' physiological age and lead to interesting results. Among them, a relation between growth and lipofuscin accumulation in lobster cerebral ganglions was shown. Aging leads to protein modifications especially protein oxidations. Their accumulations during aging are well described for mammalian models. We have investigated aging biomarkers as lipofuscin accumulation in the olfactive gland, lipid peroxidation adducts and carbonyl content in the hepatopancreas of an iconic spiny lobster species of the Northeast Atlantic and the Mediterranean Sea, also representing an important economic marine resource: Palinurus elephas. Results from about a hundred of spiny lobsters around Corsica with a large range of cephalothorax length (from 52.52 mm up to 186.7 mm, which is one of the maximum size reported for this species) are discussed. We confirmed the potential of lipofuscin assays for a broad range of specimen sizes as shown in the literature for other decapodes. Surprisingly, biomarkers as HNE, were particularly low in biggest individuals while smaller sizes showed high variability, suggesting some individual's capacity for cellular defence mechanisms against oxidative damage. This study could pave the way for a new method combined with an accurate evaluation of spiny lobsters' growth.

1129 Simon Thill, Suzanne Kane, S. Tonia Hsieh

How toe spacing affects impact dynamics during passive "foot" intrusions into poppy seeds

Granular materials are challenging to navigate due to their nonlinear behavior and ability to change between fluid-like and solid-like states. However, some sand specialist lizards exhibit greater and more robust running speeds than non-specialist lizards. Preliminary results from a study of subsurface foot movement revealed that these species space their toes approximately 3-5 particle diameters apart during a step, whereas non-specialist lizards often use spacings outside of this range. Curiously, our previous simulations show that when two horizontal and parallel cylinders are intruded into a granular medium, they produce the maximum force at the same particle spacing. Here we used 3D printed models of simplified lizard feet to investigate how toe spacing and impact velocity affect intrusion dynamics into poppy seeds. Models had toes spaced 1, 3, 5, and 7 particle diameters apart and were dropped from three different heights to include, and bracket, foot intrusion speeds in running lizards. We recorded impact forces, 3-axis acceleration and rotation data, and high-speed video (1069fps) for n = 5 trials per condition. Consistent with our results from our other studies, we observed that patterns of work done and torque correlated with toe spacing. The relevance of this work to how animals run on sand will be explored.

1087 Rysa Thomas, Lauren Merlino, Deborah Lutterschmidt, M. Rockwell Parker

Sex- and life-history-dependent variation in stress hormone receptor expression in garter snakes

Life-history transitions are energetically expensive, and the molecular toggle between glucocorticoid (GC) activity and energy storage is a central-yet-understudied component of vertebrate homeostasis. GCs function through tightly regulated activation of the glucocorticoid (GR; low-affinity) and mineralocorticoid (MR; high-affinity) receptors. In species with extreme life-history transitions, individuals modulate expression of these receptors to budget energy across these demanding events. Red-sided garter snakes emerge from an eight-month dormancy to a brief-but-explosive mating event and subsequent long-distance migration, all while aphagic/non-feeding. Plasma GCs fluctuate to balance opposing energetic demands, peaking during mating and decreasing throughout migration. Because GCs act through receptor activation, we measured expression (qPCR) of GR and MR in energy storage tissues of snakes while either courting/mating or migrating in spring. We observed sex differences in the liver of mating snakes, and MR expression was positively correlated with GR. Because males and females differ in energy storage strategies, we expect expression of GR and MR to be highest in male skeletal muscle and female liver and to observe comparatively decreased expression of both receptors in all tissues of migrating snakes. Given the remarkable ability of this species to moderate energy use across life-history events, our results will connect patterns of energy budgeting with the molecular stress response during the transition from mating to migration.

1112 Rysa Thomas, Dima Salih, Emily Plant, Fareeha Ahmed, Ash Eury, M. Rockwell Parker

Stress hormone-receptor relationships and their dose-dependency in garter snakes

Metered allocation of energy stores to reproduction or survival presents a major challenge for vertebrates with truncated active windows. Glucocorticoids (GCs) are crucial mediators of energy balance by acting at target tissues via receptor-induced modulation of metabolism and energy mobilization. Two receptors transduce the effects of GCs: glucocorticoid (GR; low-affinity) and mineralocorticoid (MR; high-affinity) receptor. In our study species, the red-sided garter snake, Thamnophis sirtalis parietalis, GCs fluctuate annually, and during peak reproduction their stress response is suppressed yet GCs are maximal. We hypothesize that GC receptor expression is dynamic and responsive to GC manipulation during the energy storage phase (summer) of the annual cycle in this species. We administered low and high doses of two glucocorticoids (corticosterone[CORT], dexamethasone[DEX]) for two weeks in summer to male T. sirtalis parietalis and measured expression (qPCR) of GC receptors in energy storage tissues. We expect GR and MR expression to be positively correlated and show higher GR expression in skeletal muscle compared to liver, and we expect GR expression to be highest in the high dose treatments based on research in other vertebrates, indicating increased tissue sensitivity. This is the first study to test dose-dependent patterns of GC receptor expression in reptiles, and our results will illuminate the physiological mechanisms that manage liberation of stored energy and directly control sensitivity to exogenous stress in animals with dynamic life-histories.

1649 Ashlyn Thomas, Dante Nesta, Sarah Lagon, Cristina Ledón-Rettig

The effects of early-life diet and social environment on testosterone and immune function

Developing organisms often must contend with variation in diet and social environment. Characterizing how such environmental cues interact to influence circulating hormones, and consequently shape physiological responses, is a critical step in understanding how organisms adapt, or fail to adapt, to environmental variation. Here, a two-part investigation was conducted in the spadefoot toad Spea bombifrons to determine whether early life social environment (high vs. low population density) and diet (detritus vs. shrimp) influenced testosterone levels, and if those testosterone levels could impact immune responsivity in tadpoles. Social density had a significant impact on testosterone concentrations, with low density animals exhibiting heightened levels of testosterone. Functional manipulation of testosterone, with the aromatase inhibitor Fadrozole, revealed that testosterone significantly depressed tadpoles' swelling responses to an injection with a vehicle, but not to a specific immune challenge (phytohemagglutinin, or "PHA"). Severe swelling reactions only occurred in PHA injected animals from the control group, whereas none occurred in the Fadrozole treated group, suggesting a depressive effect of testosterone on immune responses, although larger sample sizes will be necessary to support this trend. Together, our results indicate that early life social environment can modulate testosterone levels, which in turn might influence immune function, and therefore individual fitness.

1593 Joseph Thompson, Kari Taylor-Burt, William Kier

One size does not fit all: diversity of length-force properties of obliquely striated muscles

Obliquely striated muscles may have evolved independently several times, yet the implications of oblique striation for muscle function are unknown. Contrary to the belief that oblique striation allows superelongation (i.e., high muscle force production over extraordinary length ranges), recent work suggests diversity in both operating length range and length-force relationships (LFRs). We hypothesize that oblique striation evolved in soft bodied invertebrates to allow adjustment of the LFR to match a muscle's in vivo operating range. Thus, we expect variation among LFRs, not universal superelongation. We measured the LFR of five obliquely striated muscles from the inshore longfin squid, Doryteuthis pealeii: longitudinal fibers of the tentacle, funnel retractor, and head retractor, and transverse fibers of the arm and fin. Consistent with superelongation, the tentacle LFR had a long descending limb, whereas the other muscle preparations exhibited limited descending limbs. The LFR ascending limb at 0.6-times P0 (i.e., maximum isometric force) was also significantly broader (p L0; where L0 is the length at which P0 occurred) than that of all other muscles (arm: 0.29 ± 0.03 L0; head retractor: 0.24 ± 0.06 L0; fin: 0.20 ± 0.04 L0, funnel retractor: 0.27 ± 0.03 L0), with smaller but also significant differences observed among the other muscles. Ultrastructural differences between the arm and tentacle may explain how obliquely striated muscles modulate LFRs.

709 Mason Thurman, Steven Lombardo, Ellis Loew, Paul Wills, Christopher Robinson, Aaron Adams

Biofluorescence as a Tool to Resolve Morphological Crypsis in Two Bonefish Species

Morphological crypsis in species complexes poses a challenge to appropriately apply management and conservation strategies. Leveraging of phenotypic traits during sampling or harvest enables rapid in situ species resolution. In the absence of visually apparent differences, biofluorescent expression in species can be a new tool for managers and the public to identify cryptic species. We used biofluorescence in two sympatric, cryptic Bonefish species, Albula goreensis and Albula vulpes, to develop a rapid and inexpensive in situ assay for species identification that can be used by managers and recreational anglers. Under ultraviolet (379–387 nm) and royal blue (440–457 nm) lights, the two species expressed differing biofluorescence upon the iris, axil of the pectoral fins, the vent, and axil of the pelvic fins. Green biofluorescent patterns were most easily discernible under royal blue light while viewing through a Tiffen Yellow #12 longpass filter, though the use of an ultraviolet light with no visual filter was the most cost-effective. We recommend the adoption of biofluorescent field assays for Bonefish using ultraviolet light upon the axil of the pectoral fins and the vent for managers and anglers to differentiate A. goreensis and A. vulpes in real time. This method will allow data to be appropriately attributed at the species level, allowing for more effective management of the economically important western Atlantic Bonefish fishery.

1523 Ben Tidswell, Eric Tytell

Limited Sensory Information Changes Schooling Structure and Behavior of Giant Danios

Schooling is a collective behavior that allows fish to better avoid predators, collect food, and lessen the metabolic costs of transportation. In order to school, and gain the benefits from schooling, fish need to be able to sense the fish around them. In the wild, sensing can be limited by environmental conditions, injury, or disease. Our research aims to investigate how giant danios (Devario aequipinnatus) change their schooling behavior when they have limited sensory information. We limit vision by filming in darkness, and we alter or limit lateral line information by filming in flowing water, or by ablating the lateral line with antibiotics. In darkness, giant danios do not school as well as they do with ablated lateral lines or in light, while the ablated fish school as well as the fish with their lateral line. However, fish in darkness turned toward their neighbors as often as fish in light, indicating that they do have some sense of where other fish are. We believe that fish in darkness may feel safer, and may not want to spend the effort it takes to find other fish to school with. We predict that if we provide a pressure to school by startling fish swimming in darkness they can be made to school in a way that more resembles how they school in bright light.

690 Natasha Tigreros, Goggy Davidowitz

Can nectar-feeding compensate for nutritional deficiencies from the larval diet?

Over the past fifty years, our understanding of tradeoffs has largely been based on Y-models of allocation, which depicts how a fixed amount of resources, from a single pool, must be divided between two (or more) competing traits. Yet, in most systems, the acquisition and allocation of resources underlying tradeoffs are not fixed, as depicted by Y-models, but rather dynamic processes that change continually across an organism's life. This is particularly apparent in organisms with complex life cycles, which acquire nutrients from several fundamentally different food types – e.g., in butterflies, leaf tissue as larvae, and flower nectar as adults. In this study, we examined whether nectar feeding by adult Pieris rapae females modulates resource allocation tradeoffs imposed by a low-protein larval diet. We find that nutrient deficiencies in the larval stage, leading to flight-fecundity tradeoffs, might be compensated with the subsequent acquisition and allocation of nectar nutrients. Our results provide new insights into the functional physiology of tradeoffs and the importance of examining tradeoffs as dynamic processes that may change continually across an organism's life.

1162 Emma Timmins-Schiffman, Jennifer Telish, Chris Monson, Chelsea Field, José Guzmán, Kristy Forsgren, Graham Young

Proteome analysis of coho salmon ovaries reveals the breadth of physiological changes during puberty

The initiation of the first reproductive cycle in female vertebrates (puberty) is due to the activation of the brain-pituitary-gonad axis and results in the recruitment of primary ovarian follicles into the secondary growth pathway. To understand the molecular and cellular events occurring in the ovary that lead to secondary follicle development, we used the semelparous coho salmon (Oncorhynchus kisutch) as a fish model. In this species, all primary follicles are recruited into the secondary growth pathway in a single event, and secondary follicles are synchronized in development. Four classes of ovarian tissue were sampled: early and late perinucleolar stages (EPN and LPN), and early and late cortical alveoli (ECA and LCA). The transition of LPN to ECA represents the initiation of secondary growth. We analyzed ovarian fragments using data-independent acquisition proteomics mass spectrometry and detected >5,000 proteins in the coho ovarian proteome. The LPN to ECA transition represented the largest proteomic shift between stages, with changes in protein abundance for a range of physiological processes including cortical granule development, iron homeostasis, extracellular matrix development, and carbohydrate metabolism. Proteins involved in reproductive hormone biosynthesis and signaling pathways were also detected in the ovarian proteome. This extensive dataset reveals the complexity of coho ovarian development and provides informative and specific biomarkers for further research.

1609 Grace Tindall, Greg Rouse, Anja Schulze, Elizabeth Borda

Cryptic Species of the Cosmopolitan Eurythoe

The Caribbean fireworm, Eurythoe complanata, has a historical circumtropical distribution within coral and rocky reef habitats due to limited morphological variation among populations. The evaluation of mitochondrial (mt) cytochrome oxidase subunit I (COI) and allozyme data in previous work revealed E. complanata as a cryptic species complex, with two Atlantic and one east Pacific (Panama) lineage. Here we continue to bring insight into the species diversity of Eurythoe based on, the evaluation of mt COI and 16S rRNA and nuclear ITS and 28S rRNA gene data compiled and collected from Pacific, Indian and Atlantic Oceans, Caribbean Sea, Gulf of California, Mediterranean Sea, and marine aquaria representatives. Phylogenetic and phylogeographic assessments support at least eight genetic lineages: (a) Pacific (n = 5), (b) Indian (n = 1), (c) Atlantic/Mediterranean (n = 1) and (d) Atlantic Island restricted (n = 1). The data also reveal possible source populations for introductions into home aquaria via live rock through the aquarium trade.

202 Jessica Tingle, Derek Jurestovsky, Henry Astley

The relative contributions of multiarticular snake muscles to movement in different planes

Muscles spanning multiple joints play important functional roles in a huge diversity of systems across tetrapod vertebrates, including human fingers, bird necks, and chameleon and primate tails. Despite the ubiquity and importance of multiarticular muscle systems, we still lack data on fundamental aspects of their mechanics, particularly the consequences of anatomical position on mechanical advantage. Snakes can serve as excellent study organisms for advancing this topic. Their trunk muscles span from one or a few vertebrae to upwards of 30; moreover, muscle architecture varies among muscles and among species. Snakes rely on their axial musculoskeletal system for a huge range of activities, including striking, constriction, defensive displays, and locomotion. However, few studies have examined how snake muscle anatomy relates to function. We characterized the anatomy of major epaxial muscles in a size series of corn snakes, Pantherophis guttatus, including cross-sectional area and locations of attachments, using diceCT scans. We then used several approaches for calculating contributions of each muscle to force and motion generated during body bending, starting from a highly simplistic model and then moving on to increasingly complex and realistic models. Our results contribute to knowledge of snake muscles specifically and multiarticular muscle systems generally, providing a foundation for future comparisons across species and bioinspired multiarticular systems.

1154 Maya Tipton, Sarah Heissenberger, Luis Luis, Daniela Rivera, Carolyn Bauer

Effects of water restriction on maternal care in Octodon degus

Maternal care is essential to the development of mammalian offspring, and variations in maternal care may result in differences in offspring phenotypes. Previous studies have investigated the role of maternal stress and nutritional restriction on rates of care; however, less is known regarding the impacts of water restriction. Species occupying dry environments, such as the common degu (Octodon degus), may be especially susceptible to variations in water availability due to the increasing prevalence and severity of droughts. This study examined the effects of water restriction on the maternal care rates of degus. Water-restricted mothers received 75% of the daily intake of water during lactation, while control mothers received ad libitum water. We then quantified the frequency of various maternal care behaviors (e.g. licking/grooming, contact with pups) as seen in video recordings of water-restricted and control mothers, hypothesizing that water restriction lowers rates of care across all behaviors. Our results provide insight into how water may function as an environmental cue affecting maternal care. This holds critical relevance for offspring development and fitness in species affected by climate change.

1416 Stefanny C Titon, Braz Titon-Jr, Vania R Assis, Alan Lima, Fernando Gomes

Restraint during breeding season impacts hormone levels and immune response of male and female toads

During reproduction in anurans, increased sex steroids, testosterone (T) and estradiol (E), allow for body and behavioral modifications (e.g., sexual pads, darkening the vocal sac, territorial and calling behavior). Meanwhile, high-energy activities, like calling, increase metabolic hormones, such as glucocorticoids (corticosterone – CORT). Both sex steroids and glucocorticoids have important immunomodulatory roles, possibly establishing relations between reproduction and immunity. To better understand the impact of stressful events during reproduction in amphibians, we submitted males (calling or foraging) and females (foraging) toads (Rhinella diptycha) to restraint protocol (1h and 24h, repeated samples). Before the restraint, a blood sample was collected to obtain reference values for plasma hormone levels (CORT, E, and T) and immune response (plasma bacterial killing ability – BKA). CORT levels increased 1 and 24h post-restraint in males (regardless of activity) and females. Although females showed higher E levels, we found decreased E levels after 24h for all toads. Calling males showed higher T than females and foraging males, and restraint reduced T levels 24h post-restraint regardless of sex or activity. BKA decreased 24h post-restraint irrespective of sex or activity. Our results show although increased CORT levels after a stressor during the breeding season are quickly identified (1h) and persistent (24h), decreased sex steroids and immune response are only evident when the stressor happens for a prolonged time (24h) in male and female toads.

1133 Kara Titus, Richardo Castellon, Julie Cooper, Cyrus Washington, Samantha Coy, Carsten Grupstra, Sonora Meiling, Jason Quetel, Alex Veglia, Joyah Watkins, Amy Apprill, Marilyn Brandt, Daniel Holstein, Laura Mydlarz, Adrienne Simoes-Correa

Caribbean fish feces disperse live and dead Symbiodiniaceae across endemic and epidemic reef zones

Consumer reef fishes, such as corallivores and grazers, contribute significantly to the dispersal of key coral symbionts (Family Symbiodiniaceae) by feeding on coral polyps and defecating as they swim across reefs. Few studies have explored the dispersal of symbionts in Caribbean reef systems, however, one study found lower Symbiodiniaceae cell densities in Sparisoma viride (3207-8900 cells per mL), a Caribbean parrotfish, compared to a Pacific parrotfish species that were 1-3 magnitudes higher. In April 2022, Symbiodiniaceae density and community diversity were analyzed from the feces of Chaetodon capistratus and C. striatus butterflyfishes, Sparisoma aurofrenatum and S. viride parrotfishes, and Acanthurus bahianus and A. coeruleus surgeonfishes across Stony Coral Tissue Loss Disease endemic and epidemic reefs in the U.S. Virgin Islands. There were no significant differences between the dead (avg = 236,950 cells/mL) or live (1,187,410 cells/mL) cell densities between the three groups or between the endemic or epidemic reefs. However, there was a significant difference in live cell densities of the butterflyfish species between the endemic and epidemic reefs with higher cell densities in the feces of C. capistratus in the epidemic reefs of St. Croix, UVI. These results suggest that butterflyfish, parrotfish, and surgeonfish are all important dispersers of Symbiodiniaceae across reefs tracks in the U.S. Virgin Islands and butterflyfish may influence the dispersal of live Symbiodiniaceae during disease outbreaks.

1214 Benjamin Titus, Theo Gaboriau, Alberto Garcia-Jimenez, Nicolas Salamin

Sea anemone host use drives convergent clownfish evolution and disentangles an iconic radiation

Broadly distributed on tropical coral reefs throughout the Indian and Pacific Oceans, clownfishes are a charismatic group of damselfishes (Pomacentridae) belonging to the genus Amphiprion and among the most recognizable animals on the planet. Yet clownfishes remain an evolutionary enigma. The group reflects many of the telltale characteristics of a classic adaptive radiation- 1) mutualism with sea anemones provided novel ecological opportunity. 2) Clownfishes have diversified rapidly and 24 of the 28 species have evolved within the last five million years. 3) Many clownfish distributions end abruptly suggesting that species interactions and competition for resources, the basis for ecological character displacement, may be occurring. But to date, no ecological variable has been identified that can explain clownfish niche partitioning, phenotypic evolution, species co-occurrence, and thus, the broader diversification of this group. Here we provide the first major revision to the known clownfish-sea anemone host associations in over 30 years to test a novel hypothesis that allows us to account for host associations in an evolutionarily significant way. Using comparative genomics, our results reveal the host sea anemones as the drivers of convergent color, pattern, morphological, and genomic evolution across the clownfishes and allows us to identify sea anemone host use as the key ecological variable that disentangles the entire adaptive radiation.

1081 Ishant Tiwari, Harry Tuazon, Saad Bhamla

Strength in Unity: Force measurements of active entangled worm blobs

A plethora of biological entities utilize aggregation with others to obtain protection, nourishment, and better mobility than what is achievable in isolation. One such example is the California blackworm (Lumbriculus variegatus) which forms entangled blobs by twisting its body along with other blackworms. These aggregates are found to sustain themselves in conditions that would prove lethal to a singular worm. Here, we explore the protective effects of blob formation from predation by attempting to measure the force applied by the worm blob against external untangling forces. We hypothesize that these external untangling forces can be applied by natural predators like leeches and small fish. The insights obtained from these biological aggregates may have applications in the development of soft robotic systems which can act as a “programmable glue” between substrates.

235 Khanh To, Michelle Stocker, Tobin Hieronymus

Is it that simple? Heterogeneous relative hardness of keratin in simple rhamphotheca in chickens

Keratinous sheaths on the jaws of beaked organisms (rhamphotheca) can be classified as simple or compound. Simple rhamphotheca is defined as one keratinous sheath covering each the upper jaws and the mandibles, respectively, rather than several keratinous plates. More than 60% of modern birds have simple rhamphotheca, but not all birds with simple rhamphotheca use their beaks for the same feeding mode. Grossly similar simple rhamphotheca may possess unreported microanatomical differences in response to different functional demands. In our study, we examine the microanatomy and biomechanical properties of rhamphotheca using chicken. We mapped the microstructure and relative hardness of keratin throughout the rhamphotheca using plastic-embedded histology and microindentation. Histological sections reveal five keratinous layers, more numerous on the anterior portion of the beak, making up the seemingly continuous keratinous sheath of the upper jaws and mandibles. Microindentation of individual layers reveals hardness differences, with the anterior rhamphothecal tomia (cutting edge) having the highest hardness, and layers comprising the posterior portion of the rhamphotheca having the lowest. This configuration shows that more resistant keratinous layers are found anteriorly to accommodate for the mechanical interactions happening at the tip. Our study shows unreported complexity within simple beaks, which when this study expands to other simple beak lineages, will allow us to determine simple rhamphotheca diversity and address the homoplasy of simple rhamphotheca in modern birds.

412 Ruben Tovar, Dana García, Tom Devitt, David Hillis

Deep homology in early eye development across divergent adaptive morphologies of Eurycea salamanders

Understanding why and how some divergent lineages evolve morphological similarities remains a central question in evolutionary and developmental biology. Groundwater salamanders (genus Eurycea) of central Texas offer exceptional potential to address this question because of past independent invasions of subterranean environments from surface habitats. Members of this clade exhibit intraspecific and interspecific variation along a continuum of morphological adaptations to the environmental pressures of life underground. Surface-dwelling species (e.g. E. sosorum and E. nana) exhibit optic anatomy typical of vertebrates endowed with sight, while obligatory subterranean species (E. rathbuni) have an incompletely developed optic system. The Cascade Caverns salamander (E. latitans) show intraspecific variation in eye reduction evident in their gross anatomy. We hypothesize similarity in the morphology of the eye only to diverge as development progresses between surface and subterranean salamanders. To test this hypothesis, we collected late stage embryos from four species (E. rathbuni, E. latitans, E. sosorum, and E. nana) to characterize ocular development. Specimens were fixed, contrast-enhanced with 1% PAXgene stabilizing-iodine (I2E) solution, microCT-scanned, and digitally reconstructed for comparison. We identified similarity in soft tissue development including the lens, optic cup, and retina in all four species, indicating similar early developmental progression across divergent phenotypes and species. These results are consistent with other studies showing the deep homology of image-forming eyes across divergent lineages (A. mexicanus), while illustrating the promise of this system for studying homoplasy and parallel evolution.

1211 Samantha Trail, Christopher Mayerl, John Capano, Armita Manafzadeh, Noraly van-Meer, Richard Blob, Jeanette Wyneken, Elizabeth Brainerd

XROMM analysis of flipper movement during locomotion in loggerhead sea turtles

Sea turtle forelimbs take the form of large, wing-like flippers. Prior locomotor studies showed that their predominate swimming gait uses simultaneous dorsoventral flapping of both forelimbs (powerstroking). External video also showed that the flippers undergo substantial rotation, supinating during upstroke and pronating during downstroke. We used marker-based X-ray Reconstruction of Moving Morphology (XROMM) to quantify motions of the flipper relative to the humerus and the humerus relative to the pectoral girdle. Although the distal parts of the flipper are flexible, we found that the proximal 1/3 of the flipper acts as a rigid body during powerstroking, with internal deformations causing rigid body error of less than 1 mm. In agreement with prior results, we found substantial long-axis rotation (LAR) of the flipper, with a mean of 88 degrees measured from XROMM versus 72 degrees previously reported. Due to the abducted posture of the humerus and flexed elbow, we found that clockwise LAR (when viewed from the distal end of the left humerus) acts to depress the flipper during downstroke and counterclockwise LAR elevates the flipper during upstroke. These XROMM results show that the posture of the forelimb, LAR of the humerus, and LAR of the flipper blade combine to produce the distinctive sea turtle powerstroke.

151 Sean Trainor, Kory Evans

Scale shape vs trophic position: testing the functional relationship in an assemblage of reef fishes

Fish scales and integuments represent understudied system which can yield insights into form-function relationships that may govern how these organisms interact with their environments. They also offer a diverse and varied source of bioinspiration whether looking at shape, internal structure, or location along the fish. In this study we have examined the scales of 24 reef fish species using computed tomography and 3D segmentation software to test the relationship between scale shape and trophic level collected via stable isotope analysis. We hypothesize that we will find that reef species in lower trophic levels will have a scale shape that allows for higher mobility in the reef, which would allow them to escape predation more effectively and locomote their feeding areas.

325 Rachel Tran, Simon Walker

High-precision insect wing and body kinematics acquisition using a flexible free-flight arena

During flight, insects can make subtle changes to their wing kinematics that in turn have large effects on their aerodynamic forces. To understand and model the above, therefore requires measurements of natural flight with appropriate spatiotemporal resolution and duration. These factors are determined by wingbeat frequency, size, and behaviour, which are limited by trade-offs within the operating equipment. Here, we describe a new and flexible arena setup that uses ten high-speed cameras to record insects flying freely in an optically clear chamber that can scale from the smallest to some of the largest insects. Pulsed far-red LEDs are used to provide bright, uniform backgrounds that eliminate motion blur. Separate, stereo cameras function as triggers when subjects enter the recording volume. These triggers can control additional stimuli, such as a white light, to induce flight manoeuvres at specific times. The resultant footage is coupled with a comprehensive voxel-carving software package to automatically calculate wing and body kinematics. This includes wing deformations in the form of wing torsion, which is important for accurate aerodynamic modelling. To date, we have documented several species, including Calliphora vicina, Drosophila melanogaster and Anopheles gambiae at high frame rates. This setup will generate a large database of high-precision insect free-flight kinematics to better our understanding of this diverse class and be used to feed into studies of insect flight control and aerodynamics.

553 Rachel Tran, Simon Walker

Kinematics of Anopheles gambiae during manoeuvring flight and with increasing temperature

Mosquitoes are major vectors of disease, which thrive in warm climates. In order to manage mosquito populations, it is important to monitor their response to temperature change and their courtship behaviour to better predict and interrupt their life cycle. From a kinematic and aerodynamic perspective, little is known regarding how they manoeuvre with their high aspect ratio wings and wingbeat frequencies ($>$ 800 Hz). Here, we recorded male Anopheles gambiae using a ten high-speed camera setup at 12,000 fps. Separate stereo cameras detect movement in the flight arena and trigger a female flight tone that stimulates flight manoeuvres. A completely automated voxel-carving package was then used to get high-precision wing and body kinematics (e.g., mid-wing pitch angle, wing torsion and body roll) when manoeuvring and flapping with increasing ambient temperature ($\sim$ 20 to 35°C). Stroke amplitude decreased with increasing temperature and reduced to even lower amplitudes (21 °) than those previously reported in literature (44 °). There was no correlation between wing length and wingbeat frequency, and wing speed remained constant with increasing temperature. Data collected here may inform the development of acoustic lures, provide some insight on migration patterns with climate change and feed into the most accurate aerodynamic modelling methods to date with wing deformation such as computational flow dynamics.

47 Brian Trevelline, Kevin Kohl

The gut microbiome influences host diet selection behavior

Diet selection is a fundamental aspect of animal behavior with numerous ecological and evolutionary implications. While the underlying mechanisms are complex, the availability of essential dietary nutrients can strongly influence diet selection behavior. The gut microbiome has been shown to metabolize many of these same nutrients, leading to the untested hypothesis that intestinal microbiota may influence diet selec- tion. Here, we show that germ-free mice colonized by gut microbiota from three rodent species with distinct foraging strategies differentially selected diets that varied in macronutrient composition. Specifically, we found that herbivore-conventionalized mice voluntarily selected a higher protein:carbohydrate (P:C) ratio diet, while omni- vore- and carnivore-conventionalized mice selected a lower P:C ratio diet. In support of the long-standing hypothesis that tryptophan—the essential amino acid precursor of serotonin—serves as a peripheral signal regulating diet selection, bacterial genes involved in tryptophan metabolism and plasma tryptophan availability prior to the selection trial were significantly correlated with subsequent voluntary carbohydrate intake. Finally, herbivore-conventionalized mice exhibited larger intestinal compart- ments associated with microbial fermentation, broadly reflecting the intestinal mor- phology of their donor species. Together, these results demonstrate that gut microbiome can influence host diet selection behavior, perhaps by mediating the avail- ability of essential amino acids, thereby revealing a mechanism by which the gut microbiota can influence host foraging behavior.

1796 Waring Trible

A socially parasitic ant lineage originated within the colony of its free-living parent

In ants, epigenetic signals, including social interactions, nutrition, and maternal effects, cause developing larvae to differentiate into distinct morphological castes as adults. These individuals cooperate to form a coherent social unit, analogous to the epigenetic processes of cell differentiation and cell signaling that underpin the development of unitary organisms. Also similar to cells, the ants in a colony typically differentiate into a germ line, the reproductive queen caste, and a soma, the non-reproductive worker caste(s). Caste development in ants provides an opportunity to understand how epigenetic information can induce alternative developmental programs at the level of an entire animal. In this presentation, I will discuss our recent research into the molecular mechanisms of caste development, with a particular focus on a novel strain of mutant ants that is providing new insights into the differentiation mechanisms that coordinate the caste-specific growth of multiple tissues. I will argue that our understanding of caste development can be advanced by new empirical results, but an equal emphasis should be placed on developing a formal mathematical framework to interpret existing data and design new experiments. In this sense, the broader aim of this research is to use ant castes to develop a reproducible approach to understand phenotypic plasticity in biological systems, including the interplay between developmental plasticity and phenotypic evolution.

1535 ALEX TROUTMAN

NFWB: Navigating Fieldwork while Black

Field Work is essential to the career of many biologists, however when working in the Field While Black (FWB) everyday tasks in the field can be life threatening. As a Black individual or PI of one, safety in the field requires a person to not only navigate weather and wildlife but also your fellow humans. In this talk I address the challenges faced by Black scientists in the field and within conservation agencies, and discuss how PIs, universities, and employers can ensure a safer, more inclusive experience for their Black friends, colleagues, and students while conducting fieldwork.

613 Sarah Troy

Infection dynamics under heat stress in tall fescue: A case for stress-mediated defense tradeoffs.

An organism's lifetime energy expenditure can be broken into the categories of growth, defense, and reproduction. Abiotic stressors directly influence the balance of energy allocation between these activities, and thus, host-parasite and parasite-parasite interactions. As such, the role that abiotic stress plays in disease susceptibility is of key research importance as shifting climates, phenologies, and ranges shape the evolution and ecology of plant infectious disease in the Anthropocene.In the cool-season grass, tall fescue (Lolium arundinaceum), the vertically-transmitted endosymbiont, Epichloë coenophiala, is broadly associated with fitness benefits under both neutral and stress conditions. The intensity of stressors has been experimentally proven to scale with the concentration of Epichloe-derived ergot alkaloids in Fescue leaf tissue. The alkaloids are not directly associated with an individual's defense against disease. We analyzed plant-parasite relationships under stress by inoculating two age cohorts of Epichloë -associated tall fescue under both heat stress and neutral conditions with a hemibiotroph (Colletotrichum cereale), a necrotroph (Rhizoctonia solani), or a coinoculation of both fungi. The resulting lesion prevalences coupled to ergot alkaloid concentrations show how heat stress can mediate growth-defense tradeoffs in tall fescue and demonstrates the foundational role of stress in shaping both plant and pathogen life-history traits.

650 Caroline Troy, Matthew Fuxjager, James Kellner

Exploring Environmental Predictors of Biogeographical Variation in Woodpecker Drumming Performance

Prior research shows biogeographical variation in bird communication, but relatively few studies examine environmental predictors of these differences across large spatial scales using machine learning methods. Here, we study environmental predictors of variation in performance of the woodpecker drumming behavior across large-scale geographic areas. Woodpeckers drum in territorial contests by rapidly hammering their bills on trees. This drumming behavioral signal has been shown to potentially be sexually-selected and has species-specific patterns that can be measured, such as beats (bill strikes) in a drum, duration, speed (beats/sec), and coefficient of a function of the number of drum beats graphed over time (each woodpecker species adheres to a drum function type such as linear or quadratic). We measured these variables for 1000 drumming recordings by the great spotted woodpecker (Dendrocopos major) available from citizen science databases. A random forest machine learning algorithm was then used to determine the predictive power of numerous environmental parameters at each recording's geographic location (eg. temperature, elevation, human population density) as predictors of drum variation. Contrary to expectations based on studies of birdsong, we find no clear evidence of robust environmental predictors on variation in drumming behavior.

1312 Aliyah True, Grace Snyder, Rowan Thomas, Nikki Traylor-Knowles, William Browne

Comparing the Cell-Specific Microbiome of M. leidyi, P. damicornis, and N. vectensis

The microbiome (including archaea, bacteria, fungi, protists, and viruses) plays versatile regulatory roles in maintaining holobiont health including reproduction, digestion, and immune response. Classifying microbes associated with specific cell types can give insight into symbiotic interactions that may contribute to spatially diverse microbiome communities in metazoans. We used Fluorescence Activated Cell Sorting (FACS) and 16S rRNA sequencing to broadly classify cell-specific bacterial microbiomes present in the lobate ctenophore, Mnemiopsis leidyi, and the anthozoans, Pocillopora damicornis and Nematostella vectensis. We hypothesize that these metazoans will demonstrate an unchanging microbial composition in varied environments, suggesting potential symbiosis. This is a necessary step in understanding how the innate immune system contributes to establishing and maintaining a distinct cell specific microbiota in both model and non-model non-bilaterians. After identification of the cell-specific microbial communities, differential abundance can be determined, informing the direction of future experiments regarding the putative roles of microbial heterogeneity and the potential selective advantages each metazoan has in response to its environment.

323 Fu-Yu Tsai, Yi-Hsien Su, Jr-Kai Yu, Dian-Han Kuo

Evolution of the FoxP gene family in bilaterians

An ancestral role for foxp transcription factor in neural development has been proposed based on results from vertebrates and arthropods. However, these results can also be interpreted as an outcome of convergent evolution. To interrogate these two alternative hypotheses, we characterized foxp genes in amphioxus, sea urchin, hemichordate, and catenulid flatworm to reconstruct the evolutionary history of foxp. Phylogenetic and synteny analyses of deuterostome foxp suggest that vertebrate foxp paralogs might have arisen through the 2R WGD events in the vertebrate lineage. Foxp is expressed in the CNS, pharynx, and gut in amphioxus, whereas foxp is expressed in the pharynx and gut, but not neural tissue, of sea urchin and hemichordate larva. Furthermore, foxp was also expressed in pharynx endodermal cells in the catenulid flatworm, which serves as a protostome outgroup here. Together, these data implicate that foxp may have a role in endoderm in the deuterostome ancestor. The role of foxp in neural development might have evolved independently in chordate and arthropod lineages. Alternatively, foxp may be involved in both neural and endodermal development in the bilaterian common ancestor, and its developmental roles in neural tissue might have been lost in ambulacrarians and catenulids. Our data revealed an alternative hypothesis for the evolution of foxp gene function in bilaterians, and data from additional protostomes and cnidarians can further test this hypothesis.

591 Natsumi Tsuchihashi, Heather Watts, Ben Vernasco, Jamie Cornelius

Use of conspecific vs heterospecific public information during food stress in captive finches

Animals utilize public information in many different scenarios, including commonly during foraging. Public information can come from both conspecifics or heterospecifics - and the use of information from these different sources is often context-specific. Some birds use advance warnings from conspecifics about food availability to prepare for declining food conditions by changing their behavior and physiology. Here, we assess whether this phenomenon occurs more broadly between ecologically relevant heterospecifics. Red crossbills (Loxia curvirostra) are conifer seed specialists that exist as a suite of different ecotypes with variable bill sizes and vocalizations, yet are considered the same species. Pine siskins (Spinus pinus) are closely related finches that are seed generalists but also utilize conifer seeds. Type 2 red crossbills were food restricted for 3 days immediately following a similar restriction of a neighboring bird - from which they could receive public information about declining food. Focal Type 2s paired with a neighbor Type 2 performed better in conserving mass during food restriction than those paired with a Type 3 or pine siskin neighbor. These results affirm that crossbills make physiological and behavioral adjustments in response to public information about declining food availability. More broadly, this study elucidates how public information use can depend upon ecological overlap and degree of relatedness, even amongst groups with dietary overlap.

698 Harry Tuazon, Emily Kaufman, Daniel Goldman, Saad Bhamla

Floatation of aquatic blackworm blobs

We have previously described our discovery of blackworms (L. variegatus) that can form a floating “worm buoy” on the underside of an air-water interface. Blackworms measure 2-4 cm in length in lab conditions and can grow up to 10 cm in the wild. They are found in low flow and anoxic regions of shallow marshy waters, which contain low levels of dissolved oxygen (< 1 mg/L). In nature, individual blackworms burrow their heads into the granular substrate to forage while simultaneously lifting and waving their tails above for respiration. In shallow water, tails can reach the water surface at a right angle, which can break surface tension due to their hydrophobic properties. We calculate that an average worm weighing 4 mg (in the water) can latch and support itself by exposing about 5 patterned segments on the interface, which could be dynamically adjusted. In this talk, we show how worms collectively survive anoxic environments through the worm buoy structure, which forms when individuals in a worm blob simultaneously latch their tails and contract. Additionally, we present evidence that this behavior occurs in nature using blackworms collected in the field (Gull Point State Park, IA). Together, our work sheds insight into both how worms form this remarkable floating structure, and what emergent functionalities it may confer for the survival of the collective under harsh conditions.

390 Elizabeth Tucker, Sonia Roberts, Swapnil Pravin, Daniel Koditschek, S. Tonia Hsieh

Toe spacing strongly influences jump height on "sand"

Running on dry sand is challenging in part because sand can make multiple transitions between solid-like and fluid-like states during a step. Sand specialist lizards have modified toe positioning, which may improve locomotor performance. Empirical and computational results from forcing parallel rods into granular media show that a spacing of 3-5 particle diameters (pd) amplifies the net work performed. We hypothesized that similar toe spacings on a bioinspired foot would result in greater jump heights for a hopping robot. We 3-D printed abstracted feet with a rectangular region flanked symmetrically on both sides by three square rod "toes." Relative foot dimensions were inspired by the foot geometries of zebra-tailed lizards (Callisaurus draconoides), a sand specialist capable of running at 20 LL/s on both solid and sandy surfaces. We tested feet with 1, 3, 5, and 7 pd toe spacings. A square foot with the same total surface area served as a control. Feet were attached to a robot hopper and jumped in a box filled with 3 mm glass beads. We allowed the robot to jump twice during each trial before catching it and preparing the material for the next jump. Jump height and intrusion depth differed dramatically between the first and second jumps. However, the 3 and 5 pd feet had consistently higher jump heights and consumed less energy relative to jump height.

1325 Faris Tulbah, Tobias Ginsburg, Talia Moore

Camoflagility: Mimicry for Predator Underestimation of Prey Evasion Ability

In Batesian and Müllerian mimicry, acquiring signals associated with dangerous traits confers an evolutionary benefit. We propose a new form of mimicry in which agile prey benefit from resembling less agile species. We developed population models from both predator and prey perspectives. First, we randomly distributed the direction of prey escape between 0 (horizontal) and 90 (vertical) degrees, which was inherited with variation. In each simulation we allowed predators to learn up to 4 prey behavior models with misidentification rates between 0 and 50%. After 1000 trials each, populations with one model of prey behavior outlived all others and favored horizontal motion. With two prey models, increasing misidentification increased longevity and vertical strategy viability. Second, we used reinforcement learning to model the predator energy expenditure of pursuing prey with different agility levels. We show that even when predators are capable of learning multiple prey behaviors and identifying prey types, it is less costly to pursue less agile prey when both are available. These two modeling approaches demonstrate that agile prey benefit from resembling less agile prey, both because their predator evasion ability is underestimated and because it is more costly for predators to pursue more agile prey. These models may explain sympatric species with convergent appearance and divergent agility, such as bipedal and quadrupedal desert rodents or gliding and non-gliding lizards, frogs, and ants.

1580 Morgan Turner, Bridger Herman, Matthias Broske, Daniel Keefe

Skeletons in Motion: Interactive visualization techniques for analyzing cyclic kinematic data

Visualizing and measuring skeletal motion is a key research pathway for some questions in functional morphology, comparative biomechanics, and locomotor evolution. Skeletal motion data, such as that produced by X-ray Reconstruction of Moving Morphology (XROMM), can be used to quantify spatial relationships between animal and environment, temporal relationships of behaviors, and anatomical form-function relationships. However, analyzing such multi-dimensional datasets can be inhibited by challenges in visualizing the linkage among these relationships. To address these challenges, we have developed novel interactive visualization techniques based around cycles of motion (e.g., walking, chewing, flying, etc.). Motion cycles are common for many animal behaviors and can be defined by homologous time-based events (e.g., heel-down of a walk cycle) despite kinematic variation—rendering motion cycles as a broadly useful 'unit' to serve as the foundation in designing a comparative visualization framework. Our visualization features three key techniques. 1) Linking data across multiple coordinated views (2D plots and 3D spatial renderings) such that interactively highlighting or masking in one view applies to all views. 2) Spatio-temporally normalizing 3D skeletal pose sequences based on motion cycles and registering with normalized 2D plotted data. 3) Displaying motion relative to multiple different anatomical structures or environmental features. Our new approach integrates multiple traditional and novel visualization techniques while maintaining important biological context and has the potential to aid in analysis of many skeletal motion datasets.

1816 Sydney Turner, Crystal Kelehear-Graham

Rhinella marina: adaptions in limb morphology that potentially promote invasion success.

Invasive species are shown to present many phenotypic changes reflecting selection pressures operating on them during dispersal. Cane toads (Rhinella marina) are a great example of an introduced species rapidly evolving to better their dispersion through morphological changes. Changes in hind limbs specifically have been studied to account for their rate of range expansion in invasive ranges. This study focuses on the morphological differences in the hind limbs of juvenile toads bred and reared under laboratory conditions but sourced from native and invasive populations. Parent toads were collected from three invasive populations (Bermuda, Hawaii, Australia) and two native populations (French Guiana and Guyana). Adults were bred in the lab to produce 8 clutches from the invasive individuals and 5 clutches from the native individuals. After metamorphosis into adult form, the specimens were then preserved in ethanol. 160 invasive and 88 native toadlets were measured; specifically snout to urostyle, femur, tibia-fibula, tarsus, and 4th metatarsus lengths to investigate limb length relative to body size. Results showed the invasive specimens had significantly longer femurs than the native range specimens, however, no significant difference was found between populations among the other limb measurements relative to body size. These results suggest that the increase in femur length within invasive individuals would allow an increase in dispersal rate along with increase in distance traveled in a shorter amount of time.

1147 Bryon Tuthill, Isabela Velasquez-Gutierrez, Mary Campbell, Leilani SantoDomingo, Michael Stastny, Jessica Hua

Predation, Pesticide and Pathogens: Stressor effects on population, organismal, and genome metrics

Human activities can profoundly alter wildlife populations and the ecosystems in which they inhabit. Notably, the use of synthetic chemicals such as pesticides have led to widespread instances of evolved pesticide tolerance. While evolving tolerance to pesticides can facilitate wildlife survival in the face of pesticide contamination, it may lead to costs when responding to the diversity of other stressors that wildlife face (i.e., predators and parasites). In this study, we aimed to understand whether evolutionary responses to pesticides influenced responses to natural enemies. Towards this end, we used populations of pesticide-tolerant and non-tolerant wood frogs (Rana sylvatica) which were exposed to factorial combinations of three stressors: a pesticide (carbaryl), a predator cue (dragonfly larvae), and a pathogen (Frog-Virus-3; FV3). We measured (1) tadpole survival and disease outcomes (FV3 load), (2) morphological metrics, and (3) gene expression. We found that relative to the control, pesticide-tolerant wood frog populations exposed to all three stressors experienced mortality at a significantly faster rate. In contrast, non-tolerant wood frog populations exposed to all three stressors experienced mortality at a significantly slower rate. For morphological metrics, we found that tolerant populations were significantly larger and more developed compared to non-tolerant populations. Collectively, this work will contribute to understanding the mechanisms influencing the interplay between multiple stressors at multiple organizational level from population to organismal to genomic-level metrics.

1047 Ariel Tysver, Katie Talbott, Sarah Wanamaker, Ellen Ketterson

Anthelmintic Treatment Effects on Coccidia Shedding in the Dark-eyed Junco (Junco hyemalis)

Direct manipulation of the density of one parasite within a host often has an impact on other coinfecting parasite species. For example, decreasing nematode load through treatment with an anthelmintic has been shown to increase the likelihood of coccidial infection in wild mice. However, this phenomenon has not been well studied in birds. Both nematodes and the protozoan that causes coccidiosis are common parasites found in the gastrointestinal tract of Dark-eyed Juncos (Junco hyemalis, 'junco'). Hence, we used these two parasites as a model of parasite interaction within host juncos in a captive experiment. To assess the relationship between Coccidia oocyst shedding and anthelmintic treatment in the host, we treated two groups of juncos with Ivermectin ($n = 10$ males, $n = 6$ females) and compared them to a third control group ($n = 7$ males). We collected fecal samples before and after treatment for every bird, which we analyzed using fecal floatation followed by microscopy to determine the number of oocysts per gram of feces. We did not find a significant difference between pre-treatment to post-treatment oocyst change when comparing Ivermectin-treated and control males ($W = 26$, $p = 0.42$). We also did not detect any difference between ivermectin-treated males and females ($W = 128$, $p = 1$). Our results did not support our prediction that Ivermectin treatment would increase the rate of Coccidia shedding in the junco.

892 Eric Tytell, Lauren Cooper, Luna Lin, Pedro Reis

Regulation of the swimming kinematics of lampreys Petromyzon marinus when viscosity increases

The bodies of most swimming fishes are very flexible. If fluid dynamic forces change, the body motion will also change, unless the fish senses the change and alters its muscle activity to compensate. We hypothesized that lampreys (Petromyzon marinus) use mechanosensory cells to regulate body curvature as swimming speed and fluid dynamic forces change. We measured the steady swimming kinematics of lampreys swimming in normal water, and water in which the viscosity was increased by adding methylcellulose. Computational results suggested that if lampreys did not compensate in 10x viscosity, the swimming speed would drop by about 52%, the amplitude would drop by 30%, and posterior body curvature would increase by about 48%, while tail beat frequency would remain the same. Five juvenile sea lampreys were filmed swimming through still water and midlines were digitized using standard techniques. Although swimming speed dropped by 44% at 10x viscosity, amplitude actually increased slightly, and curvature only increased by 21%, much less than the amount we estimated with no compensation. To examine the waveform, we performed a complex orthogonal decomposition and found that the first mode of the swimming waveform varied little even at 20x viscosity. Thus, it appears that lampreys are at least partially compensating for the changes in viscosity, which in turn suggests that sensory feedback is involved in regulating the body waveform.

1119 Abigail Uehling, Lisa Mussoi, Gustav Paulay

Cryptic diversity and concordant geographic restriction in Arabian Aquilonastra sea stars

Marine diversity is influenced by many modes of genetic restriction, such as environment and dispersal ability. Identifying patterns of genetic discontinuity across a region will improve our understanding of the mechanisms influencing speciation in these environments. Recent work has shown that the asterinid, Aquilonastra (Echinodermata: Asteroidea), is the most diverse genus of sea stars in the Indo-West-Pacific, with many species occupying restricted ranges. Species are morphologically cryptic and have a diverse array of life history strategies including benthic and planktonic lecithotrophy and fissiparity. This genus is abundant on hard bottoms across the Arabian Peninsula, an area characterized by steep gradients in primary productivity, temperature, salinity, and seasonality. We sequenced over 50 specimens for the COI gene across this region and used phylogenetic and population genetic methods to evaluate diversity and differentiation. Both local and regional diversity are higher than currently recognized. Geographic ranges of all lineages are limited, with concordant genetic breaks between the Red Sea, Arabian Sea, and Gulf of Oman in multiple lineages. These concordant breaks suggest common drivers. These results allow for the evaluation of the role of environmental gradients and dispersal barriers in shaping genetic connectivity in this region.

1371 Jennifer Uehling, Jennifer Houtz, Allison Injaian, Conor Taff, David Winkler, Maren Vitousek

Do glucocorticoids predict movement? Observational and experimental studies in a free-living bird

Movement behavior can have wide-ranging effects on fitness, and yet it varies widely, even among individuals of the same species. We still do not understand the full suite of factors governing this variation, but hormones likely play a role. In vertebrates, glucocorticoid hormones (GCs) have been shown to mediate movement behavior in some contexts, but few studies investigate this through measuring the effects of both natural variation in GCs and experimental manipulation of GCs. Here, we examine the relationship between GCs and two metrics of movement behavior, geographic space use and parental offspring provisioning, in breeding female tree swallows (Tachycineta bicolor). We use two years of data: one year in which we measured natural variation in corticosterone (CORT, the main GC in birds), and one year in which we experimentally elevated CORT. We investigate whether baseline CORT levels in year one, and CORT treatment in year two, predict movement behavior. To quantify movement, we monitored geographic space use with solar-powered radio tags (“life tags”) and provisioning behavior with an RFID system. If our results show that CORT levels predict movement patterns, our findings will illuminate the role of GCs in mediating movements. Furthermore, these movements are important for offspring feeding, so our findings could suggest a pathway through which GC variation could affect fitness via differential foraging and nestling feeding outcomes.

458 Ava Umlauf, Henry Astley, Kaelyn Gamel, Jared Pettay

Underwater Ground Reaction Forces of Spotted Prawn

Underwater Ground Reaction Forces of Spotted Prawn As a predecessor to terrestrial locomotion, underwater walking plays a key role in studying the water-land transition. While tetrapods have been a major research focus in underwater walking, arthropods also frequently use this form of locomotion. However, the consequences of their different body plan, most notably their greater number of legs, remain unknown. To further understand underwater walking in arthropods, a custom-built 3D printed underwater force plate was used to gather ground reaction forces (GRF) from 6 adult spotted prawns as they walked along the force plate. We synchronized kinematics and force results to calculate velocity, acceleration, and kinetic and potential energy, as well as total force production and isolated vertical, propulsive, braking, and lateral force components. GRF were collected and found that the average vertical force was around 12 mN, the average propulsive force was 2 mN, the lateral force was + or – 2 mN. The peak braking force of 6 to 10 mN can be attributed to the prawn tripping. We observe less variability in the prawn locomotion than recently observed axolotls, due to multiple contact points from its limbs. These results suggest that the major differences in body plan between arthropods and tetrapods have similarly substantial differences in underwater walking mechanics.

845 Irving Upshur, Mikhyle Fehlman, Vansh Parikh, Chloe Lahondere

Sugar-feeding by invasive mosquito species on ornamental plants

IRVING FORDE UPSHUR1, MIKHYLE FEHLMAN, VANSH PARIKH, and CHLOÉ LAHONDERE11Steger Hall, College of Agriculture and Life Sciences, Department of Biochemistry, 1015 Life Science Cir, Blacksburg, VA 24061Email: uforde96@vt.eduFeeding on plant-derived sugars is an essential component of mosquito biology that affects key aspects of their lives such as survival, metabolism, and reproduction. Mosquitoes locate plants to feed on using olfactory and visual cues. Aedes aegypti and Aedes albopictus are two mosquito species invasive to the US, and are vectors of diseases such as dengue fever, chikungunya, and Zika. These species live in heavily-populated, urban areas, where they have a high accessibility to human hosts as well as to plants in backyards and town landscapes. Therefore, it is important to understand what plants may attract / repel mosquitoes to inform citizens and municipal authorities accordingly. Here, we observe Ae. aegypti and Ae. albopictus sugar-feeding behavior with eleven different commonly-planted ornamental plant species. We then assessed feeding activity using the anthrone method and identified volatile composition of plant headspace using gas-chromatography mass-spectroscopy. Finally, we determined the sugar-feeding activity of local mosquitoes using the plant DNA barcoding technique and compared these results with the eleven ornamental species tested in the lab.

379 Carmen Urban, Julia Clarke

Description and comparison of ostrich and common quail natal down: developmental implications

Natal down is a feather stage that differs in both form and function from the definitive feathers of adult birds. It has a simpler form that has been speculated to be similar to the body coverings of non-avian dinosaurs. However, inference of the evolution of natal down has been limited by our understanding of its variation in structure in extant birds. Most descriptive work has focused on neognath birds, limiting our knowledge of the full diversity of feathers in extant taxa. Here we describe the post-hatch natal down of an ostrich (Struthio camelus) and compare it to that of a post-hatch quail (Coturnix coturnix). We confirm the presence of featherless spaces (apteria) in ostriches and the lack of barbules on the tips of natal down in both species. We also find dorsal and ventral differences in the natal down, especially in the extent of the bare portion of the barb in both the ostrich and quail. Finally, we find that the structure of ostrich natal down follows a different developmental pattern than that described in other birds. These results have implications for our understanding of how structure informs function and development in understudied feather types, such as those shared by non-avian dinosaurs. The evolution of barbule-less tips in crown bird natal down and role of simplified natal plumages need to be further investigated.

410 Veronica Urgiles, Dylan Wainwright, Molly Womack

Warts and all: A comparative approach to understanding the evolution of amphibian skin

In amphibians, the skin is directly responsible for regulatory processes, including gas exchange, osmoregulation and immune responses. Although variation in skin characteristics have been broadly reported across body regions (e.g., dorsal vs ventral surfaces) and across species (generally in aquatic vs non-aquatic species) we still lack a comprehensive understanding of the evolutionary patterns driving this variation. Furthermore, current categorizations such as "smooth", "tuberculated" or "granular" that are used to describe the external texture of skin across species, don't reflect its complexity. In this study we use gel-based profilometry to generate 3-D models that quantify ventral and dorsal skin surface texture based on roughness parameters in hundreds of species that span the amphibian tree of life. While accounting for phylogeny, we identify shifts in skin features among species and body regions to test if texture variation is correlated with shifts in microhabitats and climate. Our work provides a reproducible pipeline for quantifying skin texture in amphibians, traces the pace and pattern of skin texture evolution across time and phylogeny, and highlights potentially adaptive skin features that predictably vary with microhabitat and climate.

1304 Karthik Urs, Aditya Srinivas Manohar, Michael Rakowiecki, Faris Tulbah, Jessica Carlson, Talia Moore

The Robot Of Theseus: A low-cost modular robot for testing the effect of morphology on locomotion

Experimentally testing the effect of limb structure on locomotion is challenging because many factors covary. For example, a study comparing goats to cheetahs found no effect of limb moment of inertia on cost of transport. Leg contact angle and duty factor also differ between these species, hindering fair comparison. Robotic models are useful for independently varying specific features, but most quadrupedal robots differ so greatly from animal morphologies that they have minimal evolutionary relevance. Here, we present a quadrupedal robot with modular legs that can match a wide range of animal morphologies for hypothesis testing. The Robot Of Theseus (TROT) is a cheap legged robot (<$4000 in materials) built entirely out of 3D printed parts and standard off-the-shelf supplies. Each limb consists of 2 or 3 links; the proximal joint can be rotated to become a knee or elbow. Telescoping mechanisms vary the length of each limb link. The open-source software accommodates user-defined gaits and morphology changes. Effective leg length, or crouch, is determined by the four-bar linkage actuating each joint. The backdrivable motors can vary virtual spring stiffness and range of motion. The robot controller is based on the widely used MIT MiniCheetah. Full descriptions of the TROT hardware and software are freely available online. We use TROT to compare locomotion among extant, extinct, and theoretical morphologies.

125 Jim Usherwood

Legs as linkages: thinking of isometric muscles and tendons as bicycle spokes

Muscles perform a number of roles, acting as motor, brakes and shock absorbers. Tendons also perform several roles, acting as transmission and/or elastic springs. But a distinct and perhaps largely overlooked role of isometric muscles and tendons is as functional tension bicycle spokes, becoming loaded in turn through simple geometry, and enabling horizontal translation during vertical weight support without high mechanical power demand. Here, quadrupedal mammal leg structure and function is considered in the context of enabling low mechanical demand at the level of the limb by maintain forces perpendicular to velocity, at the same time as providing low power supply by keeping muscles isometric when loaded, or unloaded when changing in length. These principles provide a simple account for the general structure of the scapula, serratus ventralis and triceps brachii of the forelimb, and the biceps femoris (curiously crossing across the femur), vastus, rectus femoris and tensor fasciae latae of the hindlimb. Different muscles experience tension at different stages in stance, each resulting in linkages where the links are isometric, and the limb supports predominantly vertical forces during horizontal translation.

126 Jim Usherwood, Alexandra Bailey

Legs, linkages and lollipop sticks: physical demonstrators for (almost) all ages

Muscles perform a number of roles, acting as motor, brakes and shock absorbers. Tendons also perform several roles, acting as transmission and/or elastic springs. But a distinct and perhaps largely overlooked role of isometric muscles and tendons is as functional tension bicycle spokes, becoming loaded in turn through simple geometry, and enabling horizontal translation during vertical weight support without high mechanical power demand. Several aspects of animal leg form and function can be considered as linkages that facilitate this economical weight support. Here, a practical class is described that demonstrates mammalian fore and hindlimb structure and function as simple linkages. It is simply adapted to range from school-level as an introduction to 4-bar and 6-bar linkages, to undergraduate anatomy level, demonstrating the origin, insertion and functions of various muscles throughout stance. The demonstrated principles include how passive linkages can 1) support the body with predominantly vertical forces (requiring varying moments about hips and shoulders), during 2) horizontal motion of the body during stance (resulting in an economical 'sliding' action), with 3) links that are isometric when under load (and so not performing mechanical power), and 4) change between linkages and loaded muscles through changes in geometry.

459 Josiah Utsch, Sophie George

Pisaster ochraceus [Asteroidea] larvae are resilient to high temperatures but not to food shortage

Over the coming century, climate models of the Salish Sea predict that sea temperatures will rise, and that species composition of algae will shift. In this study, we compared how planktonic larvae of the sea star Pisaster ochraceus, were affected by the combined effects of heightened sea water temperatures, and access to food. We reared bipinnaria and brachiolaria larvae under control (11-14°C) and experimental (18-21°C) temperature regimes with either a high or low concentration of algae. Thirty-three and forty days after fertilization, we measured larval length, width, and survival. In line with expectations, larvae raised with four times as much food grew to be 1.6 times longer, and 1.3 times wider by forty days, and developed into brachiolariae faster. Surprisingly, temperature had only a minimal effect on larval size, compared to food availability. Pisaster larvae raised in seawater above 18°C, were nearly indistinguishable from those raised under historical summer temperatures of around 12°C. Interestingly, our study suggests that higher than average temperatures along with high food availability were associated with increased survival of Pisaster ochraceus larvae. These results suggest that Pisaster larvae are resilient to direct effects of sustained ocean warming, but may be heavily affected by secondary ecological effects like shifting algal species composition and biomass.

246 Saraswathy Vaidyanathan, Natalie Steinel

Identification of a teleost lymphoid structure analogous to mammalian germinal center

Mammalian B cell proliferation and affinity maturation occurs in a microanatomical structure called germinal centers (GC) and is highly dependent on lymphoid cell spatial organization. Fish lack GCs; instead, they possess melanomacrophage centers (MMC), the suggested site of fish B cell proliferation and affinity maturation. While mammalian GC microarchitecture is well defined, it is unclear if this organization is conserved in other vertebrates. We hypothesized that lymphoid cells aggregate and form organized zones around fish MMCs. To test this, threespine stickleback fish were immunized with either protein antigen (NP-CGG in alum), polysaccharide antigen (NP-Dextran in alum), or alum only and analyzed weekly up to day 49. Fish MMCs increase in size in response to protein, but not polysaccharide immunization, suggesting that MMCs, like GCs, increase in response to T-dependent antigens. To determine the spatial organization of lymphoid cells, mRNA in-situ hybridization was performed on splenic tissues. We found that IgM+ cells aggregate in discrete but unorganized regions around stickleback MMCs. Similarly, cells expressing CD4+ and TCR-beta+ cells aggregate diffusely near IgM+ cells in close proximity to MMCs, suggesting that splenic lymphoid cells are arranged loosely around MMCs and do not form the highly organized T and B cells zones seen in mammalian GCs. These results suggest the cellular organization necessary to mount an effective immune response may have evolved from fish.

1441 Brent Zeyus Valdez Valdez, Daravuth Cheam, Michele Nishiguchi

Can we mow your bacterial lawn? Protozoan grazing on evolving Vibrio biofilms

Marine bacteria in the family Vibrionaceae have a specific beneficial symbiotic relationship with squids in the family Sepiolidae (Mollusca: Cephalopoda). Sepiolids use their Vibrio fischeri symbionts, creating bioluminescence to camouflage themselves against predators and prey through counterillumination. V. fischeri are transmitted environmentally, and although much is known about the factors driving the specificity of the association, little is known about the environmental factors that influence V. fischeri prior to colonization. Therefore, we have experimentally evolved V. fischeri biofilms treated with protozoan predators including Acanthamoeba castellanii and Tetrahymena pyriformis under non-grazed and grazed conditions to examine the effects of grazing on V. fischeri outside their squid host. The Hawaiian V. fischeri strain ES114 and Australian strain ETBB-1C increased in biofilm concentrations over a number of generations when treated with A. castellanii. ES114 generally had a decrease in biofilm concentration when treated with T. pyriformis, whereas ETBB-1C had a general increase in biofilm concentration. Comparative analysis of non-grazed and grazed biofilms along with predator concentrations demonstrate how V. fischeri have responded to predation pressure. This may have downstream effects on the squid-Vibrio symbiosis such as evolved strains being more competitive than their ancestral clones and shaping the evolution of future symbiotic relationships.

1165 Miles Valencia, Apolo Ibáñez-Rincon, Haleigh Hernandez, Gabby Morgan, Brooke Baker, Jenna Monroy, Theodore Garland, Angela Horner

Early-exercise effects on mice tendon mechanics

Exercise is frequently studied for its myriad of effects on the musculoskeletal system such as muscle hypertrophy and tendon rehabilitation. Although researchers have demonstrated different exercises to affect tendon materials properties, rarely does an individual study address multiple exercises at the same life stage. To study the effects of exercise intensity on maturing tendon, I used a mice colony artificially selected for high voluntary wheel running behavior called High Runners (HR). I divided HR and control mice into two age groups resembling young (3-weeks) and adult (9-weeks) mice. Each cohort was separated into three exercise groups with varying training intensities: wheel running (high-frequency, low-impact), jumping (low-frequency, high-impact), and a sedentary group. After 9 weeks of exercise, mice were sacrificed and stored at -20°C until the gastrocnemii tendons were isolated for processing. Tendon cross-sectional area and length was measured using ImageJ. Materials testing recorded force measurements using a muscle ergometer while mechanical strain was recorded via high-speed videography. My study found that young mice exhibited more compliant tendons with higher yield and failure strains. HR mice had significantly higher yield stress due to their significantly longer and thinner tendons. However, varying training intensities resulted in a few significant differences in mechanical properties suggesting training type does not significantly impact maturing tendon. Future studies should investigate tendon mechanical properties after aging out mice exposed to early exercise.

76 Natalie van-Breukelen, Nicholas Santangelo, Morgan Lane

Natural pair distribution predicts convict cichlid parental defense towards other parental pairs

As parental defense is costly, parents may adjust their defense behavior based on the proximity of threats, which may impact pair distribution. Our previous field studies in convict cichlids, Archocentrus nigrofasciatus, showed that the risk of brood mixing determines aggression towards conspecific intruders. We also observed that parental pairs seem to distribute differently in relation to conspecifics versus heterospecific Hypsophrys nematopus. Parental aggression appeared to vary depending on species, with more aggression towards conspecifics than heterospecifics at closer distances. Here, we mapped pair distribution and verified that convict cichlid pairs position themselves further from other conspecifics than H. nematopus. We then presented pairs of parental convict cichlids with stimuli consisting of other parental convict cichlid pairs or parental H. nematopus pairs. Each focal pair was exposed to each species separately and then simultaneously at both near (20cm) and far (60cm) distances. During separate presentations, focal parents were more aggressive at near distances versus far distances for both conspecifics and heterospecifics, though the aggression towards heterospecifics was always less than that toward conspecifics at each distance. In the simultaneous presentations the focal parents were always more aggressive toward conspecific stimuli. These results further support our previous finding that brood mixing is the likely risk that other parental convict cichlid pairs pose and may also explain the natural distribution of these species within the same river.

1268 Emily Van-Buren, Kelsey Beavers, Laura Mydlarz, Nicholas MacKnight, Li Wang

Coral Disease Fate in Caribbean Corals Influenced by Coral Lineage and Biological Choices

The Caribbean is known as a coral disease “hot spot” due to the high prevalence of acute and chronic diseases that have plagued corals in the area. Stony Coral Tissue Loss Disease (SCTLD) and White Plague (WP) are the most common diseases and infect many coral species. These two diseases have been studied in a genotype-matching study that at transcriptomics of baseline and post-exposure to disease in four species of corals. While transcriptomic analyses have improved our knowledge of host response, a knowledge gap regarding the disease risk corals have prior to disease exposure still exists. Understanding disease risk of a. coral before an outbreak is an essential step in modeling the disease dynamics of coral. By applying novel but proven layers of machine learning programs and using healthy corals whose disease fate is known, we can identify which biological processes are relevant to disease susceptibility. In this study, we used the machine learning tools Independent Principal Component Analysis and Logistic Regression to identify expression patterns correlated to disease fate. In total, 40 IPCA transcripts and 237 LR transcripts were significantly correlated to disease outcomes. IPCA results indicate that lineage plays a significant role in the differentiation of genetic expression regardless of disease outcome. Logistic Regression identifies enriched GO terms that indicate different nitrogen metabolic and RNA processing expressions that correlate to disease outcomes.

1007 Karin van-Hassel, Grant Greisman, Evyn Dickinson, Xuan Qu, Daniel Powell, Patsy Dickinson

Modulation of the stretch feedback pathway by neuropeptides in the heart of the American lobster

Central pattern generators are neural networks that, when activated, produce patternedmovements such as breathing and walking. The cardiac ganglion (CG) controls the neurogenic heartbeatof the American lobster, Homarus americanus. The CG is made up of nine neurons: four premotorneurons that drive five motor neurons, causing bursts of action potentials from the motor neurons thatelicit cardiac muscle contractions. Stretching the cardiac muscle produces an excitatory feedback-response to the CG. This stretch feedback pathway is mediated by stretch-sensitive dendrites thatrespond to hemolymph filling and stretching the cardiac muscle. Previous research established thatnumerous neuropeptides modulate the cardiac neuromuscular system by acting on the CG andperipheral sites such as the neuromuscular junction and cardiac muscle. We have found that two relatedneuropeptides, GYSNRNYLRFamide (GYS) and SGRNFLRFamide (SGRN), whose effects on the wholeheart are generally excitatory, suppress the excitatory stretch response. This led us to ask the question,do neuropeptides with different or similar effects on the whole heart modulate stretch feedback in acomparable manner? Myosuppressin, an endogenous neuropeptide, decreases the burst frequency inthe CG and consequently decreases the heartbeat frequency while it increases the heart contractionamplitude. Calcitonin-like diuretic hormone (CLDH), another endogenous neuropeptide, increases thefrequency and amplitude of cardiac muscle contractions. We are currently determining howmyosuppressin and CLDH modulate the stretch feedback pathway.

328 Sam Van-Wassenbergh, Peter Aerts, Falk Mielke, Van Nguyen, Jan Sijbers, Jan De-Beenhouwer, Joris Dirckx, Joaquim Sanctorum

Fast and flexible CT scanning with a high-speed cineradiography system

X-ray video systems composed of analogue image intensifiers and digital high-speed cameras are popular and important tools for biomechanical research, especially in stereoscopic configurations to perform XROMM (X-ray Reconstruction of Moving Morphology). Their high temporal resolution makes them promising to be used as high-speed tomographs as well. We explored this potential by building a rotation stage equipped with an angle decoder that triggers the high-speed camera(s), and by developing methods for geometry calibration and projection-angle-dependent correction of image distortion. With up to 1800 projection images acquired for a full revolution of an object in about 2 s, quick computed tomography (CT) scanning of rabbit-sized animals with a voxel size of about 0.14 mm is possible. As expected, the relatively high noise and low dynamic range of the projection images compared to those of commercial scanners with flat-panel detectors is limiting CT quality. Still, the speed, flexibility, and open configuration of the set-up opens up opportunities for innovative biological research, such as CT of living or briefly anaesthetised animals, cadaveric manipulations, and quantification of 3D shape changes in organisms or organs. We offer both fast or high-resolution (4D) CT scanning and XROMM services as part of a new core facility at the University of Antwerp, DynXlab (center for 4D quantitative X-ray imaging and analysis).

1239 Jason Vance, Kayla Pehl, Catherine Waggoner, John Swallow

Morphological compensation and the development of flight performance in stalk-eyed flies

Several species of stalk-eyed flies exhibit exaggerated sexual dimorphism where females favor males with longer eyespans. However, longer eyespan increases a fly's moment of inertia, and may impact maneuverability and predator evasion. Flies with longer eyespans tend to have larger thoraces and wings, suggesting co-selection for compensatory traits, potentially ameliorating the costs of bearing long eye-stalks. The purpose of this study was to investigate the flight performance of stalk-eyed flies and its relationship to body morphology and development. The flight performance of 1-to-30 day old Teleopsis dalmanni (n = 124) and Diasemopsis meigenii (n = 83) were assessed by presenting normoxic, variable-density mixtures of heliox (O2, N2 and He) in 10% increments ranging from air to pure heliox; the least-dense gas allowing flight represented maximal performance. Flight kinematics were analyzed using high-speed (5930fps) videography. Immediately following flight assessment, flies were euthanized, photographed, dissected and weighed. Total body mass, thorax and abdominal mass increased across age. Wingbeat frequency, stroke amplitude and maximal flight capacity were associated with thorax mass, and increased with age as flies became heavier. Although flies with longer eyespans were indeed heavier, had larger wings, and thoraces, maximal flight capacity and kinematics were independent of eyespan. Thus, bearing long eye-stalks did not impair flight performance; instead, variation in flight performance appears associated with the development of the flight motor, and improved ratio of thorax-to-total mass, across age.

75 Brinton Vandegrift, Kit Yu Karen Chan

Ocean acidification but not GABA manipulaitons affect predator avoidance of larval sand dollars

Population dynamics of many marine organisms are strongly influenced by their dispersiveplanktonic stage. To survive and navigate their patchy surroundings, planktonic larvae detect andrespond to chemical and mechanical cues. Ocean acidification (OA), caused by anthropogenicCO2 dissolving into the ocean surface, can negatively affect larval growth and survival.However, few studies have examined if OA influences larval ability to detect and respond tocues. Using a customized tank with stratified water columns, we tested whether rearingenvironment (ambient, pH 8.0 or acidified, pH 7.6) and larval age (3 and 9 days postfertilization) change the response of the larval sand dollar Dendraster excentricus to a knownpredator cue (fish mucus). Larval response to predator cue appeared concentration dependent andthe effect of acidification was more apparent on older larvae. To determine if the shift inbehavioral response was GABA mediated, we performed another experiment exposing larvae to-GABAA receptor agonist (muscimol) and antagonist (gabazine). GABAA receptor manipulationhad no effect on response to predator cue for either condition (ambient or acidified). Our findingssuggest OA not only stunts larval growth but contributes to larval response to predators. Suchobservations illustrate that the biological impact from climate change cascade upwards fromchanges in molecular levels, to individual behaviors, and ultimately population and communitydynamics.

74 Megan Vandenberg, John Michael Racy, Olivia Hawkins, Adam Summers, Cassandra Donatelli

Agonidae armor: an advantage or disadvantage?

Dermal armor is a multifunctional system which has evolved many times in freshwater and marine fishes. Two potential functions of armor are protection and drag reduction. We examine whether armor complexity follows a protection vs drag trade-off. The poachers (Agonidae) are a family of 47 species, with armor varying from protruding spines, to bumpy notches, to flat plates. This range of profiles affects the way water flows around these fish. Poachers are poor swimmers, using their pectoral fins in a drag-based sculling motion, making drag a serious issue for them. We used computed tomography (CT) scanning to study the morphology of poacher armor and computer aided design (CAD) to make idealized models to study the effect of isolated morphologies on drag. We 3D printed biological and idealized armor models, embedded them in a thunniform soft rubber model and measured drag in a flume with a force transducer. The biological and idealized models did not follow the same drag trends, with the biological having the least drag when the armor did not overlap and the idealized models having the least drag when overlapped. It is possible to distinguish armor traits as drag-producing or drag-reducing leading to a better understanding of the trade-off between defense and hydrodynamics.

1224 Megan Vandenberg, Karly Cohen, Robert Rubin, Jeremy Goldbogen, Adam Summers, Misty Paig-Tran, Shirel Kahane-Rapport

Bundles of bristles: a look inside baleen morphology

Filter feeding has independently evolved among vertebrates many times, in birds, mammals, bony fishes, and sharks. Rorqual whales are gigantic marine filter-feeders that lunge at dense masses of prey, engulfing both food and water. All 9 species of rorquals have baleen - a bristle-type filter made of keratin attached to their upper jaw, which varies greatly between species. The bristle filter is made of both major (larger) and minor (smaller) keratin plates containing many hairs. Baleen morphology plays a role in prey size and prey capture behavior. Rorquals could be sieve filterers, but there are difficulties with this hypothesis, including how the filter is cleared. We used micro-computed tomography (uCT) and scanning electron microscopy (SEM) to image and quantify variability in baleen morphology in 5 species that span one order of magnitude in body length. There are differences in hair density, plate thickness, and hair diameter between major and minor plates within each individual, and between species. CT revealed that the keratinized hairs are embedded in a matrix covered by a sheath of differing densities. Larger whales have disproportionately smaller hair diameters than smaller whales relative to their body size. Overall, most of the measured morphology parameters of baleen exhibit negative allometry when compared to whale body length. It may be that the morphology is influenced by the hydrodynamics of filtering rather than whale physiology.

1534 Lauren Vandepas, Reed Boohar, Giles Goetz, Nikki Traylor-Knowles, Frederick Goetz, Adam Lacy-Hulbert, William Browne

Immune cell phenotype to genotype: cell behaviors and transcriptomics across diverse metazoans

Metazoan immune cells deploy diverse behaviors, including phagocytosis, secretion of inflammatory cytokines, and the casting of extracellular DNA “traps” (e.g. ETosis). Vertebrate leukocytes (“white blood cells”) display functionally distinct immune responses across cell types. Invertebrate immune cells (hemocytes, coelomocytes, etc) phenotypically exhibit a variety of morphologies and cellular behaviors in bilaterians such as insects and molluscs. However, behavioral and transcriptional signatures driving invertebrate immune cell behaviors are broadly undescribed, particularly among non-bilaterians. Consequently, it is unknown whether cells capable of phagocytosing bacteria may be distinct immune cell types, and pathogen defense mechanisms associated with the evolution of metazoan innate immunity remain unclear. Using functional assays for immune cell behaviors combined with RNAseq, we have analyzed putative immune cell gene expression from hemocytes isolated from the oyster Crassostrea gigas and amoebocytes isolated from the model ctenophore Mnemiopsis leidyi. We additionally analyzed cell populations for behaviors associated with immunity. Comparative analyses of our gene expression datasets show both deep conservation of some immune pathways as well as uncharacterized lineage-specific immune genes. Strikingly, for example, oyster hemocytes competent for ETosis also significantly express immune genes associated with mammalian neutrophil function. These comparative data sets of functional immune cell behavior and gene expression provide an opportunity to explore not only conserved mechanisms of pathogen defense but also novel aspects of metazoan innate immunity evolution.

1378 Isaac VanDiest, Samuel Lane, Korin Jones, Taylor Fossett, Kendra Sewall

How Similar are Urban and Rural Arthropod Communities?

Most work in urban ecology has focused on charismatic fauna despite lower trophic level taxa, such as arthropods, being vital to the function of ecosystems. Urbanization often lowers diversity and abundance of arthropod communities. However, few studies have investigated how urbanization changes community structure, and how it relates to prey abundance. In the current study, using vacuum sampling that collects arthropod taxa with diverse life histories, coupled with multivariate comparisons, we investigated how arthropod communities differ between replicate urban and rural sites in southwest Virginia. We found that rural sites had higher average arthropod biomass and abundance compared to urban sites, and that higher trophic level arthropods (e.g. Araneae and Coleoptera) were more common in rural areas. Our findings are consistent with other studies of the effects of urbanization on arthropods and suggests that higher trophic level species in urban areas may be impacted by prey availability and quality. These results were further used as the basis for questioning how predators of arthropods might be affected by having different prey communities to rely on. This is likely an issue for urban birds that exist in these same field sites, specifically song sparrows (Melospiza melodia), where they are found in lower abundance and density than in our rural sites.

889 Rebecca Varney

A checklist for reproducible publication of genomic data from non-model taxa

Genome sequencing is becoming more accessible and powerful, but unfortunately there is a lack of consensus on what information must accompany genome-based publications. The result is a flood of sequencing data without a framework to evaluate its quality, completeness, and future utility. Worse, in non-model taxa, a lack of detail in methods often hinders us from adopting new techniques and results in researchers repeating failed protocols. Here, we present a set of guidelines to promote consistency between publications, to increase transparency of sequencing projects, and to preserve the value of sequence data as sequencing technologies advance. We propose a checklist for journals to adopt as a requirement for articles publishing new sequencing data, and that reviewers could use to thoroughly vet methods and results of future ‘omic publications. We also recommend specific updates to current repositories to increase accountability in data availability. We anticipate that this set of guidelines will serve as a foundation of best practices that will persist as genomic sequencing becomes just one part of larger publications.

1714 Gabrielle Vaughn, Lauren Ballou, Thomas Iliffe, Elizabeth Borda

Population Genetics and Distribution of Typhlatya Species of the Yucatán Peninsula

Species of the cave dwelling shrimp genus Typhlatya are found within anchialine habitats worldwide and commonly observed throughout the aquifer of the Yucatán Peninsula, Mexico. Typhlatya species draw great curiosity from researchers regarding conservation concerns and potentially play an important role in carbon cycling within cave systems. Recent work demonstrates the presence of at least five species, (two undescribed), of which all can be found co-existing in coastal caves where the groundwater is stratified with fresh/brackish and saline water. This study will assess the population genetics, via deeper sampling, of Typhlatya species from ∼30 inland and coastal Yucatán caves, as well as marine caves in Belize. The analysis of mitochondrial (mt) COI and 16S rRNA and nuclear ITS and 28S rRNA gene data will yield a better understanding of species distributions and connectivity among cave systems across the Peninsula (and beyond). Preliminary analysis of mt 16S rRNA gene data reveals that although the freshwater sister species T pearsei (n = 10) and T. mitchelli (n = 31) overlap in range and broadly distributed within the meteoric lens (~270 km), T. pearsei exhibited little to no genetic diversity. Whereas both T. mitchelli and the euryhaline, T. dzilamensis (n = 64) each exhibited the highest genetic diversity (HBd; 0.60 and 0.50, respectively). Of note, T. dzilamensis is shown to be coastal restricted with a distribution extending to marine caves in Belize (>700 km).

273 Diego Vaz, Tess Avery, Molly Gabler-Smith, George Lauder

Denticle Multiverse 1: Morphological Madness of Placoid Scales in the Portuguese Dogfish

The Portuguese Dogfish (Centroscymnus coelolepis) is a type of Sleeper-shark (Somniosidae) with worldwide distribution in deep-water oceans. This species presents such drastic differences in dermal denticle morphology across ontogeny that some juveniles were previously described as an entirely different species in a separate genus. Using both scanning electron microscopy and micro-CT, we show that variation in placoid scales is substantially higher than previously described, not only across ontogeny, but with remarkable variation across different regions of the body. Thirteen denticle morphotypes are described across ontogeny. Additionally, three body regions (e.g., snout, interspiracular surface, and trunk/tail) are recognized as having the same group of denticle morphotypes throughout development. For example, on the trunk and tail of small juveniles (~350 mm TL), denticle crowns have two to three longitudinal ridges and three posterior cusps that are gradually replaced by ridgeless and cuspless crowns in adults (> 800 mm TL). On the snout, crowns are always rounded with no cusps, but the number of longitudinal ridges increases as sharks grow in length. These ontogenetic transformations in denticle morphology are among the most dramatic known in sharks and suggest a number of interesting future studies of intraspecific and interspecific variation, taxonomy, and function to better understand the denticle multiverse.

1070 Carrie Veilleux, Rebecca Lewis

Fat storage as a possible strategy for coping with drought in a seasonally-adapted lemur

Rapid global warming is changing habitats and affecting biodiversity, and is expected to exacerbate aridification in many regions. Animals and plants in seasonal habitats often exhibit adaptations to cope with seasonal resource-limiting conditions. It is currently unclear how these adaptations will affect responses to more prolonged and more frequent drought episodes. In this study, we explore the effects of two recent droughts (2016-2017, 2022) on the health, behavior, and food resources of a population of Verreaux's sifaka (Propithecus verreauxi), a critically endangered folivorous lemur inhabiting the dry deciduous forests of Madagascar. We combined behavioral data from over 72,000 focal instantaneous point samples across 9 years for 48 lemurs, 10 years of morphometric data collected each dry season, and nearly 12 years of phenological data from lemur food trees. Unexpectedly, we found that subcutaneous fat increased during the drought years in both adults and subadults. We also observed significant changes in behavior during drought periods, particularly in feeding time budgets. Specifically, lemurs spent more time eating fruits and flowers during drought months, even though phenological analyses found no difference in the availability of these foods. Our results suggest that these lemurs may use dietary shifts and/or physiological changes to increase fat storage and survival during periods of water scarcity. Such adaptations to seasonal resource-limitation may increase an organism's resilience to future climate change impacts.

409 Isabela Velasquez-Gutierrez, Jessica Hua, Obed Hernandez-Gomez, Bryon Tuthill, Mary Campbell, Karin Sauer, Eve Milusich

Evolutionary responses of bacteria to antibiotics affect their ability to inhibit a fungal pathogen

Emerging fungal diseases in wildlife are arising at unprecedented rates. Other microbes in the community (e.g., bacteria) can produce and release anti-fungal compounds potentially influencing fungal disease outcomes. However, changing environmental conditions may alter the inhibitory effectiveness of these compounds. For example, antibiotic contamination can lead to the evolution of antibiotic-tolerant bacterial strains which may incur costs that influence the inhibitory compounds that bacteria produce. In this study, we investigated whether the inhibitory compounds produced by antibiotic-tolerant vs. non-tolerant bacteria (Pseudomonas aeruginosa) differentially influence the growth of an amphibian fungal pathogen (Batrachochytrium dendrobatidis- Bd). We cultured four strains of P. aeruginosa: (1) non-tolerant biofilm, (2) tolerant biofilm, (3) non-tolerant planktonic, and (4) tolerant planktonic. We exposed Bd cultures to 0.0002, 0.002, 0.02, 0.2, 2, or 20 mg/mL of bacterial secretions and measured Bd growth after 14 days. Secretions collected from P. aeruginosa strains that have not evolved tolerance to antibiotics inhibited Bd growth. In contrast, secretions collected from P. aeruginosa strains that have evolved tolerance to antibiotics enhanced Bd growth. The strength of Bd inhibition or enhancement was dose-dependent and did not depend on the morphology of the bacteria (biofilm vs. planktonic). Understanding how evolutionary changes in bacteria influence the suite of compounds released into the environment may have important implications for understanding patterns of emerging infectious diseases in the face of human-induced environmental change.

230 Ashwini Venkatanarayana-Mohan, Anjali Goswami, Jeffrey Streicher

Ultraconserved Elements as landmarks on genomes: extracting "genospaces" from mammalian genomes

Ultraconserved Elements (UCEs) are small regions within genomes that are conserved across tetrapods and have been extensively used for phylogenomic studies. Research in the past has identified specific UCEs to be directly or indirectly associated with gene regulation and genomic stability. The conserved nature of these sequences found all over the genome and across millions of years of tetrapod evolution calls for further exploration of their potential role in stability and morphological development. We developed a novel pipeline to decipher UCE architecture within genomes using reference mapping and concepts borrowed from landmarking morphology. This multivariate landmark data from genomes is directly comparable to other biological data such as morphometric data and provides a new framework for comparative studies. In this study, we UCE landmarked >30 published high-quality mammal genomes and quantified "genospace" (synonymous with morphospace) by applying statistical ordination methods. To demonstrate the comparative potential of this approach, we further tested for associations between mammalian genospace and morphospace based on skull shapes extracted from 3D geometric morphometrics.

1417 Alexandra Venuto, Timothy Erickson

Initial swim bladder inflation in larval zebrafish is mediated by the mechanosensory lateral line.

Larval zebrafish achieve neutral buoyancy between 3-4 days post-fertilization by gulping air from the water's surface to inflate their swim bladders. We define this behavior as "surfacing." Little is known about the sensory basis for this behavior. A strong candidate is the lateral line (LL), which is a hair cell-based sensory system that detects hydrodynamic information from sources like water currents, predators, prey, and surface waves. However, the influence of the LL on larval behaviors that mediate swim bladder inflation remain unexamined.To explore the connection between the LL and surfacing behaviors, we utilize a genetic mutant (lhfpl5b-/-) that silences the LL. Approximately half of LL mutants over-inflate their swim bladder. Thus, we hypothesize that larval zebrafish use their LL to sense the air-water interface and regulate swim bladder inflation. We find that over-inflation is caused by abnormal surfacing behaviors in LL mutants by blocking access to the surface and recording surfacing attempts. Additionally, we determine that LL defects in mutants are responsible for over-inflation by reproducing the mutant phenotype with ototoxic ablations in wild type fish and rescuing the over-inflation phenotype with a transgene. Finally, we show that decreasing surface tension results in wild type over-inflation. In summary, we discovered a novel sensory basis for achieving neutral buoyancy where larval zebrafish use their LL to sense the air-water interface and regulate swim bladder inflation.

715 Emma Vequist, Veronica Martinez-Acosta

Making the Cut: An Analysis of Regeneration in Lumbriculus variegatus

Lumbriculus variegatus is a freshwater oligochaete that is capable of whole body regeneration. While studies have broadly characterized regeneration in Lumbriculus, little is known regarding the limitations on its regenerative capacity. In this study, regenerating fragments were created with either 3, 6, 9, or 12 segments worth of original body tissue. Differences in segmental regeneration are observed in the number of tail segments regenerated when comparing fragments removed from anterior or posterior regions. In addition, recovery of rapid escape behaviors associated with anterior and posterior body positions occurs more completely in 12-segment fragments in comparison to 3-segment fragments ($p < 0.05$), suggesting a limitation on the number of original segments needed to fully regenerate. Regeneration capacity was also examined at 8 different axial positions across the length of the worm. Fragments removed from the outermost anterior and posterior axial positions (position 1 and 8) regenerated fewer head and tail segments, as compared to fragments removed from axial positions found within the body. EdU labeling of these regenerating fragments also demonstrates a difference in the number of stem cells contributing to head and tail regeneration in anterior regions as compared to posterior regions. This data suggest that regeneration is limited by the initial size of the body fragment and that the axial position where the initial injury occurs plays a role in successful regeneration and recovery of function.

385 Taylor Verrett, Kristin Dyer, Daniel Becker

Urbanization and haemosporidian infection in overwintering sparrow communities

Urbanization can shape vector-borne parasite transmission by altering host susceptibility, host community composition, and vector distribution. The net effect of urbanization on parasitism varies; for example, host immunity can be fortified by abundant anthropogenic resources, but vector contact may be increased in urban environments. Avian haemosporidia (genera Plasmodium, Haemoproteus, and Leucocytozoon) are intra-erythrocytic parasites commonly associated with sub-lethal impacts on host fitness, but have also been implicated in population declines. We investigated how urbanization may drive patterns of haemosporidian infection by sampling overwintering sparrow communities (8 species) across rural and urban/periurban habitats in central Oklahoma. Haemosporidian infection status, intensity, and diversity were determined using microscopy and PCR. Using generalized linear mixed effect models, we examine how a habitat's degree of urbanization (using the Human Footprint index) affects haemosporidian parasitism. Leukocyte profiles will be used to examine the relationship between urbanization and chronic stress. We predict haemosporidian prevalence and intensity will be higher in urbanized sites because of increased vector contact and habitat-related stressors, but parasite diversity will be lower in alignment with homogenized urban bird communities. In addition to providing insights on infectious disease dynamics in a rapidly urbanizing world, this study provides a starting point for future work investigating the impacts of urbanization on parasite transmission in avian systems between winter and the start of spring migration, with implications for parasite dispersal.

600 Mathieu Videlier, Pierre-Olivier Montiglio, Francois Dumont

Sex-and period-specific genetic (co)variance matrix of behaviour and body mass in Lygus linealoris

Worldwide, producers use insecticide, predators, or traps to control pest density. Such biocontrol strategies can exert new selective pressures and potentially evolutionary changes in pest populations; especially in exploratory behaviour (change in foraging or dispersion rate). Evolutionary response to selection is determined by the additive genetic (co)variance among traits or groups within population. It is thus necessary to analyse these patterns of genetic (co)variance to anticipate the evolutionary consequences of biocontrol strategies. Here, we quantify the additive genetic variance of body mass and exploratory behaviour in multiple populations of Lygus lineolaris, a major pest in North America. Using a half-sibling breeding design (1148 offspring from 286 families), we estimated the G-matrix of body mass and distance traveled in an open field, as well as partitioning (co)variances between sexes and periods (early and late summer) during which was extracted the field population.Mass and distance were heritable in both sexes, with a strong positive cross-sex genetic correlation for mass (rfm = 0.78[0.60,0.88]) but unsignificant for distance (rfm = 0.35[-0.21,0.66]). For females, the genetic correlation between mass and distance was positive (rg = 0.33[0.02,0.55]), whereas in male it was weaker and unsignificant (rg = 0.17[-0.11,0.41]). Finally, the genetic correlation across periods was close to zero for both sexes. In conclusion, the G-matrix revealed independence between periods and sexes in behaviour, leading to a possible sex-specific evolutionary response to producer's strategies.

738 Rylee Vigil, Isabella Garino-Heisey, Victor Gonzalez, John Hranitz

Summer acclimatization by high/low elevation bees yields different thermal and desiccation tolerance

Bees are important pollinators of wild and cultivated plants that are experiencing changes in population vigor and range shifts caused by climate change. Bee communities on islands are geographically restricted, where only high-elevation refugia may offer habitats that range shifts otherwise provide. Summer bee communities at different elevations offer an opportunity to study physiological responses by bees during summer acclimatization, and to evaluate importance of potential high-altitude island refugia in bee conservation. We measured thermal and desiccation tolerances of more than 70 species (30 genera of 5 families) at two elevations (0 and 800 m) on Lesvos Island (Greece). We predicted that high-elevation bees will tolerate low temperatures better than low-elevation bees and that low-elevation bees will be more heat and desiccation tolerant than high-elevation bees. We found that high-elevation bees displayed better low- temperature tolerance than low-elevation bees but had similar high-temperature tolerance. Interestingly, high-elevation bees tolerated desiccation stress more than low-elevation bees. These results indicate that summer acclimatization in high-elevation (mountain) environments does not affect upper thermal limits but does improve lower thermal limits and desiccation stress tolerance. In contrast, summer acclimatization at low-elevation (coastal) regimes decreased lower thermal limit performance and reduce desiccation stress tolerance. The physiological performance of high- and low-elevation bees supports the hypothesis that high-elevation refugia are important to pollinator conservation under current climate change patterns.

1067 Natalie Villafranca, Sofia Diaz-de-Villegas, Isabella Changsut, Haley Womack, Alicia Schickle, Koty Sharp, Lauren Fuess

Investigation of trade-offs associated with immunity and reproduction in Astrangia poculata

Most living organisms face ubiquitous pathogenic threats, and have consequently evolved the immune systems, which protects against potential invaders. However, the components of the immune system are physiologically costly to maintain and engage, often drawing resources away from other organismal processes such as growth and reproduction. These trade-offs have been studied in a wide diversity of systems in order to better understand how organisms respond to competing needs and optimize fitness. However, few studies have investigated these topics in cnidarians, which include ecosystem engineers like hard corals. Here, we characterize trade-offs between constitutive immunity and reproduction in the facultatively symbiotic coral Astrangia poculata. We hypothesized that there would be trade-offs between constitutive immunity and reproduction. Further, we expected that variation in symbiont density would affect energetic budgets, and therefore dynamics of these trade-offs. Male colonies underwent ex situ spawning and sperm was quantified. We then correlated reproductive output to immune metrics including melanin production, antioxidant production, and antibacterial activity. We found no significant associations between reproductive output and immunity. The lack of observed trade-offs, highlights complexities in energetic budgets, and the importance of characterizing multiple traits when considering these questions. Our results provide a preliminary framework for future studies to understand immune trade-offs in cnidarians, which will further improve knowledge on how corals allocate their resources in response to disease conditions.

1460 Alondra Villalba, Jodie Jawor, Tim Wright

Early life stress and the physiological stress response in juvenile budgerigars

Stressful events experienced early in life can have long-lasting impacts on organismal responses to similar events later in life. It remains unclear, however, whether early life stressors buffer or conversely, heighten, an organism's response to stressors later in life. These effects may be particularly important in the cognitive domains of learning and memory. The budgerigar (Melopsittacus undulatus), a small parrot, is an excellent model to better understand such effects due to its ability to learn vocalizations throughout its entire life. As a first step, we developed a 21-day chronic stress protocol that presents a single stressor at unpredictable intervals to nestlings and measured physiological stress response and changes in glucocorticoid and mineralocorticoid receptors (GR and MR) in learning-related brain regions. We found changes in the glucocorticoid-mediated stress response resulting in the increase of baseline circulating corticosterone levels and a decrease in stress response levels in stressed birds relative to non-stressed controls. Analysis of changes in neural GR and MR between treatments is ongoing. The remaining birds will be housed separately until adulthood and then subjected to either stress or non-stress treatment. This two-step experiment allows us to investigate the interactive effects of juvenile and adult stress in a species that, like humans, has open-ended vocal learning in groups.

1088 Bridget Vincent, Emily Lau, Sriram Ramamurthy, Clara Bourguignon, Todd Oakley

Spotlight on cephalopods: How early evolutionary steps constrain photophore morphology

Evolutionary convergence can arise from both similar and radically different evolutionary trajectories. Similar paths to the same trait may indicate the presence of historical constraints or selective pressures toward a phenotypic optimum. Here, we explore how the mode of light production in cephalopod light organs, or photophores, may influence the organ's morphological diversity across evolutionary origins. Using a maximum-likelihood coalescent phylogeny and ancestral state reconstruction, we find that autogenic photophores (those that create their own light) are more morphologically diverse than bacteriogenic (those that use light produced by symbionts). This suggests that the mode of light production may constrain evolutionary routes to diversity. We propose that bacteriogenic photophores converged on similar morphologies because the colonization, housing, and culturing needs of light-producing symbionts imposed constraints on the diversity of tissue morphology. Convergence may result from a mechanistic constraint, which could shape patterns of morphological and organismal biodiversity.

1078 Naomi Vliet, Sadie Small, Brooke Weigel

Effects of sori incubation temperature on Nereocystis luetkeana gametophyte & sporophyte development

Climate change is affecting marine ecosystems around the world. Warming ocean temperatures have been linked to kelp forest declines, including Nereocystis luetkeana forests in the Salish Sea. However, the temperature tolerance of different stages of the N. luetkeana life cycle are not well established. We examined the effects of a short-term marine heatwave on N. luetkeana sori and subsequent microscopic life stages. We incubated sori at temperatures of 18°C, 20°C, and 21°C for 3.75 days, and grew gametophytes from each sori treatment at both 10°C and 16°C for 40 days. Gametophytes were able to develop normally and produce sporophytes from sori incubated at all temperatures, but gametophyte growth temperature had significant impacts on the life cycle. Gametophytes grew larger and at a faster rate at 16°C, but sporophytes developed faster and were more abundant when gametophytes were grown at 10°C. When sori were incubated at 21°C, gametophytes were more numerous but fewer sporophytes developed. Our findings suggest that sori can withstand temporary high temperatures and develop into gametophytes and sporophytes, but if gametophytes experience high temperatures the development of sporophytes may be hindered. A decrease in sporophyte development would disrupt the life cycle and could lead to loss of important kelp forest habitat. While all temperature treatments produced sporophytes, further research should identify the impacts of prolonged temperature stress (>3 days) on microscopic life stages.

590 Charles Voirin, Toshi Tsunekage, Yujie Liu, Kate Alexy, Iris Levin

Brood size and growth rate affect telomere length and dynamics in nestling barn swallows

Early life for animals is often a time of rapid growth and development. In a resource- limited environment, life history theory predicts that there must be tradeoffs between resource sinks in ways that optimize future survival and reproductive success. Telomeres have emerged as putative indicators of these early life tradeoffs, but there are conflicting accounts as to how developmental traits and conditions impact telomere length and dynamics. For two years, we studied the nestlings of a breeding population of barn swallows from day six to day twelve of life, measuring various ontogenetic factors to understand to what extent they explain variation in telomere length and dynamics. We unexpectedly found that telomeres lengthened between the two sampling points. Nestlings in large broods had shorter telomeres, but surprisingly, individuals that grew faster from day six to day twelve had longer telomeres and more telomere lengthening. Nestlings with higher mass relative to their nestmates on day six had shorter telomeres. These effects were only found in the first year of study, when there was more variation in telomere length. Telomere lengthening may be due to the initiation of new hematopoietic cell lines during development or the expression of telomerase early in life. Favorable early life conditions and high parental investment could allow for more growth with little to no cost to telomere length or dynamics.

252 Rajal Vyas, Michael Rosario

The Effect of Activation Dynamics on the Muscle-Tendon Unit's Ability to Decelerate Mass

Although muscle-tendon units (MTUs) are studied for their ability to accelerate masse (e.g., generating propulsive power during jumping), they are equally important in decelerating mass (e.g., absorbing the impact during landing). Little is known about the dynamic flow of energy between muscles and tendons during these decelerations. Given that the time to maximal muscle activation can vary from instantaneous (pre-contraction before deceleration) to up to 30 ms (contraction period of a single muscle twitch), do the activation dynamics of muscle affect the muscle's role in mass deceleration? In this study, we use a muscle-tendon simulation to model a mass-spring system in which a falling mass is decelerated by an MTU. We included simulations in which muscle activation instantaneously reached 100% (to simulate pre- contraction) and compared those results with simulations in which muscle activation was delayed (using a model for realistic muscle recruitment). When considering scenarios in which activation is delayed, work is always done on the muscles but with instant acceleration, muscle does work before any work is done on it. In other words, with instant activation, the function of the muscle changes. These results reveal the importance of activation in the functional role of the muscle during mass deceleration and provide greater insight into the mechanisms that determine energy flow in the MTU.

1240 Catherine Waggoner, Kayla Pehl, John Swallow, Jason Vance

Growth and allometry in the adult stalk-eyed fly, Teleopsis dalmanni

Eyespan in the stalk-eyed fly, Teleopsis dalmanni, is sexually dimorphic, and both sexes exhibit considerable variation in eyespan which may impact moment of inertia, maneuverability and flight behavior. T. dalmanni are sexually mature approximately 4 weeks post-eclosion, suggesting that investment into gonads may further increase abdominal mass and overall body mass across age. The purpose of this study was to determine how morphology changes across age and between sexes, and investigate the potential for compensatory traits. The morphology of 1-to-56 day old male ($n = 175$) and female ($n = 189$) flies were assessed: flies were anesthetized with CO_2, photographed, dissected, and their heads, thoraces and abdomens were individually weighed. Images were analyzed to determine eyespan, thorax width and length, and wing length. Males were heavier and had longer eyespans and wings than females. Wing length, and thorax width and length, varied proportional to eyespan in both sexes. Total body mass, abdominal mass and thorax mass increased logarithmically across age in both sexes; body mass increased 48% during the first week post-eclosion, then an additional 31% over the following 7 weeks. The ratio of thorax to total body mass did not vary across age, suggesting that increased abdominal mass, resulting from investment into abdominal tissues due to sexual maturation, is met by proportional, compensatory growth of thorax tissues, presumably to maintain flight performance as flies become heavier with age.

174 Madison Wagner, Paul Moore

Variations to cue indices elicits prey behavioral responses even when predators are relatively small

Anti-predator behavior is often evoked based on measurements of risk calculated from sensory cues emanating from predators independent of physical attack. Yet, the exact sensory indices of cues utilized in risk assessment remain largely unknown. To examine how different predatory cue indices of information are used in risk assessment, we presented prey with various cues from sub-lethal sized gape-limited predators. Rusty crayfish (Faxonius rusticus (Girard, 1852)) were exposed to predatory odors from sub-lethal sized largemouth bass (Micropterus salmoides (Lacep?de, 1802)) to test effects of changing predator abundance, relative size relationships, and total predator length in flow through mesocosms. Foraging, shelter use, and movement behavior were used to measure cue effects. Foraging time depended jointly upon predator abundance and total predator size ($p = 0.030$). Specifically, high predator abundance resulted in decreased foraging efforts as gape ratio increased. Similarly, sheltering time depended on the interaction between predator abundance and gape ratio when predator abundance was highest ($p = 0.020$). Crayfish significantly increased exploration time when gape ratio increased ($p = 0.010$). Thus, this study shows crayfish can utilize different indices of predatory cues, namely total predator abundance and relative size ratios, in risk assessment but do so in context specific ways.

456 Daniel Wagner, Michael Rosario, Frank Fish

Drag Reduction in the Snailfish Tail Curl

When suctioning to a surface, snailfish are known to bend the posterior part of their body into a postural position referred to as the tail-curl. In the tail-curl posture, the tail is tucked neatly under the head, which makes the snailfish appear smaller as well as minimizes its lateral surface area. Little is known about why snailfish adopted the tail-curl posture. One biomechanical explanation is that it may help reduce the drag forces imparted on the snailfish by fluid flowing over the body. The purpose of this study was to determine the effects of the snailfish tail-curl on the hydrodynamic forces imparted on the snailfish by the fluid flowing over the fish. Three 3D snailfish models (representing straight, curled, and bent-tail postures) were created using 3D modeling software (Blender) and printed using a UV Resin 3D printer. Hydrodynamic testing at various speeds were used to measure the drag force from flow perpendicular to each model. Our results indicated that the reduction of projected surface area in the bent-tail and curled postures lowered the measured drag force compared to the straight snailfish. Therefore, a significant reduction in the coefficient of drag compared to the straight-tail model was seen in both curled ($p = 2.44$ E-6) and bent-tail postures ($p = 2.61$ E-15). Our results reveal hidden aspects of the interactions between organismal posture and fluid environment.

1278 Dylan Wainwright

Studying scale-space: an exploration of fish scales across species

Scales are bony, overlapping plates that cover the bodies of most species of teleost fishes that come in a variety of shapes and sizes. Although we recognize that scales are morphologically diverse, it has been challenging to understand why this diversity exists, largely due to two reasons: 1) scales are likely multifunctional with possible roles in protection, hydrodynamics, and beyond; and 2) the texture of scales is difficult to quantify, especially in three-dimensions. We confront this second issue with new methods (gel-based profilometry) that allow for the collection of topographic data from fish surfaces, but the first issue remains to be resolved. During the pandemic I sought to better understand the morphological patterns of fish scale diversity by imaging the surface topography across hundreds of species of fishes. I will present some preliminary results from this sampling, including a comparison of scale morphology across body regions in the Centrarchidae (basses and sunfishes), patterns of scale diversity in coral reef fishes, and an examination of how body shape and a species' habitat may relate to scale morphology. This comparative dataset will let us better understand the ways in which scales are diverse and determine what factors (like ecology and body morphology) are related to scale diversity.

817 Cassidy Waldrep, Paul Schaeffer, Adam Parlin, Ann Rypstra

Repeatability of biologging data from turtles suggests a new methodology for assessing personality

Repeatability has been used in many previous behavioral studies to assess the differences among animals within a population. Not only can it indicate if a behavior is different between individuals, but it can also investigate whether or not a trait is consistent over days. Acknowledging this helps drive animal personality research since consistency is essential in showing personality. We used long-term biologging from the Eastern box turtle (Terrapene carolina carolina) and the Painted turtle (Chrysemys picta) in their natural environments to investigate the presence of repeatable behaviors. We evaluated the behavioral consistency of whole-body acceleration (ACC), heart rate (HR), body temperature, and movement across multiple weeks and calculated the repeatability of such traits between the individuals studied and across days. We detected consistent behaviors throughout the week for many individuals, with ACC being the most consistent trait in box turtles and HR being the most consistent trait in painted turtles. Multiple behaviors were found to be significantly different between individual turtles hinting at the presence of personality. More specifically, box turtles varied the most in heart rate values while painted turtles varied the most in body temperature. By discovering consistency and repeatable differences in free-living animals, biologging data can offer a fuller insight into the behaviors of animals.

1720 Lindsay Waldrop, Shilpa Khatri, Yanyan He

Flash or Sniff: Testing the evolutionary divergence of firefly antennae due to selection

Many species of beetle within the family Lampyridae (fireflies or lightning bugs) produce a visual signal (abdominal flashing or glowing) instead of a chemical signal (pheromones) to attract mates from a distance. A number of lampyrid species have secondarily lost abdominal flashing, reverting back to pheromone signaling. The primary organs responsible for sensing olfactory cues are the antennae which bear specialized chemosensory sensilla used for capturing olfactory pheromones. Since visual signalers no longer use these sensilla, will there be differences in the number, size, and/or arrangement of sensilla on the antennae of visual versus chemical signaling lampyrids? We used scanning electron microscopy to image the antennae of fifteen species of lampyrid beetles from the LA County Natural History Museum and measured sensilla length, width, arrangement, spacing, and angle to assess species differences in morphology. To investigate the impact of these difference on performance, we used morphometrics to model odor capture using the immersed boundary method and advection-diffusion modeling. Our preliminary results suggest that no significant differences exist in the antenna morphology of visual versus chemical signalers, and this translates to no significant differences in odor-capture performance between species. To further understand and explore how these results are set in terms of the physics of the system efficiently, uncertainty quantification is used to analyze the uncertainty and create a computationally cheaper surrogate of the odor-capture model.

362 Nicolas Walker, Sean Burke, Isaac Ligocki

Behavioral responses to competition and perceived predation risk in two teleost fish

Both competition and perceived predation risk may influence an organisms behavior. In the present study, we observed the impact of competition and perceived predation risk on exploratory behavior and sociality in Eastern Mosquitofish (Gambusia holbrooki) and Fathead Minnows (Pimephales promelas). We established single and mixed species replicate groups in outdoor mesocosms. Half of these mesocosms also housed a largemouth bass (Micropterus salmoides) that was physically separated from the focal fish, but focal fish were exposed to visual and physical cues associated with the predator. After six weeks in each treatment, fish underwent a series of behavioral tests to quantify exploratory behavior and sociality. We found that P. promelas did not change their exploratory behavior as a result of predator presence or the presence of a competitor. P. promelas exposed to a predator spent more time with conspecifics, but not specifically in larger groups of them. We did not find a significant effect of compe-

tition or predators on G. holbrooki exploratory behavior or sociality. Our findings suggest that these species respond differently to perceived predation risk, but neither modified their behavior as a result of competition with heterospecifics.

1757 Nia Walker, Erik Hanson, Stephen Palumbi

Genetics of recovery in corals with differing heat resistance capacity

Heat stress resistance and recovery are two integral components of overall resilience, and it is vital to measure the relative contributions of resistance and recovery to resilience and variation of resistance and recovery mechanisms within coral populations. In this study, we investigate the recovery of 26 known Acropora hyacinthus colonies from three generalized levels of heat resistance—low, moderate, and high. We tracked transcriptomic change at the following timepoints: 2 hours pre-heat stress, 16 hours post-heat stress, 2 weeks post, 1 month post, and 4 months post-heat stress. Pre-heat stress variation between the three heat resistance categories suggested that different transcriptome baselines contributed to performance in the heat stress experiment. We also found strong differential expression patterns at later recovery timepoints based on initial resistance, for example, gene upregulation for metabolic processes and skeletal matrix proteins in moderately resistant corals 1 month into recovery compared to others. This dataset represents one of the first transcriptomics studies to investigate resistance adn recovery ability in individual corals and illuminates links between these mechanisms of heat stress resilience.

477 Whitney Walkowski, Robert Rosencrans, Elizabeth Alexis, Joshua Lott, Fernando Blank, Corinne Richards-Zawacki, William Gordon, Nicolas Bazan, Zhide Fang, Hamilton Farris

Differences in the Retinal Inner Nuclear Layer of Diurnal vs. Nocturnal Amphibians and Reptiles

Visual ecology causes selection on the optical and neural phenotypes of eyes. For the retina, where the selective consequences of nocturnal and diurnal ecologies are well known for photoreceptor phenotypes, less is understood at subsequent cell layers. This study measured the number of neural cells, the width, and cell density of the inner nuclear layer (INL) in nocturnal and diurnal frogs and lizards. INL measurements were made at nine evenly spaced positions in superior-to-inferior 1 μm thick retinal sections. We found that INL cell count and layer width are significantly greater in diurnal than nocturnal species. The space occupied by the INL cells is not compensated by increased width, however, as the mean cell density in diurnals is 1.4 times that in nocturnals. The increased INL cell count in diurnals varies with retinal position and animal class, as reptiles, and not amphibians, exhibit variation associated with position: diurnal reptile central INL counts are relatively greater. INL hypertrophy may be driven by increased photoreceptor input, as diurnal photoreceptor outer segment count is greater than that in nocturnals. Thus, the retina of diurnal species exhibited more INL neurons at denser packing, which may be linked to greater photoreceptor outer segment density. This comparative approach suggests INL hypertrophy may be characteristic of diurnal retina in any vertebrate taxon, as the species here independently evolved their day-active ecologies.

1533 Robert Walsmith, Elizabeth Walsh, Rick Hochberg

Nervous system morphology of three gnesiotrochan rotifers with a focus on metamorphosis and sex

Reorganization of the nervous system during metamorphosis in indirect developers is a common feature in many invertebrates. This process is also found in some female rotifers. Sessile females of Superorder Gnesiotrocha develop from a larval stage that undergoes metamorphosis, which involves expansion of the corona or loss of the corona and its replacement by a new head called the infundibulum. Male gnestriochans are of similar size to female larvae but do not undergo metamorphosis and have simpler anatomies that may influence the complexity of the nervous system. Here, we examine serotonin-like immunoreactivity (SLIR) and FMRF-amide-like immunoreactivity (FMRF-IR) in the sessile rotifers Acyclus inquietus (solitary), Collotheca ferox (solitary), and Lacinularia flosculosa (colonial). We hypothesized males and larval females will have similar patterns of immunoreactivity because of similarities in body size, while adult females will have fewer IR-positive structures based on observations from earlier studies. Immunohistochemistry and confocal laser scanning microscopy were used to map neurotransmitter expression. Results revealed that expression patterns in the cerebral ganglion were arch-shaped in C. ferox and A. inquietus and x-shaped in L. flosculosa. One commonality between C. ferox and L. flosculosa was the reduction of SLIR-elements after metamorphosis. Male nervous system expression closely resembled larval female SLIR expression in all species. Results may suggest reorganization of larval nervous systems during metamorphosis is necessary to meet the lifestyle constraints associated with sessility.

352 Olivia Walthaus, Frederik Püffel, Victor Kang, David Labonte

A comparison of cutting and bite forces in Atta vollenweideri leaf-cutter ants

Leaf-cutter ants cut fragments from fruits and leaves to feed a fungus used as a crop. Their colonies consist of workers which vary vastly in size, potentially increasing foraging efficiency. A crucial part of a leaf-cutter foraging trip is the mechanical interaction between ant mandible and plant, defined by two key forces: the maximum force the ant can apply (bite force), and the force required to fracture the plant fragment (cutting force). The bite force is determined by the physiology and anatomy of the bite apparatus; the cutting force, in turn, depends on the tissue's structural and mechanical properties, and the mandible geometry. How do these two forces compare? To address this question, we used a custom-built fibre optic force setup to measure the force required to cut a range of natural and synthetic substrates with both worker mandibles and razorblades. Mandible cutting forces were typically lower than those of razorblades, demonstrating extreme mandible sharpness. However, peak mandible cutting forces can be more than 1000x the body weight of a typical worker. To assess if ants can generate forces of this magnitude, we measured bite forces using a custom-built rig. Leaf-cutter ants generate exceptionally large bite forces, corresponding to almost 3000x their body weight. We argue that the evolution of this remarkable bite performance was driven by the need to cut plant fragments during foraging.

43 Silu Wang, Devin de-Zwaan, Jacqueline Mackenzie, Else Mikkelsen, Chris Wood

Pleiotropic opposing dominance within a color gene block contributes to a nascent species boundary

The divergence of plumage color genes contributes to songbird radiation. However, the mechanisms by which color gene divergence counteracts gene flow to maintain reproductive isolation during the formation of new species boundaries remain elusive. The hybrid zone between Setophaga occidentalis (SOCC) and S. townsendi (STOW) in the Cascade Range provides a natural observatory to investigate potential behavioral mechanisms underlying divergent selection on color genes. Recently, we found that selection within a single gene block associated with plumage color variation has maintained a stable and narrow hybrid zone. Here, we investigated the potential role of plumage signals in moderating a behavioral mechanism of selection. Specifically, we assessed whether two plumage traits are associated with body size among breeding males and if trait mismatch predicted aggressive behavior within hybrid and parental individuals in response to simulated territorial intrusion. The two plumage signals, cheek and flank coloration, though associated with the same gene block, reflect opposing dominance of SOCC and STOW alleles. We found that both plumage traits significantly predict the body size in the territorial sex (i.e. males). The opposing dominance of the single color gene block resulted in plumage signal discordance in heterozygotes, which in turn was associated with reduced hybrid territorial performance, an important proxy of fitness in this system. Taken together, these observations point to a single-locus-two-alleles mechanism of incompatibility in shaping a nascent species boundary.

44 Silu Wang, Qin Li, Dahong Chen

Tinamou egg color displacement at ecoregion co-partitioning

The divergence of reproductive traits frequently underpins the evolution of reproductive isolation. One of the most enduring puzzles on this subject concerns the variability in egg coloration among species of tinamou (Tinamidae), endemic to neotropics. Here we investigated the hypothesis that tinamou egg coloration is a mating signal and its diversification was driven by reinforcement. For most tinamou species, the male guards the nest that is sequentially visited and laid eggs in by multiple females. The colorations of the existing eggs in the nest could signal mate quality and species identities to the upcoming females, preventing costly hybridization, thus were selected to diverge among species (Mating Signal Character Displacement Hypothesis). If so, two predictions should follow: (1) egg colors should coevolve with known mating signals as the tinamou lineages diverged; (2) species that partition similar ecoregions should display different egg colors. The tinamou songs are important mating signals and are highly divergent among species. We found that the egg luminance was significantly associated with the first principal component of the song variables, which supports prediction (1). In addition, we found support for (2): tinamou species that co-partition ecoregions tend to display different egg colors, controlling for song variation. Egg color and songs could be multimodal mating signals that are divergently selected as different tinamou species diverged. Mating signal evolution could be opportunistically exploitative.

529 Rui Wang, Robert Steele, Eva-Maria Collins

Body axis inheritance via Wnt gradients in regenerating Hydra tissue fragments

How an animal establishes its body axis is a fundamental question in developmental biology. The freshwater cnidarian Hydra is uniquely suited to the study of pattern formation. Hydra's simple body plan - radially symmetric with a single oral-aboral axis - is amenable to modeling, and its legendary regenerative abilities enable manipulations that would be impossible in other systems. It was recently proposed that the orientation of the new body axis in a regenerating Hydra polyp is determined by the oral-aboral orientation of the actin-myosin contractile processes (myonemes) in the animal's outer epithelial layer. However, it remained unknown whether myoneme orientation was sufficient for axis orientation and how axis polarity was established, given that myonemes are not known to have polarity. Because Wnt signaling is known to control axis polarity in Hydra and bilaterians, we hypothesized that Wnt plays a role in axis formation during regeneration of Hydra tissue pieces. We tested this hypothesis using pharmacological activation of Wnt signaling and novel tissue grafts, setting myoneme orientation and Wnt signaling perpendicular to each other to determine which controls axis formation. Our results demonstrate that Wnt signaling is the dominant encoder of both axis orientation and polarity, in line with its conserved role in axial patterning.

1043 Ziheng Wang, Alison Weber, Abigail von-Hagel, Mahnoush Babaei, Bingni Brunton, Sarah Bergbreiter, Tom Daniel

Sense and extensibility: two dimensions of stimulus features for wing strain improve sparse sensing

Mechanosensory feedback is critical for flexible coordinated movements. In insect flight, applied forces and torques yield complex spatiotemporal patterns of wing bending. Information about these shape changes is encoded by strain-sensitive neurons embedded in the wings, but it remains unclear which features of wing bending drive neural responses. Using a combination of experimental and computational approaches we elucidate this feature space by first recording from mechanosensory neurons as the wing is driven through a range of motions. We use a multi-laser system for simultaneous measurements of wing position to reconstruct the spatiotemporal patterns of wing strain. We then characterize the temporal features encoded by individual neurons using reverse correlation, covariance analysis, and maximally informative dimensions. We show that single neurons are selective for multiple distinct features, suggesting a richer feature space is encoded by these neurons than previously known. We next build a computational wing model that allows us to mimic strain-sensitive neurons using both one- and two-dimensional nonlinear filtering. We use this model to identify a small number of neurons that can detect perturbations in body and wing dynamics. We further show that tiny strain perturbations resulting from Coriolis forces can be accurately classified and measured. With 10 sparsely placed sensors, our one-dimensional neural filter can detect 1 rad/s body rotation with 88% accuracy. The two-dimensional neural filter can do so with 98% accuracy.

1185 Ruiqi Wang, Yakun Cao, Nick Gravish

The roles of traction and actuation in cockroach crevice traversal

High accelerations during walking and running are constrained by the contact forces between the animal and the ground. Foot morphology, muscle actuation, and surface roughness can all be possible limiting factors for generating high contact forces. We developed an experiment to determine how ground substrate roughness affects foot-ground contact forces in the cockroach (B. discoidalis). We measured the fore-aft, mediolateral, and vertical ground reaction forces while individuals (N = 10) attempted to push through a narrow crevice (70% stance height). This escape behavior elicits large pushing forces while also allowing for high-resolution observation of foot-ground interactions from high frame rate top and side view videos. We found that there was no significant difference in force production on different roughness sandpaper substrates (60 grit to 150 grit). Cockroaches were able to produce traction force and sustain vertical suppression upwards of 50 times their body weight. The hind legs produced the majority of the traction force needed for passing through the crevice, which is about 2 times the vertical forces the hind legs produced. Foot-ground observations indicate that the interactions between tibia spines and the asperities are likely responsible for the high traction forces across all substrates. Future work includes characterizing the relation between the large traction forces and the insect's high-acceleration maneuvers.

1327 Wayne Wang, Alex Gunderson

A multi-level analysis of correlated divergence in sperm and adult thermal tolerance in lizards

Predicting how climate change impacts populations requires an understanding of thermal thresholds and evolvability of reproductive traits. Despite this, empirical data on the evolution of thermal performance in gamete stages directly tied to reproductive success are rare. Theoretically, sperm traits should be selected to maximize fertilization success under prevailing environmental conditions. Therefore, as thermal niches of populations diverge, we expect sperm performance to undergo adaptive evolutionary change in concert with other aspects of organismal performance. To fill this gap in our knowledge, we investigated the correlation between sperm and adult thermal tolerance at both intraspecific and macroevolutionary levels. For the intraspecific level, tested for an association between the heat tolerance of adult male brown anoles (Anolis sagrei) and ejaculated sperm from the same individuals. For the macroevolutionary level, we tested for an association between sperm and adult heat tolerance data among 11 lizard species. We found no significant correlation between sperm and adult thermal tolerance among male brown anoles. In contrast, we found that sperm and adult thermal tolerance are significantly associated at the species level. Overall, our results provide evidence for the correlated divergence of adult and sperm thermal performance and suggest the potential evolvability of sperm physiological trait over macroevolutionary timescales.

1611 Tianyu Wang, Velin Kojouharov, Christopher Pierce, Kelimar Diaz, Baxi Zhong, Valerie Zborovsky, Daniel Goldman

Robophysical modeling reveals the role of passive body mechanics in C. elegans locomotion

The millimeter-size nematode C. elegans displays versatile locomotion in diverse environments. Previous research has focused on neural controls, while the role of body mechanics is often overlooked, particularly in heterogeneous environments. Our observations of nematode locomotion in regular obstacle arrays suggest that many behaviors instigated by collisions (e.g., glancing, body buckling) occur passively, and therefore are determined as much by body mechanics as neuronal dynamics. We further hypothesize that the bilateral muscle actuation mechanism in C. elegans provides favorable passive mechanics for navigating environmental challenges. To test these hypotheses, we constructed a bilaterally actuated robophysical model of C. elegans ($L = 86cm$), which allows us to isolate passive mechanics from active controls, and systematically study the intelligence inherent in body mechanics. Robophysical experiments in various obstacle arrays (40cm, 20cm, random spacing) reveal that mechanical compliance improves locomotion performance (higher speed and lower energy cost) in open-loop locomotion. The observed kinematics in the robot show passive glancing and buckling behaviors analogous to those found in nematode. We observed in nematode that direct head collisions can generate reversal behaviors (reversing wave propagation direction for $\sim$0.1-2 cycles), and hypothesize such behavior is triggered by touch sensors in the worm's head. To model this, we augmented the robot with force sensitive resistor array and implemented an analogous behavior. The closed-loop control improves the success rate of robot navigating through obstacle arrays.

859 Jessica Ward, Alexa McDonald

Role of the lateral line in embryonic communication in oviparous fishes

In many oviparous species, individuals perceive and respond to external cues during embryogenesis—including those from siblings. In some birds and reptiles, physical disturbance cues function as sources of social information that influence the behavior of individuals in the clutch. Embryonic communication has not been studied to the same extent in oviparous aquatic vertebrates, and so the sensory mechanisms that facilitate the transfer of information among neighbors remain unknown. In this study, we used behavioral assays and pharmacological sensory ablation techniques to test for the role of the lateral line system in embryonic communication in a common freshwater fish, the fathead minnow (Pimephales promelas). Eggs were collected on the day that they were laid and maintained in simulated predator-rich or control environments for 5 days. Locomotor activity levels of physically clustered or dispersed embryos were assessed in response to predator and non-predator cues. For half of the tests, we temporarily disabled the lateral line of individuals prior to testing to reduce the detection of neighbor movements (= total of 8 test scenarios). We found significant overall effects of lateral line ablation and neighbor proximity on embryo locomotor activity, suggesting that individuals may indeed attend and respond to mechanosensory information from developing conspecifics during embryogenesis. These data are a first step toward understanding embryonic social communication in oviparous fishes.

489 Clinton Warren, Rachel Bowden, Anthony Breitenbach, Ryan Paitz

How does cold snap exposure affect sex determination in a freshwater turtle?

In species with temperature-dependent sex determination, temperatures above or below a given threshold result in the formation of either an ovary or a testis. Research suggests these thresholds exhibit limited variation within species, however, few studies have considered whether individuals exhibit temporal differences in temperature-induced gonadal differentiation. To investigate this, we have begun characterizing the temporal variation in gonadal differentiation as a metric of thermal sensitivity in embryos of the red-eared slider turtle (Trachemys scripta). We previously demonstrated that a 5-day heat wave is enough to induce ovary formation in some embryos, suggesting that individuals vary in their responsiveness to warm temperatures. To determine if T. scripta show similar variation in their responsiveness to cooler temperatures, we exposed embryos to cold snaps at different points in development from warmer baseline conditions to identify the minimum time required for cold temperatures to induce testis formation in some individuals. We predict that thermal responsiveness to cold snaps will decrease with developmental stage as embryos commit to ovary development at baseline conditions. This should be reflected by a lower expression of testis-promoting genes (Kdm6b, Dmrt1) for treatments later in development. These findings will help reveal whether variation in thermal sensitivity could facilitate an adaptive response by turtles to climate change.

1195 Charles Watson, Sadie Gent, Christian Cox

Sex-specific interactions between signal expression, energetics, and parasitism in canyon lizards

The relationship between sexual signals and parasitism likely exists along a spectrum. On one end, a high-quality sexual signal is an honest indicator of mate quality, such that there is a negative relationship between favorable attributes of a sexual signal and parasitism. On the other end, sexual signals might suppress defenses against parasites by diverting energetic resources or as a result of immunosuppressive testosterone, such that there is a positive relationship between sexual signal quality and ectoparasites. Previous research has rarely evaluated how the relationship between energetics and parasites might vary among components of complex sexual signals. We compared the components of sexual signals (ventral color patches), blood testosterone levels, masses of fat bodies and liver, and parasite loads for both sexes of the canyon lizard, Sceloporus merriami. We found complex relationships between parasite load and brightness, hue, and saturation of both blue and orange patches where some are positively and others negatively correlated with scant fat bodies, less massive livers, and higher mite loads. Females had larger fat bodies and livers and a similarly complicated relationship of color to mite loads, but also exhibited a higher frequency of intestinal parasite infections. Our findings indicate that the components of complex sexual signals might have different interactions with energetics, circulating testosterone, and parasites, implying that the evolution of these signals might be constrained by these interactions.

138 Emily Watt, Ryan Felice, Anjali Goswami

Use it or lose it: decreasing mandibular complexity through time in amphibians and stem tetrapods

Tetrapods (limbed vertebrates) have undergone considerable evolutionary changes during and since their initial water-to-land transition around 390Ma. Following this major ecological shift, there was a surge of morphological innovation due to expansion into unexplored terrestrial niches. Whereas trends across this evolutionary radiation in cranial anatomy and locomotor structure/function are well-studied, less attention has been given to mandibular evolution. Mandibular and dental morphology are important because they reflect adaptations to different diets and also constraints imposed by development and phylogeny. Here, we reconstruct the morphological evolution of the tetrapod mandible to identify trends and shifts in disparity through time, potentially related to large-scale events (e.g. mass extinctions). We scored 570 species of early tetrapods, temnospondyls, lepospondyls, and lissamphibians for 31 traits, including tooth count, toothed-element count, and mandibular complexity (element count). We reconstructed the likelihood of transitioning between states and ancestral states, finding higher mandibular complexity at the base of the tree. Shifts from an edentulous or hyperdont state occurred much less frequently than shifts from a moderate tooth count to either extreme. Jaw disparity generally decreases through time, with the most disparity at the base of the tree and stasis over the last ∼150M years. Our results demonstrate that the lower jaw has undergone substantial morphological and structural change across tetrapod evolution, but different aspects of jaw morphology show distinct evolutionary patterns.

1415 Savanna Watts, Nathanael Campbell, Jennifer Dearolf, Shawn Noren

Locomotor Muscle Morphology of the Pelagic Delphinid, Stenella longirostris

Spinner dolphins (Stenella longirostris) are intermediate divers, routinely diving to depths of 200 to 300 meters. Based on their diving behaviors, we hypothesized that S. longirostris would possess an equal mix of slow- and fast-twitch fibers in their primary locomotor muscle, the longissimus dorsi (LD), as exhibited by striped dolphins (S. coeruloalba), another pelagic species with similar behaviors. To test our hypothesis, LDs from adult spinner dolphins were sectioned using a cryostat and stained for their myosin ATPase activity after acidic pre-incubation. Digital micrographs of the stained tissue were captured and then overlaid with a Mertz curvilinear grid to determine fiber-type profile by area. We found that the locomotor muscle of spinner dolphins was primarily composed of fast-twitch fibers (59.53±7.9%), a profile that is more comparable to the shallow diving (∼60 meters) Atlantic spotted dolphin (S. frontalis) (58.7±3.9%). Thus, these results suggest an alternative muscle design for the spinner dolphin, as it is an intermediate diver, but its muscle also displays features that may limit its aerobic capacity. Our findings could potentially be explained by the unique feeding behavior of spinner dolphins. These animals spend only a small proportion of their time in deep water looking for prey. In comparison, the striped dolphin, whose LD has primarily a slow-twitch profile (46.7±3.3% fast-twitch, 53.3±3.3% slow-twitch), almost exclusively hunts in deep water (∼700 meters).

1273 Alexander Waye, Andrew Ray, Matthew Holding, Talia Moore

Cutting down the time for comparative FEA studies: a case study with snake fangs

Finite Element Analysis (FEA) combined with phylogenetic comparative methods analyzes how biological structures respond to loading, which provides insight into how selective pressures drive morphological adaptation. In comparative analyses, statistical power is proportional to the number of species; however, each species requires CT scanning, building 3D meshes, setting boundary conditions, and running the model. Therefore, each additional species exponentially increases the hours of work required. We propose a method to rapidly obtain FEA results for large datasets by leveraging geometric morphometrics, which we evaluate on a 46 species dataset of snake fangs.First, we used the geomorph package to landmark all species and compute a phylogenetic Principal Components Analysis. By deforming a natural fang to represent the extremes of the first 3 principal components (PCs), we effectively sampled on the borders of PC space that includes all natural fang shapes. We then performed FEA on all deformed fangs and modeled the histograms of stresses generated at each node as Weibull distributions. We fit a non-linear model of these Weibull parameters over our PCs 1-3 to predict loading responses for points in the PC space. We assessed accuracy by measuring average differences between predicted distributions and empirical FEA results for multiple natural fangs. Using this method, we can greatly reduce the amount of time necessary to analyze large datasets for comparative FEA studies.

926 Sydney Wayne, Daniel Warner, Kerry Cobb, Jocelyn Miracle, Cindy Scruggs

The influence of water availability on reproduction and embryo development in the brown anole lizard

Water availability has strong effects on an individual's behavior, physiology, and fitness. In oviparous reptiles, for example, water availability can affect adult reproduction (e.g., female fecundity), as well as offspring traits (e.g., embryo survival, hatchling size). Moreover, maternal hydration might influence egg hydration in ways that affect how embryos develop under future moisture conditions of the nest. In this study, we quantified the effects of water availability on female fecundity and egg hydration in brown anole lizards (Anolis sagrei). We then incubated their eggs to determine if maternal hydration influences embryo development under different moisture conditions. Using a full-factorial design with two levels of hydration for mothers (low vs high) and their eggs (dry vs moist), we tested the predictions that poorly hydrated females have reduced fecundity, and that their developing offspring are better prepared for dry incubation conditions compared to offspring from well-hydrated females. Preliminary results show that low water availability decreased egg production but had no effect on maternal or egg hydration. This pattern may reflect a strategy that minimizes maternal and egg water loss at the expense of reduced egg production. Upcoming analyses will examine interactive effects of maternal and egg hydric environments on egg survival and offspring phenotypes. This study will provide a novel evaluation of the potential adaptive value of maternal effects that are mediated by the hydric environment.

909 Ryan Weaver, Justin Havird

How to test temporal predictions of the nuclear compensation mechanism of mitonuclear coevolution

Mitochondrial (mt) and nuclear-encoded proteins are integrated in aerobic respiration, requiring cofunctionality among gene products from fundamentally different genomes. Different evolutionary rates, inheritance mechanisms, and selection pressures set the stage for incompatibilities between interacting products of the two genomes. The mitonuclear coevolution hypothesis posits that incompatibilities may be avoided if evolution in one genome selects for complementary changes in interacting genes encoded by the other genome. Nuclear compensation, in which deleterious mtDNA changes are offset by compensatory nuclear changes, is often invoked as the mechanism for mitonuclear coevolution, yet direct evidence supporting it is rare. Specifically, if nuclear-encoded proteins are the compensatory partner, amino acid changes should occur in mt proteins first, followed by changes in the interacting nuclear protein. Here, we detail methods for how to test this prediction using 3D structures of mitonuclear proteins and variant effect prediction tools. We highlight key examples that call into question the ubiquity of this mechanism of mitonuclear coevolution and make a call for future studies to explicitly test these key predictions and explore other possibilities for the maintenance of mitonuclear coevolution.

720 Amani Webber-Schultz, Kayla Hall, Ayi Ajavon, Adam Summers, Brooke Flammang, Lauren Simonitis

Who nose what flows: dermal denticle morphology and narial flow

The dermal denticles of sharks are placoid scales that cover their body and have a profound effect on fluid flow around the body as a whole. Denticles vary in morphology by regions of the body and water flow is affected by denticle shape and size. We recorded variation in the denticles surrounding the incurrent and excurrent nares and made a qualitative assessment of the effect of shape and direction on flow. We describe the morphology and orientation of dermal denticles around the nasal region of the Pacific spiny dogfish (Squalus suckleyi) using computed microtomography (microCT) and scanning electron microscopy (SEM). We couple these morphological data with flow analysis using dye flow visualization. Denticle density, orientation, and shape influence flow at the nares. In the posterior region of the incurrent naris a high density of denticles with reversed orientation act as a flow barrier. In other parts of the nares the denticles are arranged to shape flow rather than simply passing it over the narial openings. It is important to consider the narial denticles when modeling flow across the sensory tissue, and our observations raise the possibility of deducing flow from denticle orientation across cartilaginous fish diversity.

437 Abby Weber, Philip Anderson

Intriguing Ichneumons: The Influence of Scale and Substrate on Parasitoid Wasp Ovipositor Morphology

While numerous organisms utilize elongate tools to inject toxic substances into targets for prey capture or defense, parasitoid wasps inject something quite different: eggs. Ichneumonidae is a massive family of parasitoid wasps, which must maneuver their ovipositors through a variety of substrate materials, such as leaves, wood, fruit and cuticle in order to deposit eggs into their host organisms. Ichneumons also show a diverse array of ovipositor morphologies, from short and stubby to extremely elongate (up to multiple body lengths), with a variety of tip shapes and features such as serrations. To better understand how host and host substrate have influenced the evolution of ovipositor structure, we have taken a range of morphological measurements to explore evolutionary trends that may be influenced by these substrate materials. These morphological measurements include body length and ovipositor length, as well as a series of measures directly related to puncture ability, such as radius of curvature and half angle of the tip as well as width of the shaft. Measures were taken across the Ichenumonidae tribe Cryptini, for which there is a published phylogeny. The data suggests that aspects of the tip morphology are generally independent of ovipositor size relative to body length. Aspects of both tip and overall ovipositor geometry are most likely influenced by aspects of the host and host substrate material.

716 Anastasia Weger, Clare Rittschof

Assessing the Predictive Power of Physiological and Epigenetic Factors on Aggression in Honey Bees

In a social environment, interactions with conspecifics and previous experiences shape physiological and epigenetic factors in an individual. In turn, these factors modulate how an individual responds to stimuli and new information, both on the level of gene expression and observable behavior. However, it's often unknown if these factors can predict an individual's response to new information and their magnitude of influence. We're addressing this question through the lens of honey bee (Apis mellifera) aggression, a social response to protect the group from threat, by assessing the predictive power of two factors known to influence aggressive behavior and associated brain gene expression: brain DNA methylation pattern and the size of the fat body, a peripheral organ with metabolic and immune function. We also examined response to new information through hypervigilance, or the more extreme response by an individual to a second aggressive encounter. We used single cohort colonies to create bees with different combinations of age, task, fat body size, and methylation and ran them through aggression assays against an intruder bee. Our preliminary results show that fat body size may be a stronger predictor than brain DNA methy-

lation. We're continuing to process samples to quantify lipid content and run bisulfite and RNA sequencing to further characterize the hypervigilance response and create generalized linear mixed models to compare the predictive potential of these factors.

1474 Julia Weil, Cali Wilson, Richard Hall

Human-provided food and heterogeneity in aggression in urbanized flocks of American white ibis

Urbanization has dramatically altered natural habitats worldwide, having profound effects on wildlife health, abundance, and behavior. Urban wildlife are often fed by people, which can alter densities and contact patterns, with implications ranging from individual foraging success to transmission of infectious diseases. To date little is known about how direct feeding of wildlife influences behavioral variation in urban-feeding wildlife. Here we quantify aggression and its potential drivers in an urban-feeding waterbird, the white ibis (Eudocimus albus), in south Florida. We experimentally provisioned ibis with bread and used overhead cameras to quantify individual ibis aggression frequency, conspecific density around focal birds, and distance from the thrown bread. We found that 72.7% of aggressive behaviors are instigated by 20% of individuals, suggesting strong heterogeneity in aggression. Preliminary analysis suggests that distance from provided food and conspecific density do not predict this variation in aggression. The finding that a few aggressive birds account for most of the aggressive interactions in fed ibis flocks could promote super-spreading of close-contact transmitted pathogens, with important implications for human and wildlife health.

1286 Ren Weinstock, Karen Kapheim

Investigating the plasticity of bee social behavior under climate change

Bees are facing rapidly shifting environments under climate change, including rising temperatures. Animal behavior and physiology are sensitive to changes in environmental temperature, but how increased temperature may alter these to influence social organization in insects has not been explored. To understand the stability of bee social organization under climate change, we tested the effect of temperature on social mechanisms in the sweat bee Halictus rubicundus. This bee exhibits environmentally-dependent sociality, allowing us to investigate how increasing temperature will affect future patterns of bee sociality. We hypothesized that in social colonies, queens and workers will respond differently to increased temperature, including changes in aggression and reproductive physiology. Using circle tube experiments in increased temperature regimes, we compared the aggression response to temperature in H. rubicundus queens and workers. Following the aggression tests, we compared the effects of temperature increase on oogenesis and lipid content, as potential mechanisms driving temperature-induced changes in behavior. Any difference in the aggressive or physiological response to temperature between castes could indicate a decrease in the stability of social structures, altering the expected response of bee populations to climate change. This study thus provides critical insight needed to predict how bee populations will respond to a changing climate.

962 Hannah Weller, Maya Weissman, Hernan López-Fernández

Bet-hedging theory helps explain life history differences between among mouthbrooding cichlids

Mouthbrooding, a form of parental care where parents shelter their offspring in their mouths, is hypothesized to evolve as a way to increase juvenile survivorship in unpredictable environments (e.g. predation, hypoxia, drought) at the cost of reduced fecundity—making it a type of bet-hedging strategy. African mouthbrooding cichlids have been well-documented as having fecundities an order of magnitude smaller and eggs twice as large as those of substrate brooders, but this observation is driven by a single radiation of mouthbrooding cichlids in Lake Victoria (and larger eggs alone would increase survivorship). To investigate whether lower fecundities and higher survivorship are a generalized feature of mouthbrooding cichlids, we measured fecundity in 45 Neotropical species, where mouthbrooding has evolved multiple times. While mouthbrooders had broods about half as big, their eggs were, on average, of comparable size to those of substrate brooders, suggesting that mouthbrooding alone explains the observed reduced fecundity. Because our findings support mouthbrooding as a bet-hedging strategy, we used stochastic individual-based simulations of bet-hedging evolution to predict where and why it should evolve. We found that mouthbrooding is more likely to evolve in highly variable environments or when fecundity reduction is minimized. We discuss possible explanations for differences in mouthbrooding evolution, fecundity, and egg size differences between Neotropical and African cichlids in light of these findings.

967 Hannah Weller, Nathan Lord, Anna Hiller, Steven Van-Belleghem

Flexible color segmentation of biological images with the R package recolorize

Color patterns are an important source of biological information in fields ranging from disease ecology to sexual selection, but most metrics for color are restricted to point measurements or require expensive equipment and restrictive data collection conditions. Methods for moving beyond point measurements rely on color maps, where every pixel in an image is assigned to one of a set of discrete color classes (color segmentation). Manual methods for color segmentation are slow and subjective, while existing automated methods often fail due to biological variation in pattern, technical variation in images, and poor scalability for batch clustering. As a result, color segmentation is the common bottleneck for a majority of existing downstream analyses. Here we present recolorize, an R package for color segmentation that succeeds in many cases where existing methods fail. Recolorize has three major components: (1) an effective two-part clustering algorithm where color distributions are binned and combined according to perceived similarity in a frequency-independent manner; (2) a toolkit for minor manual adjustments to automatic output where needed; and (3) flexible export options. We illustrate how to use recolorize and compare it to existing methods, including examples where we segment formerly intractable images from a variety of taxa including birds, insects, snakes, and fishes, and demonstrate the downstream use of methods that rely on color maps to quantify color patterns.

1012 Lindsey Wells, Molly Wingard, Andrew Fuller, Mark Garcia

The Influence of Age on Experience-Induced Behavioral Changes

Studies have shown that animals will modify their behavior based on prior experiences. These "experience effects" can be obtained in a variety of contexts including courtship, aggression, and foraging. For example, individuals become more cautious and risk-avoidant after being exposed to a predation experience. Despite a multitude of studies focusing on experience induced behavioral changes in adults, the effects of experience on juvenile behavior remains unknown. The aim of this study is to investigate the effects of age on experience-induce behavioral changes. We selected the Mangrove Rivulus (Kryptolebias marmoratus) fish as our study system. Adult rivulus are known to alter their aggressive and explorative behaviors following a fighting experience. We measured boldness and risk-taking behaviors in juveniles (2 months of age) and adults (6 months of age) before and after a predation experience. Boldness and risk-taking were measured as an individual's willingness to leave the safety of a shelter and explore an open field, respectively. The predation experience was elicited by vigorously chasing individuals for 10 seconds within the open field. Data collection is still ongoing but initial results indicate juveniles respond to prior predation experiences with increased latency to leave shelter, reduces willingness to explore an open field, and increased tendency to seek shelter. Results of this study may provide greater insights into how prior experience shapes an individual's behavioral phenotype across life-history stages.

1760 Christopher Wells, Joseph Benz, Kaitlyn Tonra, Emily Anderson, Howard Lasker

Grazers mediate the post-settlement bottleneck in Caribbean octocoral forests

Caribbean octocorals have not suffered the decades long decline in abundance that has plagued reef-building scleractinian corals. Their success and the formation of octocoral forests has been attributed to their continuing recruitment to reef habitats. Assessing the processes controlling recruitment is essential to understanding the success of octocorals and predicting their future. Benthic grazers on coral reefs can facilitate the growth and recruitment of corals by reducing the abundance of competitive algal turfs and macroalgae or hinder corals through predation of coral tissue and recruits. We assessed the effects of grazing by fishes and the sea urchin Diadema antillarum and mesofaunal predation on octocoral recruitment in a series of manipulative experiments using varying grazer/predator exclusion and inclusion conditions in in situ and ex situ experiments. Exposure to fish and urchin grazing significantly reduced survival and recruitment of single-polyp octocorals, while turf-associated mesofauna did not significantly affect neither recruitment nor survival. We also found a positive relationship between octocoral recruitment and turf algae, a potential related response to the deleterious effect of grazing exposure. These data suggest that grazers and predators mediate the mortality bottleneck characteristic of recruitment. Thus, the declines in the abundance of grazing fishes and urchins throughout the Caribbean may have contributed to the increase in abundance of octocorals in the Caribbean, concurrent with the loss of scleractinians.

1509 JoJo West, Kory Evans

Catch a Fish, Catch a Ride:How Alternate Piscivory Strategies Drive Skull Evolution

Characterizing the relationship between form and function has been a longstanding goal of evolutionary biology. Convergence in lineages with distant phylogenetic relationships resulting from similar ecological niches has bolstered our understanding of the processes which drive morphological diversification. Still, the ambiguity in how exactly diversity arises when factoring in convergent evolution remains largely unsolved. Predation, a function which virtually all animals must perform, offers a direct look into understanding the relationship between form and function. Within piscivorous acanthomorph fishes, there are generally two strategies; lie-and-wait predation and pursuit predation. Here we use three-dimensional geometric morphometrics and a phylogenetic comparative toolkit to quantify the relationship between skull shape and prey capture mode across several disparate clades of piscivorous teleost fishes. We find that pelagic pursuit predators exhibit levels of morphological disparity equivalent to their lie-and-wait counterparts, while not overlapping in traitspace. Taken alongside the phylogenetic overrepresentation of ambush predation, this points to chase-down piscivory driving high levels of morphological evolution.

1798 Aaron West, Thomas Hart, Eve Schneider

Tactile Specialization in Domestic and Muscovy Ducks: Integrating Behavior and Physiology

Ducks are known to use a variety of foraging strategies including dabbling, diving, pursuit, and grazing. Dabbling ducks, such as the Pekin duck, are thought to be expert tactile foragers based on their behavior, anatomy, and physiology. Yet there are few studies that directly compare tactile acuity between species of ducks with varying foraging strategies. Thus, we conditioned two phylogenetically distant domesticated duck species (Pekin and Muscovy ducks) to associate objects differing in size and shape with food reward using touch alone (West et al., Front Physiol 2022). Females of both species spent more time foraging in the bowl with the correct shape significantly more than the incorrect shape. However, when we tested them on objects differing only in hardness only Pekin females were able to make the correct association. This presentation will show anatomical and functional data from the individuals in our behavioral dataset, and position these results in the context of tactile anatomy in other Anseriformes.

1276 Molly Westbrook, Nicholas Guilbeault, Aristides Arrenberg, Tod Thiele, Scott Juntti

A Comparison of the Visual Behavior of Astatotilapia burtoni and Danio rerio

Understanding how organisms perceive motion in the visual environment remains unsolved. Complicating matters, each species has evolved neural adaptations that improve perception within an environmental niche. We use an easily elicited innate stabilization behavior, the optomotor response (OMR), to compare visual behavior between the African cichlid fish Astatotilapia burtoni and the zebrafish Danio rerio. Using automated tracking and closed-loop optomotor behavioral assays, we show that A. burtoni and D. rerio exhibit this behavior in different ways. A. burtoni exhibit stabilization bouts that closely follow the moving stimuli beneath them, and exhibit a more constant swimming velocity. D. rerio exhibits bouts consisting of a high velocity tail beat followed by a low velocity glide. We show that A. burtoni are able to complete stabilization trials faster than D. rerio, and exhibit a more constant locomotion compared to D. rerio's beat and glide movement. We also characterize optomotor response across A. burtoni's early life history, demonstrating the onset of this behavior at yolk-sac absorption and that A. burtoni are able to exhibit this behavior for up to one month post fertilization. Together these data give insight to how these fish species exhibit different locomotion strategies tailored to different environments.

961 Erica Westerman, Sushant Potdar, Madison Jennings, Conor Moriarty, My Ly, Neelendra Joshi

What apples do in the shadows: plant-pollinator interactions at night

Pollinators play a vital role in angiosperm diversity and agriculture. For this reason, diurnal pollinators, especially bees, are some of the most well studied insects. Nocturnal pollinators such as moths also play a role in flower pollination and fruit production, but plant-pollinator dynamics associated with nocturnal pollination of fruit is virtually unexplored. Apple blossoms are open day and night, and are visited by both diurnal and nocturnal pollinators. The nocturnal pollinators may be opportunistic visitors, or they may be targeted by flower volatiles or nectar. To assess whether apple trees exhibit circadian rhythms in volatile attractants and nectar rewards, we collected volatiles and nectar every five hours for six days in spring 2021 and 2022 at the University of Arkansas apple orchard. We also conducted nocturnal insect surveys to document time of peak nocturnal pollinator visitation. We found that time of day did not influence the amount of nectar in apple blossoms, but it did influence the volatiles blossoms produced, with nocturnal blossoms having a distinct bouquet relative to diurnal samples. These nocturnal bouquets included volatiles known to attract moths, such as heneicosane. We observed peak nocturnal visitation occurring between 10pm-midnight. Our results indicate that apple blossoms exhibit a circadian rhythmicity in floral bouquet that may enhance visitation by nocturnal pollinators, suggesting that apple trees may have a long history of pollination in the dark.

1164 Grace Westphal, Tara Stewart-Merrill

Partitioning variance in immune traits in a zooplankton host – fungal parasite system

When immune traits have a strong genetic basis, the presence and severity of disease in a population may influence the distribution of those traits. Our study addressed how two immune-related traits (gut penetrability, hemocyte response) are shaped by genetic and environmental sources of variation, and how the presence of a virulent disease altered the relative frequency of these traits in natural populations. Daphnia dentifera hosts were sampled from five Indiana lakes before and during epidemics of their fungal pathogen, Metschnikowia bicuspidata. Collected Daphnia were experimentally exposed to Metschnikowia and assayed for their gut penetrability, hemocyte response, and multi-locus genotype. Mixed effects models were constructed to partition variance in immune traits between genetic and environmental sources. We then isolated the genetic sources to produce genotype-specific estimates of immune traits for each multi-locus genotype. Finally, we assessed the relative frequency and dynamics of genotypes during epidemics and asked whether changes in genotype frequencies were related to their immune traits. Although genotype was an important source of variation for both gut penetrability and the hemocyte response, environmental factors explained a large portion of observed variation, suggesting a high degree of flexibility in Daphnia immune traits. No significant associations were detected between a genotype's immune traits and its frequency in a population. Our study highlights the power of variance partitioning in understanding the factors driving variation in Daphnia traits.

84 Sarah Westrick, Ryan Paitz, Eva Fischer

¿Por qué no los dos? Measuring both cortisol and corticosterone in poison frogs

The hypothalamic-pituitary-adrenal (HPA) axis shows variation across species in the production of glucocorticoids (GCs) in absolute levels and relative proportions of different GCs. As we measure physiological stress responses in more and more species, it is essential to keep this interspecific variation in mind. We often make default assumptions about the predominant GC based on the more classic models of that clade and only measure the GC we assume to be 'dominant'. For example, corticosterone is typically 'dominant' in amphibians, but we know there are exceptions to the rule. To better understand how stressors impact a species, we first need to characterize its general GC profile and identify which GC is primarily responsive to a stressor. Across five species of poison frogs, we found interspecific variation in water-borne cortisol, water-borne corticosterone, and the ratio of the two GCs. While overall we found higher concentrations of cortisol than corticosterone in D. tinctorius water samples, we found corticosterone - but not cortisol - increased in response to physiological activation of the adrenals through a hormone challenge. These results suggest the two GCs may be regulated differently and play different physiological roles in poison frogs. It is particularly important to develop non-invasive hormone collection methods, such as water sampling, to measure the physiological stress response in poison frogs due to their susceptibility to environmental stressors and conservation status.

104 Rebecca Westwick, Gavin Brackett, Brown Cameron, Bethany Ison, Clare Rittschof

Alarm cues alter nursing behavior in aggressive honey bee colonies (Apis mellifera)

Communication is a critical feature of animal societies. This is particularly true for large, eusocial insect colonies. Communication can become more difficult, however, in the face of competing information. One form of competing information that may be especially potent comes in the form of other conspecific signals, as many animals' nervous systems have features that selectively amplify conspecific information. Furthermore, social context can be important for understanding how social animals respond to any signal. Honey bees (Apis mellifera) provide a unique opportunity to study how conspecific signals interact. They live in large, dense, enclosed nests where more than a dozen different pheromones can be in play at once. We conducted an experiment to test the ability of nurse honey bees to appropriately respond to larval cues when presented with alarm pheromone, a conspecific signal which they are able to detect but typically show a low behavioral sensitivity to on its own. We found that nurses that originated from high-aggression colonies decreased their larval care behaviors in the presence of alarm pheromone, suggesting that this conspecific signal interferes with the nurses' ability to either detect or respond to larval signals. Meanwhile, nurses from low-aggression colonies did not decrease their larval care when alarm pheromone was present. This research demonstrates that social signals can influence critical parental care behaviors in honey bees in social-context-dependent ways.

160 Lindsey Wheaton, Marosh Furimsky

The Effect of Bisphenol F Exposure on Zebrafish Eye Development

Endocrine disrupting chemicals are chemicals that can mimic hormones and bind to hormone binding sites, causing a disruption of body pathways. Bisphenols, a type of chemical used in the manufacturing of plastic products, fall into this category. One type of bisphenol, Bisphenol F, is gaining popularity due to the widespread banning of other bisphenols like Bisphenol A. Bisphenol F affects the thyroid hormone signaling pathway, which is directly related to the development of the visual system in vertebrates. In this study, zebrafish (Danio rerio) were used as a model organism for aquatic vertebrates. In order to determine the effect of BPF exposure on zebrafish, embryos were exposed to different concentrations of BPF and observed using various types of microscopies. Transgenic line zebrafish and different sectioning and staining techniques were utilized to determine the effect of exposure on retinal cell differentiation and retinal health. Exposed embryos were observed to have smaller eye diameter as well as significant depigmentation of the eye in early developmental stages. These observations further support the idea that BPF exposure has a negative impact on the eye development of zebrafish, and further expands on the harmful effects of bisphenols, specifically BPF, providing evidence that it is not safe to be used in consumer goods.

1351 Miles Whedbee, Eva Fischer, Laura Stein, Tai Montgomery, Kim Hoke

The evolution of miRNA expression in the Trinidadian guppy

Complex phenotypes are constructed from the combined actions of genes and environment; and the regulation of gene expression has been shown to be a potent mediator of developmental plasticity, i.e. predictable changes in phenotype that depend on environmental conditions. This study characterizes microRNAs, a major class of small RNAs that function in RNA silencing and post-transcriptional regulation. How miRNA transcriptome plasticity (here, the differential transcription of miRNAs in response to chemical predator cues) affects evolutionary trajectories is largely unknown. We present a reaction norm framework as a means for addressing questions related to the dynamics of gene expression plasticity and molecular evolution. Using the Trinidadian guppy system, we address two major questions: (1) does miRNA gene expression plasticity itself evolve, and (2) do the miRNAs exhibiting expression plasticity within populations also differ in expression between populations? To answer these questions we used next generation small RNA sequencing to characterize the guppy small RNAome, including the detection of hundreds of known and novel miRNAs. We found numerous examples of miRNAs exhibiting expression plasticity, as well as the evolution of their expression plasticity. Our work characterizes these evolutionary patterns of expression plasticity by categorizing the expression of each miRNA gene and compares patterns of plasticity in miRNA expression within a population to patterns of population divergence.

876 Nathan Whelan, Austin Hannah, Kentaro Inoue, David Berg

Molecular ecology of the federally endangered freshwater mussel Cumberlandia monodonta

Freshwater mussels are among the most globally imperiled organisms. Yet, little is known about the genetic diversity of most natural populations or how anthropogenic river modifications have altered landscape genetics. Cumberlandia monodonta (Unionoidea: Margaritiferidae) once ranged across much of Mississippi River drainage. However, impoundments and other river modifications have caused extirpations and fragmentation. Past research using microsatellite markers indicated an absence of genetic structure across most of the range of C. monodonta, but we hypothesized that genome-scale data would reveal greater population structure. We generated a dataset of thousands of single nucleotide polymorphisms (SNPs) for collection sites across the contemporary range of C. monodonta. Even with thousands of nuclear loci, little genetic structure was found across the range of C. monodonta. Only individuals from the Ouachita River drainage in Arkansas formed a unique genetic cluster from other collection sites. We observed no genetic patterns that could be attributed to contemporary habitat fragmentation. The lack of genetic structure is likely mediated by a highly vagile host fish during the parasitic stage of the C. monodonta life cycle. Furthermore, the long life cycle of C. monodonta likely obscures effects of fragmentation. Our results also provide evidence that genomic data will not always result in inferences of finer-scale genetic structure than microsatellites. From a conservation standpoint, C. monodonta in Arkansas should be treated as a distinct management unit.

1744 Dwight Whitaker, Guido Dominguez, Andrew Estrada, Amiri Rivers-David, Larry Liu, Aiden Karpf

A numerical analysis of peat moss vortex rings

On a warm summer day in the bog, sporophytes of Sphagnum moss rupture and produce vortex rings to disperse their spores. Vortex rings carry the dust-like spores to heights exceeding 15 cm where they can be held aloft indefinitely by wind currents, and far higher than these non-vascular mosses can grow. We have numerically simulated these vortex rings using ANSYS Fluent. The results of these simulations are compared to high-speed video data to determine the initial pressure of the exploding sporophyte. Simulations with conditions matching those seen in nature also indicate that the vortex rings created are optimal. An optimal vortex ring is one where the circulation in the leading vortex ring is maximized and no trailing vortices are created. Optimal vortices are also observed in animals such as squid and jellyfish.

162 Britt White, Illiam Jackson, Kelly Zamudio, Melissa Kemp

Effect of congeneric competition on size dimorphism in the Anolis carolinensis clade

Body size variation between insular and mainland populations reflects the degree of heterospecific competition and thus resource differences between these habitats. Greater Antillean Anolis have served as replicated, natural experiments for testing ecological theories behind patterns of phenotypic variation, adaptation, and niche theory. In Antillean anoles, sexual size dimorphism is negatively associated with congeneric richness, meaning sexual dimorphism is reduced in the presence of more congeneric species. It is unclear if the degree of size dimorphism would result in the same pattern within a species across multiple competitive regimes and how readily adaptation to novel competitors occurs. Here I investigate the influence of congeneric competition on size dimorphism for traits under sexual and non-sexual selection in the Anolis carolinensis clade among island and mainland populations. We address this question using 3D morphometrics on high resolution CT scans of the skull and hyoid apparatus. Preliminary findings indicate that sexual and non-sexual traits may be similarly influenced by geographic location. While final results are still pending, this project provides a promising approach for resolving ecological sexual dimorphism dynamics.

234 Noor White, Zachary Batz, Edward Braun, Michael Braun, Karen Carleton, Rebecca Kimball, Anand Swaroop

A novel exome probe set captures phototransduction genes across birds (Aves)

The diversity of avian visual phenotypes provides a framework for studying mechanisms of trait diversification generally, and the evolution of vertebrate vision, specifically. Previous research has focused on opsins, but to fully understand visual adaptation, we must study the complete phototransduction cascade (PTC). Here, we developed a probe set that captures exonic regions of 46 genes representing the PTC and other light responses. For a subset of species, we directly compared gene capture between our probe set and low-coverage whole genome sequencing (WGS), and we discuss considerations for choosing between these methods. Finally, we developed a unique strategy to avoid chimeric assembly by using "decoy" reference sequences. We successfully captured an average of 64% of our targeted exome in 46 species across 14 orders using the probe set and had similar recovery using the WGS data. Compared to WGS or transcriptomes, our probe set: (1) reduces sequencing requirements by efficiently capturing vision genes, (2) employs a simpler bioinformatic pipeline by limiting required assembly and negating annotation, and (3) eliminates the need for fresh tissues, enabling researchers to leverage existing museum collections. We then utilized our vision exome data to identify positively selected genes in two evolutionary scenarios—evolution of night vision in nocturnal birds and evolution of high-speed vision specific to manakins (Pipridae). We found parallel positive selection of SLC24A1 in both scenarios, implicating the alteration.

896 Connor White, Theodore Castro-Santos, George Lauder

Volitional burst swimming in White Sucker, Catostomus commersonii, quantified with biologgers

Measuring maximal fish swimming performance under standard laboratory conditions can underestimate maximum swimming speeds and tailbeat frequencies. Traditional tools, like high-speed video, limit the spatial and temporal scale of measurements and data extraction is challenging, while biologging devices allow longer duration temporally and spatially unbiased estimates of behavior as well as the ability to measure multiple individuals simultaneously. We tagged white sucker, Catostomus commersonii, (TL: 37-48 cm; $n = 6$) with accelerometer, magnetometer, and gyroscope biologgers near their center of gravity with an additional accelerometer($n = 4$) on the caudal peduncle. Over a 10-hour period, fish were allowed to enter a large ($0.6\times0.6\times23$ m) flume with flow velocity ranging from

1 - 3.5 ms-1. All individuals attempted to swim against the flow and the number of attempts was variable between individuals (1 – 11 attempts), for a total of 38 attempts. These attempts consisting of bursting behavior lasted 7.3 + 2.7 s, and tags recorded instantaneous accelerations of the center of mass of 75 ms-2, rotational velocities of 500 deg s-1 and tailbeat frequencies of 10-13 Hz, which decreased as the burst progressed. Accelerometers on the caudal peduncle recorded comparable frequencies to the center of mass, but greater accelerations (>200 ms-2). Biologgers enable characterization of volitional high-performance swimming kinematics throughout the entire locomotor repertoire of fishes under near-field conditions.

158 Katie Whitlow, Callum Ross, Mark Westneat

***Cranial kinematics and modulation of feeding strikes due to prey-type effects in Amia cal*va**

Many vertebrate taxa employ different kinematic and biomechanical strategies for feeding on different prey types. Despite this widespread capacity for modulation across vertebrates, the extent to which non-teleost fishes modulate suction feeding strikes remains unknown. Early research suggested that hydrodynamics necessitate a generalized kinematic pattern across all suction feeding fishes—an antero-posterior wave of cranial kinematics—and that this results in feeding strikes that are stereotyped within individuals and species. The idea that strikes are stereotyped has been disproven, although the extent to which individuals or species modulate their strike kinematics is not yet documented. Here we examine the kinematics of suction strikes in bowfin, Amia calva, a holostean fish most closely related to gars. Amia are generalist predators, enabling a specific investigation of whether non-teleost actinopterygians modulate strikes in response to different prey types. We recorded Amia feeding on feeder fish and worms, two live prey differing in evasiveness, using X-Ray Reconstruction of Moving Morphology (XROMM). We found significant prey type effects on the velocities of cranial bone motions, but minimal magnitude differences. This effect is primarily driven by a shorter overall strike duration, meaning that Amia reached the same magnitudes but performed faster strikes when feeding on more evasive prey. These prey type effects suggest that the ability to modulate feeding strikes is primitive at least for actinopterygian fishes, and possibly for jawed vertebrates.

1019 Sydney Wilcoxson, Wonil Choi, Madeline Choi, Haruka Wada

The effect of hypoxia on sex ratios in zebra finch embryos

Hypoxic conditions can reduce survival of cells, affect organ function, and can lead to mortality among species. For embryos, hypoxic conditions can arise due to high incubation temperatures or lack of oxygen. Suboptimal incubation temperatures have been shown to affect sex ratio in oviparous animals; specifically, avian species producing a male-biased ratio when placed under suboptimal temperature conditions during incubation. Here, we tested the effects of hypoxia during incubation on sex ratios in zebra finches (Taeniopygia guttata). To do this, a 2×2 factorial design was implemented in which half of the eggs received a beeswax coating while the other half served as controls and incubated in either optimal (37.4°C) or high temperature (38.9°C). Using this manipulation, we previously showed that beeswax and high temperature have an additive, negative effect on hatching success. We are currently determining their sex based on PCR amplification from zebra finch Z and W chromosomes (male– ZZ, female– ZW) from tissue collected in this experiment. We hypothesize that female embryos have higher mortality when exposed to both increased incubation temperatures and to hypoxia than males, resulting in a male-biased sex ratio.

1425 Alexander Wilde, Jarrod Petersen, John Capano, Thomas Roberts

Effects of large prey ingestion on the kinematics of rectilinear locomotion in Boa constrictor

Rectilinear crawling is a mode of snake locomotion where the internal skeleton moves relative to the external skin and ventral scales (scutes) without the need for axial bending. This type of locomotion is particularly important in snakes following large prey ingestion where the distended body may limit axial bending. Distension of the body may also pose challenges for the muscles within the body wall that drive rectilinear locomotion, thus we might expect differences in kinematics in pre- and post-fed snakes, if rectilinear locomotion is possible at all. We used high-speed videography to record rectilinear locomotion in Boa constrictor prior to and following the ingestion of large prey ranging from 30-40% body mass. We found that all snakes tested were capable of performing rectilinear locomotion following large prey ingestion. Surprisingly, kinematic variables such as the length of scute protraction and cycle frequency were not significantly different between feeding conditions. In contrast, after feeding, snakes did not lift their body segments, backward slipping of scutes decreased by an average of 1mm (∼33%), and dorso-ventral compression increased by an average of 1.5mm (~50%). Our study replicates the results for pre-feeding kinematics of Newman and Jayne 2018 and raises questions regarding how muscles involved in rectilinear locomotion can accommodate the stretch imposed by massive distension of the snake body wall after large prey ingestion.

336 Matt Wileyto, Rebecca Bottiglio-Kramer, Jeanette Wyneken, Samantha Trail, Frank Fish

Turning Corners in Sea Turtle Maneuvering Performance

Sea turtles are known for being accomplished swimmers, capable of covering great distances. Despite the importance of maneuverability, little has been done to define the mechanics of turning in these marine organisms. To examine maneuvering performance, juvenile loggerhead (Caretta caretta) and green sea turtles (Chelonia mydas) were video recorded overhead in pursuit of a food reward in a large tank. The turtles were observed performing two types of yawing turns: pure rotational turns and translational-rotational turns. The trajectory of points on the body of the turtles (rostrum, anterior of shell, and posterior of the shell) were digitally tracked. X and Y coordinates were analyzed over time with a custom MatLab code, which estimated center of mass (COM), turn radius, and turn rate. Rate of turn was positively related to turn radius. Loggerhead turtles had small length-specific turn radii for both pure rotational (0.23 r/L) and translational-rotational (1.27 r/L) turns. Green sea turtles had the highest maximum turn rate (301.10 deg s-1) when making pure rotational turns, while loggerhead turtles had the highest maximum turn rate (104.53 deg s-1) when making translational-rotational turns. The difference in turning performance may be associated with the different diets of the turtles, and morphological differences between the two species (i.e., body length, shell height, fore-flipper length, and the role of hind-flippers).

536 Alec Wilken, Julia Schultz, Callum Ross, Zhe-Xi Luo

The effect of trabecular bone on force transfer in the jaws of mammals

The vertebrate feeding apparatus must transfer muscle force through tissues of differing material properties and complex geometries to a bite force. In mandibles of many tetrapods, trabecular bone, cross-sectional geometry, and the mandibular symphysis are known to influence bite force. However, the exact role of these factors in force transfer is poorly understood. Here we apply finite element analysis (FEA) and load path analysis (LPA) to address how trabecular bone effects force transfer. We created 3 models of the mandible of Didelphis virginiana with varying internal geometry and compared load path morphology and function among these models. Using a novel load path detection algorithm we found that including trabecular bone lowers bite force load path efficiency but yields more consistent load paths. Results of FEA and LPA methods are complementary to each other and reveal new aspects of mammal mandible mechanics.

133 Allison Wilkins, Dara Orbach

Population abundance of bottlenose dolphins in the Texas Coastal Bend using photo-identification

The Texas Coastal Bend has expanded dramatically in industrial growth, yet no research has been published since 1983 on the local imperiled population of bottlenose dolphins (Tursiops truncatus) inhabiting the region. There are many anthropogenic impacts of industrialization on marine life. Therefore, it is important to monitor the population abundance of dolphins in the Texas Coastal Bend to inform policymakers of conservation mitigation needs. Boat-based surveys have been conducted quarterly following Polluck's Robust Design model since 2018 to photograph dolphin dorsal fins. Individual dolphins are identified by unique markings on their dorsal fins that are compared across photographs. Photographs were quality checked, cropped, and matched using a semi-automated software to determine the number of uniquely identifiable dolphins. Preliminary results indicate that there are approximately 858 uniquely identifiable individuals, indicating a considerable population growth from the 281 dolphins reported in 1977. Different numbers of dolphins were photographed in Corpus Christi Bay (n = 415), Port Aransas/Redfish Bay (n = 409), and in both bay systems (n = 34). Findings from this study and additional photo-identification surveys will provide insights on the stability of the population and if the dolphins are year-round residents. By pairing sighting data with GPS coordinates, it will be possible to determine if the dolphins inhabit areas of high vessel traffic and extensive anthropogenic threats.

248 Keiffer Williams, Samantha Price

Resolving a dental dilemma: quantifying tooth variation along the jaws in polyphyodont vertebrates

Dentition in non-mammalian vertebrates is often overlooked due to the difficulty of identifying homologous dental structures in polyphyodonts. As diphyodonts, mammals develop a permanent set of adult teeth, which makes tracking changes to homologous dental structures far less challenging. Mammalian dentitions are further defined by heterodonty, in which a tooth's form and associated function varies predictably along the jaws. While the ecological success and radiation of mammals is attributed in large part to heterodonty, we know little of heterodonty's evolutionary consequences in polyphyodont vertebrates. To address the evolution of heterodonty in the far more speciose polyphyodont vertebrates we use the orientation patch count rotated (OPCR) metric to quantify tooth complexity in damselfishes (Pomacentridae). Using a phylogenetic comparative framework, we investigate how dental complexity varies along the jaws and if the pattern differs between ecotypes. We hypothesize that tooth complexity will vary predictably with position along the lower jaw, with the highest complexity teeth positioned anteriorly. We also expect herbivores will exhibit higher tooth complexity due to the mechanical challenge of attached prey removal. Preliminary results are consistent with our predictions, tooth complexity is highest in anterior jaw regions, and herbivores have the highest anterior tooth complexity. This study provides a means to quantify polyphyodont dental variation without requiring homologous dental landmarks, establishing a comparative framework to investigate established hypotheses of vertebrate dental evolution.

444 Tony Williams

Why is egg size the 'Cinderella' of avian life-history traits?

A survey of the literature in the early 1990's would have suggested that the key questions around intra-specific (individual) variation in egg-size were resolved: females laying larger eggs produced fitter offspring – though this simple view was subsequently refuted. A handful of subsequent studies suggested that producing more eggs – though not necessarily larger eggs – generated 'costs of reproduction' which could counter selection for larger eggs, maintaining trait variation. Now, 30 years on, interest in egg-size variation appears to have completely waned even though major questions remain unresolved. In this talk I will highlight what we do know about individual variation in egg-size and, importantly, what we don't know, with the aim of highlighting key questions for future research. These include, a) why do some females lay larger eggs or, more importantly, why don't all females lay the smallest, viable egg-sizes? (given, at best, weak selection on egg size; itself "something of a puzzle"); b) what are the physiological mechanisms underlying individual variation in egg size [does lipid metabolism play a key role?], and how can we leverage these for experimental manipulation of egg-size?; and c) how might an understanding of physiological mechanism feed back into our understanding of selection for, and evolution of, egg-size in a life-history context?

625 Claire Williams, Maria Alcivar, Anabarbara Gonzalez, Kelly Wuthrich, Leah Bakewell, Renata Pirani, Noa Ratia, Daniel Romero, Noah Gripshover, John David Curlis, Samir Gulati, Karla Alujevic, Guillermo Garcia-Costoya, Akhila Gopal, W. Owen McMillan, Candace Williams, Christian Cox, Michael Logan

Characterizing rapid shifts in the Anolis gut microbiome after introduction to a novel environment

As rising temperatures threaten biodiversity worldwide, tropical ectotherms may be particularly vulnerable due to their narrow thermal tolerance ranges. Although most studies of ectotherm responses to rapid environmental change focus on tolerance traits of the host, resident gut microbes may also affect thermal physiology and can change rapidly in response to the environmental conditions experienced by the host. Thus, shifts in gut microbiome communities might play a major role in adaptation of hosts when their thermal environments change quickly. Regardless, real-time field studies on the responses of gut microbial communities to changing conditions are exceptionally rare. We transplanted slender anoles (Anolis apletophallus) from a mainland population to four islands in the Panama Canal—several of which were warmer than the source environment. We collected fecal samples from all individuals prior to transplantation, and repeatedly in the weeks afterwards to collect a time series of shifts in their gut microbiomes (characterized using 16S rRNA sequencing) as they acclimated to the warmer island environments. We also compared shifts in the microbiomes of lizards from these four new islands to those of four additional island populations that we transplanted in previous years to examine the extent to which microbiome structure converges across similar thermal environments. Ultimately, we plan to leverage our discoveries about shifts in microbiomes to understand how this process impacts host fitness in our rapidly changing world.

873 Elizabeth Williams, Kei Jokura, Gaspar Jekely

Environment-neuroendocrine interactions regulating larval settlement in the marine worm Platynereis

For many marine invertebrates, larval settlement is a key developmental transition. This process is strongly linked to the environment in that larvae must detect specific cues to determine the time and place of settlement. How environmental cues are detected and activate internal hormone signalling to regulate larval settlement is not yet clear. To better understand this, we are investigating larval settlement in the nereid polychaete Platynereis dumerilii. Behavioural assays show that Platynereis larvae have a species-specific response to biofilms composed of benthic microalgal diatoms. Platynereis larval settlement is internally regulated by the neuropeptide myoinhibitory peptide (MIP), an ortholog of insect allatostatin B neuropeptide. I will discuss recent advances in understanding the function and signalling mechanisms of MIP and assessing its link to environmental cue detection in Platynereis. Understanding how external and internal signals combine to guide the developmental transition of marine invertebrate settlement will inform our understanding of animal-microalgae interactions and the evolution of environmentally-guided animal development.

1610 Bethany Williams, Lauren Pintor, Matthew Toomey, Suzanne Gray

Male Nuptial Coloration is Influenced by Plastic and Population Effects in an African Cichlid

The role of sexual selection in adaptation to new environmental conditions is currently unclear. However, the strength of sexual selection may be relaxed and/or the direction shifted if environmental changes interfere with cues used for mate choice. The primary aim of our study was to understand whether two environmental stressors (oxygen and turbidity) and population affect nuptial coloration and carotenoid concentrations in males of a sexually dimorphic African cichlid. Pseudocrenilabrus multicolor, is a widespread haplochromine cichlid found in environments that vary dramatically in dissolved oxygen concentrations and turbidity levels. To disentangle the effects of population, turbidity, and oxygen on carotenoid concentrations and male color, we measured the concentration of carotenoids in the skin and the color of adult male fish from a swamp and a river population raised in a split-brood rearing experiment (full factorial, hypoxic/normoxic x clear/turbid). For the concentration of carotenoids, the interaction between oxygen, turbidity, and population was significant. Additionally, in turbid conditions the hue (wavelength of maximum reflectance) was shifted by 9.8 nm towards longer wavelengths. There was no effect of oxygen or turbidity on the overall amount of red and yellow coloration expressed; however, fish with parents from the river (turbid) environment had marginally less ($p = 0.067$) red and yellow coloration overall. Together these results suggest that both population of origin (e.g., local adaptation) and rearing environment (plasticity) affect male coloration.

853 Sara Wilmsen, Edward Dzialowski

Phenotypic plasticity of the respiratory physiology of Manduca sexta in response to altered oxygen

Environmental stressors can have large impacts on the metabolic physiology of developing organisms. Changes in developmental oxygen concentration have been shown to influence body size, tracheal volume, and mitochondrial density in insects and can lead to distinct phenotypes associated with those concentrations. For insects that regulate body temperature well above that of the environment (e.g., facultative endotherms), the demand for oxygen is much higher and the impact of developmental stressors is likely more pronounced. Here we examine the plasticity of the respiratory system of a large Sphingid moths, Manduca sexta, that offers substantial ecological service to their ecosystems through pollination. Manduca were chronically exposed to three different oxygen concentrations (10%, 21%, and 30%) throughout development. Once moths eclosed, we tested for phenotypic plasticity of whole animal respiration, mitochondrial respiration, flight performance, and flight muscle tracheal and mitochondrial morphology. If there is significant phenotypic plasticity, we would expect that moths exposed to hypoxia will have a higher capacity for respiration at low oxygen concentrations due to physiological compensation to hypoxia. Conversely, we expect that moths raised in hyperoxia will have lower capacity for respiration due to a decrease in tracheal surface area driven by ROS production. However, if there is limited plasticity due to the high oxygen demand from aerobic endothermy in this system, then there may not be any significant changes to the phenotype.

1497 Sara Wilmsen, Clément Vinauger, Chloe Lahondere, Pascha Shevchenko, Kamel Fezzaa, Jake Socha

Comparison of the feeding mechanism between sexes in two blood-feeding mosquitoes

Mosquitoes feed on a variety of fluids, but the blood-feeding (hematophagy) that they are known for is only present in females of specific species. These hematophagous females are known to feed on a variety of hosts, including both endothermic and ectothermic species. By contrast, most species of mosquitoes, along with all males, are nectivorous. Overall, mosquitoes feed on a range of fluids that vary widely in viscosity, presenting a mechanical challenge for ingestion.

How mosquitoes have adapted morphologically and behaviorally to feeding on fluids of differing viscosities is largely unknown. Here we conducted a preliminary study of the feeding mechanism of males and females of two species of blood-feeding mosquitos (Culex quiquefasciatus and Aedes aegypti) using synchrotron imaging at the Advanced Photon Source, Argonnne National Laboratory. We used full-field phase-contrast imaging of live insects at beamline 32-ID to examine dynamic changes in cibarial and pharyngeal pump dimensions during ingestion. To increase contrast, the sucrose feeding solution was mixed with an iodine solution (Isovue) and x-ray energy was tuned just above the k-edge. Additionally, we used synchrotron microtomography (SR-μCT) at beamline 2-BM to examine differences in morphology between sexes and species. This research was supported by National Science Foundation grant 2114127. The use of the APS was supported by the US Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract DE-AC02-06CH11357.

685 Desi Wilson, Ana Ospina-L, Nigel Anderson, Ximena Bernal

Distribution Predicts Global Patterns of Extinction Risk in Toads

Among vertebrates, amphibians are the most vulnerable group to extinction as novel selective agents, like disease and habitat degradation, have resulted in increased mortality. There is substantial variation between species in their extinction risk. Given that the main threats to amphibians vary predictably with latitude and altitude across the world, especially in anurans, species are expected to differ in extinction risk along those geographic axes. We examined this prediction in Bufonidae (toads), a large anuran family with a worldwide distribution and variation in their extinction risk. We characterized the latitudinal and altitudinal distribution for 458 species and determined toad species richness along those spatial axes. We evaluated how distribution affects extinction risk in toads worldwide using phylogenetic analysis. We found that species distribution is a strong predictor of their extinction risk. Overall, species that occur at low latitudes and high altitudes are more likely to have a high risk of extinction. These findings highlight the conservation challenge in this clade as our results also revealed that low latitudes hold the highest toad diversity and high altitudes have a high proportion of endemic species. We also found that species that share evolutionary history exhibit similar extinction risk. This study displays predictors of extinction risk that offer insights for developing and targeting conservation strategies given limited species assessment information.

1172 Conrad Wilson, Chris Mansky, Jason Anderson

A New Paleozoic Fish Provides Insight into the Evolution of Actinopterygian Feeding

Modern actinopterygians have incredible diversity and a vast range of morphologies, behaviours, and ecologies, but this has not always been the case. A key interval in the history of actinopterygians occurred approximately 383-323 Ma, when a very few morphologically restricted Devonian lineages radiated into a diverse and disparate assemblage in the Carboniferous. Tournaisian-aged strata from Blue Beach, Nova Scotia capture part of this moment and yield a diverse vertebrate fauna which has allowed better understanding of faunal and ecological change.Here we report an actinopterygian mandible from Blue Beach, representing a new genus and species. This mandible is elongate, gracile, deeply curved upwards, and bears a primary dentition of heterodont fangs. We hypothesize that mandible length, curvature, and fang morphology interact to produce a functionally differentiated dentition with distinct regions for prey capture and processing. We establish this taxon as a back-fanged macrodont, distinct from front-fanged macrodont actinopterygians of the Late Devonian. This earliest known instance of back-fanged macrodonty in the actinopterygian fossil record provides further evidence of actinopterygian morphological and functional differentiation post-Devonian, and implies early experimentation in feeding mode. Although this specimen is compatible with current models of cranial differentiation in Early Carboniferous actinopterygians, we emphasize the role of cranial morphology in feeding in interpreting this specimen and the Devonian-Carboniferous transition in actinopterygians more broadly.

1568 Libby Wilson, Cassandra Delich, Lydia Zeglin, Sonny Lee, Michi Tobler

Host-microbiome associations in livebearing fishes adapted to sulfidic environments

Animal microbiomes influence the host's physiology and ecology, and they are also shaped by the host's environment and genetic background. Furthermore, the host's microbiome can mediate tolerance to environmental stress and facilitate adaptation. Despite the well-established importance of vertebrate microbiomes for host physiology and fitness, the role of symbionts mediating adaptation in vertebrate extremophiles remains unstudied. We are using a system of livebearing fish

that repeatedly colonized toxic sulfide springs in southern Mexico to explore what factors shape host microbiomes and how host microbiomes change upon colonization of extreme environments. This system facilitates investigations into the mechanisms of adaptation due to strong selection by hydrogen sulfide and hypoxia and natural replication in the form of paired sulfidic and nonsulfidic populations that allow for comparative analyses. Using 16S rRNA amplicon sequencing, we analyzed the gut microbiomes of 23 lineages of livebearing fishes (8 of which have colonized sulfide streams) throughout the Grijalva River basin to better understand how host-associated microbial communities are shaped by the environment and host evolutionary history. This approach provides insight into the eco-evolutionary dynamics shaping host-microbe interactions, and it establishes a core extremophile microbiome consisting of taxa that are unique to—and consistently present in—fish from sulfide springs. Analyzing microbiomes within an evolutionary framework provides a foundation for understanding how host-microbe associations arise and what role they play in adaptation.

863 Alexa Wimberly

Predicting body mass in ruminant artiodactyls using multiple regression

Predicting body mass is critical for inferring aspects of extinct mammal ecology. For example, the unique digestive physiology of extant ruminant artiodactyls is suggested to place constraints on their body mass depending on the type of food resources available. Thus, reliable body mass estimates could provide insight into extinct ruminant habitat preferences. However, most regression equations proposed thus far have used craniodental predictors or have relied on measurements requiring complete limb elements, which are infrequently preserved in full in the fossil record. I used multivariate phylogenetic regressions and 65 postcranial measurements to establish predictive equations for body mass in 85 species of extant ruminant artiodactyls, focusing on measurements at the proximal and distal ends of long bones and articular surfaces. Unsurprisingly, multiple regressions based on all measurements of an individual element performed better than univariate regressions. However, multiple regressions on smaller groups of measurements from the proximal radius and ulna and from the distal femur were also found to be very reliable, though best of all models were the multiple regressions comprising all measurements of the calcaneus and astragalus and individual measurements from each. This suggests that using multiple regression on fragmented proximal and distal ends of long bones and individual measurements from the abundantly preserved calcaneus and astragalus provide new opportunities for expanding data collection from fragmented remains.

109 Kristin Winchell, Shane Campbell-Staton, Jonathan Losos, Liam Revell, Brian Verrelli, Anthony Geneva

Genome-wide parallelism underlies urban morphological adaptation

Drastic environmental transformations associated with human activities generate novel ecological conditions and selective landscapes. Urbanization represents an extreme form of anthropogenic environmental modification that has been associated with repeated adaptive responses in diverse taxa. The tropical lizard Anolis cristatellus exhibits morphological adaptations to the urban structural environment, yet the genomic underpinnings of these parallel phenotypic adaptations as well as the extent to which phenotypic parallelism is mirrored at the genomic level remain unknown. We analyzed exome sequence data for paired urban-forest populations of A. cristatellus across the island of Puerto Rico. Our findings indicate that the morphological parallelism in response to parallel urban environmental change is also underlain by genomic parallelism. We identify loci associated with this adaptive morphological divergence and find that polygenic selection on standing genetic variation is a key process in the rapid adaptive responses to urbanization in this species. Together, these results shed light on the genomic basis of complex morphological adaptations and underscore the value of urban environments to address fundamental evolutionary questions.

398 Olivia Wing, Baruch Rinkevich, Dietmar Kueltz, Alison Gardell

Some like it hot: Temperature stress and juvenile development in an invasive colonial ascidian

The Salish Sea, a vital region for marine biodiversity in the Pacific Northwest, is predicted to increase ~1.5°C over the next century. Rising sea temperatures can change species distributions and may support the range expansion of invasive species with broader temperature tolerances or of tropical/subtropical origin. Botrylloides violaceus is a colonial ascidian native to the subtropical waters of the West Pacific and has successfully invaded the Salish Sea. In this study, acute temperature challenge experiments were conducted to understand how rising temperatures impact colony proliferation. Juvenile colonies were cultured in unfiltered seawater over three temperature ranges: 10-12°C, 14-16°C, and 18-20°C. Growth was assessed using counts of healthy, regressing, and budding zooids, while stress was inferred based on colony heartbeat and a qualitative health assessment. Production of healthy zooids and primary buds significantly increased with temperature and yielded larger colonies within 10 days. Heart rate significantly decreased in colonies that were maintained at 20°C, however, more baseline data are needed to relate this metric to overall colony health. These results indicate that rising temperatures in the Salish Sea are expected to increase the proliferation of B. violaceus, intensifying resource competition in benthic communities and potentially spelling danger for native populations. Funded by NSF grants MCB-2127517 and DBI-2149705.

602 Molly Wingard, Lindsey Wells, Andrew Fuller, Mark Garcia

Seasonal Patterns in Reproductive Output in a Self-Fertilizing, Hermaphroditic Fish

Animals adjust their reproductive output dependent on their physiological state (e.g., energy stores) and environmental conditions (e.g., temperature), which underlies seasonal variation in reproduction. Timing of reproduction often coincides with environmental conditions that can favor offspring survival. The Mangrove Rivulus (Kryptolebias maroratus) is a self-fertilizing, simultaneous hermaphrodite capable of producing year-round, but evidence suggest reproductive output is greatest in fall and winter months. Our study's aim is to examine how cold-exposure during development affects developmental timing and life-history traits and elucidate possible mechanisms underlying seasonal variation in rivulus reproduction. We incubated eggs (zero-day post laying) under temperature conditions that varied in either magnitude (15-20C for 17d) or duration (18C for 5-17d). Control groups were reared at 26C until hatching. Hatchlings were then measured every two months (up to six months of age) for growth and maturation rates. Data collection is ongoing, but initial results indicate that cold exposure increases developmental time from ∼17d (control) to ∼30d (treated). The rate of successful egg development decreased with increasing cold exposure, with zero hatchlings from 15 and 16C exposure treatments. Further, treated juveniles were significant smaller (∼0.05-0.06g) relative to control juveniles (∼0.09-0.1g) at two months of age. Results of our study may provide insights into whether offspring quality and survivorship drive seasonal variation in rivulus reproduction.

481 Kendra Wisenbaker, Emma Ortiz, Donald Powers

Do Hummingbirds Select Microclimates to Assist in Post-Flight Heat Dissipation in a High Temperature

Hummingbirds generate excess heat during flight from flight muscles activity. To avoid hyperthermia, they must rapidly dissipate heat especially in high temperatures. One possibility is using cool microclimates to maximize thermal gradients post-flight. To test this, we monitored perch use during daytime in black-chinned (Archilochus alexandri) and Rivoli's hummingbirds (Eugenes fulgens), and blue-throated mountain-gems (Lampornis clemenciae) in the Chiricahua Mts, SE Arizona. Daily ambient temperatures (Ta) ranged from 11-36?. Perch use across temperatures did not change suggesting hummingbirds might not be selecting perches in specific microclimates. Hummingbird density decreased 26% in hottest Ta (>30°C), suggesting macroclimate to be a more important driver of activity. This is further supported by a 30.6% decrease in perch time at the highest Ta in blue-throated mountain-gems compared to black-chinned hummingbirds, which showed little change in perch time across all Ta (suggested to have higher thermal tolerance than the mountain-gems). This pattern is likely driven not only by Ta but also competition. Black-chinned and Rivoli's hummingbirds possibly tolerate activity in higher Ta to take advantage ofterritorial blue-throateds absences. High thermal tolerance explains this trend in black-chinneds. It is unclear in Rivoli's, which have been shown to have similar thermal tolerance to blue-throateds. Understanding thermal tolerance in hummingbirds is important because of their pollination services in ecosystems. How they respond to global temperature increases could be key for future ecosystem management.

1451 Shannon Wiser, Michael Markham

Electrosensory and Metabolic Responses of Weakly Electric Fish to Changing Water Conditions

South American weakly electric fish use self-generated electric fields, or electric organ discharges (EODs), for sensory processes such as navigation and communication. EOD production incurs significant metabolic costs that can be as high as 30% of the daily energy budget. EOD amplitude (EODa) in the water is determined by the fish's electric organ (EO) output and the electrical conductivity of the surrounding water, in accordance with Ohm's law. Water conductivity in neotropical habitats varies with both natural seasonal rainfall/drought cycles and in response to unnatural anthropogenic activity. These changes in water conductivity alter the fish's EODa, directly affecting electrosensory performance. Some species are known to modulate EO output in response to circadian cues and social encounters, which leads to the question of whether weakly electric fish might compensate for the effects of changing water conductivity on EODa by altering EO output. We hypothesized that if fish compensate for increased water conductivity by increasing EO output, this will be associated with an increase in metabolic rate, likely to preserve electrosensory performance. We measured EODa and metabolism from low to high water conductivity in two gymnotiform species, the wave-type Eigenmannia virescens and the pulse-type Brachyhypopomus gauderio. Following the conductivity increase B. gauderio increased EODa but with no associated increase in metabolic rate, while the EODa remain constant and metabolic rate decreased in E. virescens.

568 Anna Wisniewski

Allometry as a driver of morphological evolution in the equid skull

Evolutionary allometry has received particular attention as a constraint on mammalian skull evolution. Among closely related groups of mammals, as body size and overall skull length increases, facial length increases proportionally more than braincase length. As a result larger species have relatively longer faces than smaller species, in a pattern known as craniofacial evolutionary allometry (CREA). These allometric trajectories may either facilitate or constrain morphological adaptation along axes of dietary diversification related to body size. However, unique morphologies such as hypsodont dentition may necessitate deviation from these allometric trajectories. Equids (fossil and modern horses), with their extensive fossil record documenting a well known transition from browsing to grazing ecologies over the Cenozoic, present an ideal model system to evaluate how allometry and other functional constraints may have biased the acquisition of traits related to dietary ecology. Here, using 3D geometric morphometric data derived from a sample of equids spanning the evolutionary history of the group, I identify the major axes of shape variation in the equid skull across the clade's evolutionary history. Additionally, I test the relative contributions of size and hypsodonty as drivers of evolutionary shape change in the equid skull using phylogenetic multivariate regression.

1414 Rebecca Witty, Lucas Kirschman, Timothy Judd

Iron supplementation and immune responses in a social insect

Immune function is often involved in trade-offs with other life history traits because immune responses can have steep energetic and nutritional costs. Differences in micronutrient availability and acquisition may explain much of the variation between populations and individual. For example, iron is an essential micronutrient that acts as a cofactor for many enzymes and affects multiple physiological processes, including immune function. Insects allocate iron to egg production and spermatogenesis. However, this requirement would be eliminated in the non-reproductive castes of social insects, potentially freeing iron for use in immune responses. We examined the immune responses of worker termites (Reticulitermes flavipes) supplemented with iron and compared them with controls. Preliminary results indicate that iron supplementation improved phenoloxidase activity and lysozyme activity.

904 Sarah Wofford-Mares, Lori Tolley-Jordan

Budget Science: How to implement inquiry-based organismal labs without breaking the bank.

Inquiry-based learning methods (IBL) in college courses provide authentic undergraduate research experiences and boost student learning outcomes and student retention in STEM. This is especially true for historically underrepresented groups in science who can often be excluded from independent undergraduate research for a variety of reasons. While IBLs are gaining popularity across a suite of institution types, implementation of IBL models at small institutions or in large classes with multiple laboratory sections can be cost prohibitive. The development of low-cost, easy-to-implement IBLs with few resource requirements are ideal for these types of institutional situations. In addition, cheaper and easier-to-access IBL materials can make the IBL experience accessible for online lab sections where materials can be shipped to students' homes. We outline broad steps needed for designing, implementing, and assessing student performance in IBL labs. We also provide two case studies for an introductory biology course (majors and non-majors) and a general ecology course for biology majors. Both case studies can be scaled up or down to fit any institution. Prior to implementation of the labs outlined in this presentation, the authors had a difficult time finding these types of pedagogical materials for organismal and ecological based labs. The authors hope to share their experience designing two such labs and hope to encourage others to post their work that likely exists at a suite of institutions.

1008 Ethan Wold, Manon Harris, Brett Aiello, Usama Sikandar, James Lynch, Nick Gravish, Simon Sponberg

What drives interspecific variation in moth wingbeat frequencies?

An insect's wingbeat frequency is a critical determinant of its flight performance and is the product of its muscles, exoskeleton, wings, and fluid environment. It is thought that resonance constrains the frequencies at which an insect can fly efficiently, but recent work has shown that moths may operate off of their resonant peak. We hypothesized that across species, wingbeat frequency scales with resonance frequency to maintain favorable energetics, but with an offset to facilitate control. The moth superfamily Bombycoidea is ideal for testing this hypothesis because their wingbeat frequencies vary interspecifically by an order of magnitude, despite similar morphology and actuation. We used materials testing, high-speed videography, and a "spring-wing" model to determine how components of an insect's flight apparatus (thoracic properties, wing inertia, muscle strain, and aerodynamics) vary with wingbeat frequency across species. Interestingly, we find that thorax stiffness does not vary substantially with wingbeat frequency, but muscle strains are significantly higher in low-frequency moths. Despite the frequency-dependence of muscle strain, wing hinge rotational stiffness remained relatively constant. Finally, we find that the resonant frequency of a moth correlates with but is consistently below wingbeat frequency. Our results demonstrate that a suite of adaptations in muscle, exoskeleton and wing drive variation in resonant mechanics, causing moths to operate above their resonant peak and reflecting potential control constraints on matching wingbeat and resonant frequencies.

203 Sarah Wolf, Elizabeth George, Jess Dong, Kimberly Rosvall

How social competition changes ageing-related gene expression in the ovary

Social competition shapes access to resources necessary for reproduction. Ovaries are known to be sensitive to the social environment, yet it is unclear whether such competition induces wear and tear on the ovary itself. Here, we evaluate how naturally- and experimentally-induced variation in the social environment affects co-expression of genes involved in ageing and stress responses. Specifically, we focus on telomere regulatory 'shelterin' proteins, which influence telomere length and transcriptional regulation, as well as other ageing-related and stress-responsive factors like glucocorticoids and antioxidants. Study subjects were female tree swallows (Tachycineta bicolor), which are songbirds that compete for limited nesting territories. Using qPCR, we quantified gene expression of shelterin proteins (TRF1, TRF2, TRF2IP, TPP1, POT1), telomerase (TERT), glucocorticoid receptors (MR, GR), and antioxidants (SOD, PRDX-1, GPX). We used co-expression analyses to detect changes in expression across genes of interest because such subtle but coordinated shifts are thought to be phenotypically salient. To the degree that these changes in gene expression persist following social challenges, the social environment may mediate lasting effects on ovarian ageing and future reproductive success.

1349 Blair Wolf, Shayne Halter

ENERGY ALLOCATION STRATEGIES OF MIGRATING HUMMINGBIRDS

Migrating hummingbirds in North America fuel their migratory flights with fat. In western North America, four common hummingbird species (Rufous, Broad-tail, Calliope, and Black-chinned Hummingbirds) vary in their breeding distribution, habitat use, body size and migration distance. Different species might be then expected to have differing strategies for fueling and in the allocation of lean versus fat mass. We measured body composition – fat and lean mass – of 1,000+ hummingbirds using QMR at a stop-over site in southwestern New Mexico during their fall migration. In Rufous hummingbirds (lean mass 2.9g), a long-distance migrant, fat masses averaged 0.9g (range 0.3 to 2.4g), averaging 23% of body mass. Broad-tail hummingbirds (lean mass 2.8g) had fat masses that averaged 0.7g and ranged from 0.3 to 1.4g, averaging 19% of body mass, whereas Calliope Hummingbirds (lean mass 2.4g) had fat masses that averaged 0.5g and ranged from 0.2 to 1.1g averaging 18% of body mass. Black-chinned Hummingbirds (lean mass 2.9g), a local breeder and migrant had fat masses that averaged 0.4g and ranged from 0.2 to 1.1g, averaging 11% of body mass. A preliminary analysis suggests that fat loads vary with age and sex and across species, with short-distance migrants (Black-chinned Hummingbirds) in moderate environments loading less fat than long-distance migrants, such as Rufous Hummingbirds.

1483 Cole Wolf, Zachary Cheviron

Variation in phenotypic flexibility of metabolic traits along an elevational gradient

Fine-grained environments, which show high variation over small spatial scales, are predicted to select for phenotypic plasticity and flexibility because individuals are expected to encounter multiple environments over their lifetime. Despite these expectations, there are few experimental tests of this hypothesis. Elevational gradients are characterized by fine-grained environmental variation. The predictable changes in temperature and oxygen availability over relatively short distances (km) makes elevational gradients ideal systems for studying the evolution of plasticity. In this study, we acclimated two populations of deer mice – one from ∼4350 m. elevation and one from 400 m. – to cold, hypoxia, and a combined cold and hypoxia treatment for six weeks. We measured a suite of physiological traits that contribute to thermogenesis and are associated with survival in wild animals, including 1) body composition (measured weekly); 2) maximum and resting metabolic rate were (measured before and after acclimation); and 3) hypothermia resistance (time to 90% Tb during a cold hypoxic challenge). Highland mice exhibited greater flexibility in hypothermia resistance than lowlanders - while both populations increased hypothermia resistance after cold acclimation, only highlanders increased hypothermia resistance under hypoxia. Evidence of variation in flexibility in other traits was mixed: populations did not differ in flexibility of maximum metabolic rate (VO2max) or metabolic scope, but highland mice added less lean mass and consumed less food under cold hypoxia than lowlanders.

482 Sophia Wolfe, Emily Blackwell, Nora Prior, Irby Lovette, Donald Powers, Anusha Shankar

***Differential gene expression between normothermy and torpor in 4 brain regions in Calypte ann*a**

Hummingbirds conserve energy overnight through daily torpor by drastically lowering their energy expenditure to 10–30% of their basal metabolic rate. In heterothermic mammals, the central nervous system regulates this metabolic suppression, with the thalamus remaining active during torpor/hibernation to control thermoregulation, hormones, and the timing of torpor. The hippocampus has also been implicated in regulating hibernation: It loses activity last during transition into hibernation and regains it first upon arousal (Drew et al. 2007). The cerebellum controls motor coordination in both birds and mammals and controls unconscious posture adjustments and occasional vocalizations in hibernating mammals, indicating its potential involvement in torpor/hibernation (Strumwasser 1959). We compared the transcriptome of these three brain regions, using the rostral telencephalon as a control, in normothermic sleep versus deep torpor in Anna's Hummingbirds (Calypte anna). We found 60 genes significantly upregulated in torpor relative to normothermy and 104 genes downregulated in torpor relative to normothermy (adjusted p-value $< 0\ .05$, log2-fold change threshold ± 0.5). The genes upregulated in torpor tend to relate to circadian rhythms, blood coagulation, inflammation, oxygen homeostasis, and the cell cycle, while the genes downregulated in torpor largely relate to the cell cycle, DNA damage checkpoints, and heat and energy production. We aim to determine which genes control hummingbird torpor in the brain and to investigate genetic differences between hummingbird and mammalian torpor.

1507 Samantha Wolfe, Alan Kneidel, Paula Cimprich, Shiloh Schulte, Stephen Brown, Rob Clay

Defining Whimbrel migration staging sites on the US Gulf Coast

Whimbrel populations that use the Western Atlantic Flyway have been declining by an estimated four percent per year since at least the early 1990s. Reversing population declines requires collaborative research to fill information gaps and coordinated management on a hemispheric scale. We are working with partners along the Atlantic coast to identify critical staging areas, establish monitoring efforts, and discover opportunities for conservation action.In 2021-22, we expanded these efforts to the Gulf Coast, an area with large numbers of staging Whimbrel that use the Atlantic Flyway. We identified large priority staging areas in eastern Texas and southwest Louisiana that consist of rice-crawfish fields and shallow water coastal impoundments. Through targeted monitoring, we located large-scale nocturnal Whimbrel roosts within each staging area and conducted repeated bird counts to determine how many birds use these sites during northbound migration.In spring 2022, we deployed 20 satellite transmitters on Whimbrel in Anahuac, Texas, as part of a multi-faceted study and conducted follow-up field surveys of live-transmitting birds to document daily site use. These preliminary surveys showed clear patterns of foraging site preference, as well as provided us with the opportunity to engage with land use managers to improve our understanding of the workings of this complex landscape. We believe this effort is a critical first step in building a conservation plan for Whimbrel on the Gulf Coast.

1421 Tim Wollesen

On cells giving rise to shells and spicules in spiralians

Spicules, shells, bristles or chaetae are hard parts present in different spiralian taxa, however, it is still debated if they are products of convergent evolution or homologs. These structures as well as the nervous system are of ectodermal origin and may develop in very different ways. For instance, the biochemical composition and ultrastructure of spicules and shells varies significantly among molluscan species. In addition, the genetic inventory underlying adult gastropod and bivalve shells is remarkably different even in closely related species. In my talk, I will highlight cell types that form the shell fields and spicules in polyplacophoran mollusks using state-of-the-art single-cell RNA-sequencing. In Acanthochitona fascicularis neurons are the closest cell type cluster related to shell- and spicule-bearing cells. The former coexists with yet another transcriptionally unrelated neuronal cell type cluster. Interestingly, the shell-less but spicule-bearing aplacophoran mollusks which form the sister group to polyplacophorans exhibit similar gene expression profiles indicating that spicules of both clades are homologous. Finally, hitherto unpublished data on the gnathiferan chaetognath Spadella cephaloptera will be discussed helping to infer the evolution of spiralian hard parts.

570 Molly Womack

Evolutionary and developmental curiosities

I really enjoy thinking about development's influence on phenotypic variation and evolution. Early in my career, amphibians were just an interesting and diverse clade I could use to illustrate and test "big ideas" that interested me. I never pictured that 10 years later I'd be in Utah watching slow motion videos of a spadefoot toad devouring a headless mealworm. Like any organism we stop to wonder at, frogs have bigger lessons to teach than the ones I started researching. And although I still spend a lot of time doing intellectual backflips through "big ideas", I now spend a lot of time just wondering about frogs. My career has benefited greatly from Dave Wake's studies, academic family, and service efforts. But perhaps even more so, my perspective on my work and academia has been greatly influenced by Dave's kindness and unabashed enthusiasm for organisms, especially that sister clade to frogs;).

1080 Haley Womack, Erin Borbee, Lauren Fuess

Investigating immunity post heat stress in the model cnidarian, Exaiptasia diaphana

Cnidarians are a broad group of symbiotic organisms including hard corals, which form the basis of essential coral reef ecosystems. However, these ecosystems are facing unprecedented declines due to a number of environmental stressors, including rising sea surface temperatures. Increased temperatures trigger a breakdown in symbiosis between the coral and its algal partner, eventually resulting in death of the host (coral bleaching). Additionally, corals have faced dramatic global declines due to increases in the severity of disease outbreaks. Most often these two stressors are considered in isolation, however ecological data suggests that they are often linked, with disease following bleaching events. In order to better understand the potential mechanisms of this phenomenon, we used the anemone model system, Exaiptasia diaphana to study the impacts of heat stress on constitutive host immunity. Anemones were exposed to a heat stressor until symbiosis breakdown was observed, as measured by a decrease in symbiont densities. Constitutive immunity was measured at regular intervals before, during, and for a two-week period after thermal stress using enzymatic assays to measure antioxidant activity, melanin synthesis, and antibacterial activity. These results give insight to how cnidarian immune systems are affected by the loss of symbiosis with algae. This new knowledge provides an important framework for understanding multi-stressor resiliency in cnidarians.

780 Jasmin Wong, Shane Windsor

Flight feathers as structural filters for aerodynamic sensory signals

Birds have been noteworthy in their ability to adapt during flight to changing behavioural needs or environmental disturbances over a range of temporal scales. This flight control is achieved by complex three-dimensional wing movements generating changes to the aerodynamic forces, and a sensory system providing rapid and accurate corrective feedback to those wing movements. As air moves over the wings, feathers will dynamically deform. Aeroelastic theory tell us that this oscillatory response depends on the input external forces and the intrinsic structural properties of the feather. Mechanical receptors capable of responding selectively to the frequency and amplitude of feather oscillations have been found in the wing near feather follicles. Whether the structural properties of feathers vary throughout the wing and how they might amplify or damp the aerodynamic signals passed to the receptors is currently unknown. To address this gap in knowledge, we performed frequency response analyses on zebra finch (Taeniopygia guttata) flight feathers. Comparing the parameters of the derived transfer functions provided a means to compare the structural dynamics properties of feathers. This information can inform on the complexity of the sensory space needed for flight control in birds and provide inspiration for distributed sensing technologies in small unmanned air vehicles.

1111 Mary Woodruff, Susanna Tsueda, Kimberly Rosvall

Why are some individuals better at coping with climate change?

Intensifying heat waves pose widespread challenges to many organisms. Physiologically, heat induces upregulation of heat shock proteins (HSPs), which prevent and repair cellular damage. However, it is unclear how or why individuals vary in HSP responses. To explore these unknowns, we experimentally simulated a hot day mirroring projected climatic changes. Using 12-day-old tree swallows (Tachycineta bicolor) and air-activated warmers, we elevated nest temperatures 4°C above controls for 4hrs during the afternoon. We measured nestling behavior during the 2nd hour of heat and measured morphology and blood HSP gene expression at the end of the heat challenge. We then tested several non-mutually exclusive hypotheses on the abiotic, morphological, behavioral, physiological, and sex-related factors that may shape heat responses. We found HSP gene expression did not differ between sexes or vary by body mass or brood size, factors that may influence heat retention or dissipation. However, HSP mRNA abundance was related to among-nest variation in temperature and was marginally related to among-nest variation in panting, a key form of behavioral thermoregulation. Siblings showed notable variation in gene expression, but such within-nest variation was small compared to among-nest variation, suggesting there may be a genetic component to HSP responses. Collectively, these results shed light on drivers of individual differences in coping with heat. These data could ultimately inform species resilience predictions amidst rising temperatures.

1117 Gavin Woodruff

Exploring the proximate and ultimate causes of variation with fig worms

What is the genetic, cellular, developmental, and evolutionary basis of phenotypic diversity? This question can be addressed from many perspectives— molecular geneticists, developmental biologists, population geneticists and ecologists have typically tackled these problems using very different approaches. However, as phenotype construction has multiple causes, a satisfying understanding of phenotypic diversity ultimately requires the integration of multiple points of view. Our lab studies the nematode Caenorhabditis inopinata to connect functional genetics with evolution and ecology to understand the causes of phenotypic diversity. C. inopinata can grow to be nearly twice as long as its close relatives, which include the highly-studied model organism, C. elegans. Furthermore, it thrives in the fresh Ficus septica figs of Okinawa and is associated with its pollinating wasps; figs and fig wasps together represent a classic system in evolution and ecology. C. inopinata is then well-positioned to connect multiple disciplines that aim to understand the bases of phenotypic variation. Here, I will share results regarding: the developmental basis of body size divergence; the evolution of nematode-microbe interactions; patterns of genomic diversity among fig nematode populations; and the evolution of repetitive genomic landscapes.

361 Mateusz Wosik, Megan Whitney, Jessie Atterholt, Ashley Poust, David Evans

Point Zero: Osteohistological Indicators for Body Size at Birth/Hatching

The earliest life histories of extant vertebrates are punctuated by a transition in bone deposition immediately after birth/hatching and indicated in teeth and bones as a ‘neonatal’ or ‘hatching’ line. Recent studies have noted comparable features in perinatal dinosaurs, allowing the approximation of hatchling size. Here we investigate embryonic and perinatal bone histology in extant ratites (emu, ostrich) and non-avian dinosaurs (hadrosaurid) in order to qualitatively compare the osteohistological signal of hatching.In ratites, femora and tibiotarsi were thin-sectioned from a series of 13 individuals with known ages that bracket the hatching period. In dinosaurs, limb bones from 17 individuals were similarly thin-sectioned and categorized by size and/or association with eggshell material. Regardless of taxonomic identity, embryos exhibit highly cancellous and disorganized woven-fibered/parallel-fibered bone complex, whereas perinates have a parallel-fibered/fibro-lamellar bone complex with longitudinally or radially orientated vascular canals. Perinates preserve a narrow circumferentially oriented zone of reduced vascularity, which is intraspecifically consistent with known hatchling sizes for ratites and partitions the embryonic and perinatal bone regions. Therefore, we suggest this is an osteohistological indicator for hatching and tentatively define it as the embryonic-perinatal interface (EPI).Clarification of the biological meaning of the EPI is important because it provides an accurate neonatal size for growth rate analyses and may convey significant insight into osteohistological cues related to precocity.

675 Mark Wright, Stephanie Pierce

A Hip New Perspective on the Synapsid “Sprawling-to-Upright” Transition

The evolution of mammals included a major reorganization of limb posture and function, from a reptile-like sprawling pose to an upright pose with limbs oriented underneath the body. While the “sprawling-to-upright” transition has been a major focus of investigation, exactly how and when it occurred is still debated. As the skeleton provides the structural framework for locomotion, the evolution of bone morphology may help elucidate the origin of upright posture and function in synapsids. Here, we quantified hip joint evolution by collecting morphometric measurements from the pelvis and femur of ∼150 extinct non-mammalian synapsids and compared them to ∼50 extant mammals and reptiles. Key morphological traits that change from basal synapsids to therians include an elongated, narrow, and anteriorly-directed ilium, rounded rather than oval acetabulum, increased femoral head angle, increased curvature angle of the femur, and femoral condyles perpendicular to the long axis. Results further indicate that basal synapsids have distinct hindlimb anatomy not reminiscent of modern-day sprawling reptiles. Additionally, the mammalian-style femur appears to have evolved at the origin of cynodonts, while the pelvis maintained a plesiomorphic morphology until the origin of therians, thus reflecting a mosaic pattern of evolution. These results suggest non-mammalian synapsids used their limbs in unique ways compared to extant sprawling and upright taxa and that the "sprawling-to-upright" transition may have included stepwise shifts in limb posture and function.

1055 Marissa Wright, Lucas Kirschman, Kelley Fritz, Logan Oleson, Rebecca Witty

Larval metabolic rate varies with deveopmental stage and does not predict disease susceptibility

Based on the principle of allocation, negative association often exist between life history traits. Theses tradeoffs are more intense in early life stages because of high rates of growth and development, which may compromise immune function. The dynamics of ranavirus infection in larval amphibians is a model system for examining trade-offs between growth, development, and immunity because all three are metabolically expensive and critical to successful metamorphosis. We measured developmental rate and metabolism in larval wood frogs (Rana sylvatica) to investigate their relationship with each other and ranavirus susceptibility. Preliminary results indicate that developmental stage was strongest predictor of time to mortality following ranavirus exposure ($z = -4.2$, $p < 0.0001$). Metabolism at the time of infection had a strong relationship with developmental rate to that point ($F1, 71 = 7.4$,$p = 0.008$), but did not affect time to death ($z = -1.3$, $p = 0.2$). Developmental rate at the time of infection had no relationship to developmental rate after infection in either infected larvae ($t = 1.1$, $df = 34$, $p = 0.27$) or uninfected controls ($t = 1.7$, $df = 35$, p-value $= 0.1$). Our results show that ranavirus susceptibility in amphibian larvae is related to immune downregulation during metamorphic climax, rather than a trade-off between developmental rate and immune responses. Furthermore, we show evidence that larvae do not have predicable developmental rates throughout their larval life stages.

1219 Patrick Wright, Janet Steven

Accumulation of metals in an agricultural weed and implications for phytoremediation

Many plant species are known to take up metals from the soil and accumulate them to potentially toxic levels. This may provide tolerance to soils with high metal content or a defensive mechanism against herbivores and pathogens. While some species have mechanisms to hyperaccumulate a particular metal and minimize its toxicity, other species appear to accumulate a wider range of metals in lower concentrations. Accumulators can be used in phytoremediation to remove metals from contaminated soils, but often these species are not native. In this study, we grew the native agricultural weed Conyza canadensis in soils contaminated with high levels of lead, barium, zinc, copper, or chromium. All five metals were accumulated by the plants. Zinc and copper, both essential elements, accumulated to the highest levels, while lead, barium, and chromium were present at lower levels. While availability of elements was constant, all treatments except chromium showed accelerating rates of accumulation over the eight-week experiment, suggesting an upregulation of accumulation mechanisms. All metals reduced aboveground biomass of the plants, indicating a cost to metal accumulation. Lead and zinc promoted early flowering, while plants accumulating barium, chromium, and copper flowered in lower numbers. Conyza canadensis has the ability to accumulate a broad range of metals, making it a candidate for phytoremediation. However, accumulation does appear to cause tradeoffs with growth and reproduction.

1309 Ricky Wright

RNA editing in response to ocean acidification in Octopus rubescens

Does RNA editing contribute to octopus acclimation to lower pH environments? RNA editing can diversify expression beyond the genome. Adenosine deaminases that act on RNA (ADARs) edit single ribonucleotides 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 octopus K+-channel modifications in cold water octopus species. Transcriptome-wide RNA editing patterns of six Octopus rubescens were examined in response to ocean acidification conditions by alignment of gDNA and mRNA reads of individual octopuses to the O. rubescens transcriptome. Potentially important edited proteins were assessed using protein modeling to evaluate potential functional changes. RNA edits resulting in potentially impactful protein modifications were verified via sanger sequencing.

562 Kelly Wuthrich, Lindsey Swierk

***Rapid body color change is unlikely to be used as a social signal in the water anol*e**

Animal coloration has a variety of functions, from camouflage to courtship. Some animals are able to rapidly change color in order to alter their appearance in response to changes in their environment. While males of many species are better known for their bright coloration and displays, females also use coloration to communicate. Water anoles (Anolis aquaticus) are known to utilize rapid color change for camouflage, yet many other Anolis species use rapid color change in a social context. We explored if water anoles also use rapid color change as a social signals. We tested the role of rapid color change as a social signal in females by comparing body coloration under two conditions: 1) a social environment in which females were placed in a tank with a male stimulus anole and 2) an isolated environment with the female in a tank alone for 25 minutes. We photographed each female before and after each trial and, using anole visual modeling, we quantified the difference in body coloration. We found that females rapidly change color in response to both environments, but they do not differ in their color change between social and isolated environments. This study broadens our understanding of the role of color change in this species and raises questions about the function and evolution of color change within the Anolis genus.

984 Kelly Wuthrich, Leah Bakewell, Claire Williams, Noah Gripshover, Maria Alcivar, Karla Alujevic, Albert Chung, John David Curlis, Guillermo Garcia-Costoya, Anabarbara Gonzalez, Akhila Gopal, Samir Gulati, Renata Pirani, Noa Ratia, Daniel Romero, Adam Rosso, W. Owen McMillan, Michael Logan, Christian Cox

***Transient heat waves induce a rapid and reversible increase in thermal tolerance in an Anolis lizar*d**

Global climate change requires organisms to tolerate warmer and fluctuating thermal environments. How organisms are able to endure these changes is important to understanding population trajectories during climatic shifts. In particular, thermoconforming ectotherms are more likely to be affected by increased mean and thermal variability. Many species can use phenotypic plasticity to maintain physiological processes under differing thermal conditions. Reversibility in these plastic traits can decrease the costs of a mismatched phenotype when climatic shifts are rapid and reversible but has ramifications for predicting their evolutionary trajectory. Here, we studied the plastic potential and reversibility of physiological traits in a tropical, thermoconforming ectotherm, the Panamanian slender anole (Anolis apletophallus), after exposure to a transient warming event (3 hours at either 32oC or 35oC). We found that their voluntary thermal maxima (VTmax) were highly plastic, increasing by as much as 3.4°C in as few as 3 hours. Moreover, VTmax had a circadian rhythm, increasing by mid-day and decreasing in the evening, but the amplitude of the cycle increased after heat shock and this increase was sustained for the length of the experiment (two days). Our results demonstrate that tropical thermoconforming ectotherms can plastically shift their thermal tolerance, implying that plasticity will be an important response to increasing thermal variability in the environment.

466 Claire Wyart, Urs Bohm, Pierre-Luc Bardet, Yasmine Cantaut-Belarif, Martin Carbo-Tano, Laura Desban, Lydia DJENOUNE, Kevin Fidelin, Jeff Hubbard, Hugo MARNAS, Andrew Prendergast, Jenna Sternberg, mingyue wu

An axial sensory system detecting spinal curvature impacts locomotion, posture & morphogenesis

We identify in macaques, mice and zebrafish ciliated neurons at the interface between the cerebrospinal fluid (CSF) and the nervous system that are in ideal position to sense CSF cues, to relay information to local networks and to regulate CSF content by secretion. By combining electrophysiology, optogenetics and calcium imaging in vivo, we demonstrate that neurons contacting the CSF detect local bending of the spinal cord via a coupling with the Reissner fiber and in turn feedback GABAergic inhibition to multiple interneurons driving locomotion and posture in the spinal cord and hindbrain. Such inhibitory feedback modulates neuronal target in a state-dependent manner. Behavioral analysis of animals deprived of this sensory pathway reveals its role in increasing the amplitude and speed of movement, as well as to stabilize posture. In addition, this sensory system instructs morphogenesis of the body axis enabling the growth and maintenance of a straight spine throughout life. Our findings in zebrafish echo with recent evidence in mice and we look forward to investigate more species, including birds and humans.

1017 Taneshia Wyman, Frank Smith

Exploring the role of twist during myogenesis in tardigrades

The gene twist regulates myogenesis in animals. The protein encoded by this gene is a basic helix-loop-helix transcription factor. We wondered whether twist regulates myogenesis in Tardigrada. We identified a single candidate ortholog of twist in the tardigrade species Hypsibius exemplaris and Ramazzottius varieornatus by reciprocal BLAST search and confirmed that this gene was an ortholog of twist by phylogenetic analysis. In order to precisely characterize the expression patterns of twist during embryogenesis in H. exemplaris, we used Hybridization Chain Reaction in situ to determine the expression patterns of twist relative to two gut markers, forkhead (fkh) and Hepatocyte Nuclear Factor 4 (HNF4). We investigated embryonic stages that fall between early and late gut development. HNF4 was expressed in the foregut region and fkh was expressed throughout the developing gut. Twist expression was associated with specific cells that presumably represent developing muscle cells. Next, RNAi experiments targeting twist will be performed to directly test the role of twist in regulating myogenesis.

1212 Nicole Wynne, Gabriella Wolff, Clément Vinauger

Identification of a Giant Fiber Neuron system mediating mosquitoes' responses to visual

Vision is essential to the behavioral ecology of several insect species because of its use in a variety of different contexts such as navigation, foraging, communication, and identifying threats. In addition to using visual cues to locate hosts, mosquitoes also use vision to detect and evade threats. Our previous work showed how landed Aedes aegypti females respond to looming visual threats by orienting their take-off flight away from the looming stimulus. Here we take it a step further and show how they respond to looming visual threats while in tethered flight in a virtual reality LED arena. The neural encoding of looming stimuli is well conserved in invertebrates, where visual projection neurons are sensitive to particular characteristics of the loom, such as speed, direction, and size. Once the threat is detected, an escape response is quickly triggered. These escape responses are typically mediated by a set of large neurons called the giant fiber system which allows rapid stimulation of flight or leg muscles after detection. We utilized immunohistochemistry techniques to help us characterize these structures as well as the neural architecture of the optic lobes in Ae. aegypti females. With a better understanding of the neural structure of the optic lobes and how their escape behaviors are being processed, this information can be used for future research to identify new targets for vector control.

227 Jiaqi Xiue, Brett Klaassen-van-Oorschot, Glenna Clifton, Dixia Fan, Fei Han

Deep Reinforcement Learning Replicates Storm Petrel Jumping on the Water

Some species of storm petrels partake in pattering, during which individuals repetitively slap their feet against the surface of the water while keeping their wings outstretched. This unique aerial-aquatic locomotion has been hypothesized to provide weight support, attract or stun aquatic prey, and/or act as a sea anchor to slow birds during foraging. Testing these hypotheses remains challenging since pattering only occurs in pelagic environments.In this work, we established a computational reduced-order model based on the anatomy of Wilson's storm-petrel (*Oceanites oceanicus*), as well as the fundamental principles of hydrodynamics and aerodynamics, to explore the locomotion mode of this species under varies wind speed. We implemented a model-free deep reinforcement learning (DRL) framework that allowed our bird model to learn how to interact with the dynamic environment spontaneously. As a result, the DRL agent enables the innocent model to produce biologically similar locomotory behaviors to storm petrels in nature (e.g., flying, pattering). Our simulation provides preliminary reference information to gain biological insights and inspire future robotic designs. Additionally, this work proposes a novel method of hypothesis testing, and exemplifies an integrated framework for researchers to implement customized systems and investigate biomechanics, animal behavior, and fluid dynamics.

752 Tianyi Xu, John Jacisin, Amber Cooper, Melissa Kemp

Morphological variation of the dentary in fossil Anolis scriptus from Middle Caicos

Anthropogenically induced environmental changes have left significant impacts on global faunas, including phenotypic changes, range shifts, extirpation, and extinction of species. Impacts are often greater in insular environments like the Caribbean, where less diverse habitats and stable communities create a natural experiment for studying morphological evolution and environmental changes. Paleontological records can provide valuable insights on how organisms responded to environmental perturbations through deep time, contributing long-term perspectives to present organismal-environmental interactions. Here, we examine morphological variation in undescribed Holocene fossils from Indian Cave, Middle Caicos, Turks and Caicos Islands. We putatively identified these fossils as Anolis scriptus, the only extant Anolis species in Middle Caicos. We measured dental row length of the specimens, calculated snout-vent length using an equation derived from 35 full-body micro-CT scans of seven Anolis species and applied geometric morphometrics to quantify changes in dentary morphology in six levels across three stratigraphic layers. Our results show relatively stable body size, but some variation in shape along the anteroposterior axis of the dental row and Meckel's canal, suggesting a potential decoupling of size and dentary morphology in the species over time. This study will allow us to better understand the ecomorphology of Anolis lizards on small islands, and how it interacts with abiotic factors through time.

607 KayLene Yamada, Kang Nian Yap, Natalie Harris, Shelby Zikeli, Vimala Kaza, Hippokratis Kiaris, Andreas Kavazis, Wendy Hood

Comparison of metabolic performance of white-footed mice in lab, semi-natural, and wild populations

Environment plays a formative role in many physiological processes. Historically, physiology studies have been conducted in laboratory or field settings. Laboratory studies provide highly controlled environments, but animals responses to these environments do not always mimic responses in natural contexts. Field studies capture physiology in the context animals evolved but are complicated by the difficultly of following individuals over time. Recently, semi-natural enclosures have been used as an alternative, allowing researchers to control many aspects of the environment while following individuals over time and maintaining ecological relevance. Here, we determined if the physiology of white-footed mice (Peromyscus leucopus) in semi-natural enclosures more closely mimics wild or laboratory-maintained animals. We compared several physiological measurements of mice in these three habitats, including hematocrit, hemoglobin, forelimb skeletal muscle strength, and resting metabolic rate. Finally, we isolated mitochondria from skeletal muscle and liver and measured respiratory control ratio to evaluate differences in cellular bioenergetics. We predicted that the physiology of mice in the semi-natural enclosures will more closely mimic the wild than lab. Preliminary results show no difference between groups in hemoglobin or grip strength, but lab mice have higher hematocrit and resting metabolic rate than the other groups, while semi-natural mice have higher muscle respiratory control ratio. Our findings will help researchers identify the best context for future experiments by providing information on how housing environment impacts physiology.

1802 AYAKO YAMAGUCHI, Manon Peltier

Phylogenetically conserved vocal central pattern generator in genus Xenopus

How conserved are the neural pathways underlying homologous behavior across closely related species? We explored this question using the central vocal pathways of clawed frogs, the genus Xenopus. Males of all species of Xenopus generate advertisement calls that can be largely divided into three categories: fast trills, slow trills, and biphasic calls containing both fast and slow trills. Previously, we discovered that the biphasic advertisement calls of male X. laevis are generated by anatomically distinct fast and slow trill central pattern generators (CPGs) in the brainstem. The fast trill CPG spans between the parabrachial nucleus and the nucleus ambiguus, whereas the slow trill CPG is contained in the caudal brainstem based on transection experiments. Here, we compared the functional and anatomical organizations of the vocal CPGs of fast trillers (male X. amieti, male X. cliivi), slow trillers (male X. tropicalis, female X. laevis), and biphasic trillers (male X. petersii, testosterone-treated female X. laevis). The results showed that the location and the function of the fast and slow click CPGs are conserved across species. We further explored if the brains of slow trillers are equipped with fast trill CPGs as an evolutionary vestige even if only slow trill CPG is presently used for vocal production. The results showed that synapses essential for the fast trill CPGs are not present in any of the slow trillers, suggesting.

1179 Emily Yamauchi, Elizabeth Mendoza, Manny Azizi

Assessing functional deficits following surgical interventions

Understanding muscle function as it relates to animal movement often requires in vivo muscle measurements. To make these measurements, a surgical intervention is required to instrument the muscle of interest with sensors that will measure muscle fascicle length changes, activity, and muscle force while the organism performs the movement of interest. Several studies have used this approach to understand muscle function during a specific task and while these measurements have been insightful, few studies have quantified a time course for regaining normal function after surgical intervention and developed a detailed criteria for best practices. Here we investigate how surgically implanting sonomicrometry, electromyography (EMG), and leaf-spring tendon buckles on the plantaris longus muscle of bullfrogs affects their jump performance. We quantify jumping kinematics and kinetics of jumps before and after surgical interventions. We will compare the effects of the intervention on whole body measures and quantify the degree of asymmetry between the instruments and uninstrumented leg to develop a rapid tool for determining whether the subject has regained full function. Developing a protocol for assessing functional deficits will serve to improve the quality of in vivo muscle data.

1413 Jose Yañez-Salas, Valeria Saro-Cortes, Yuhe Cui, Brooke Flammang, Aimy Wissa

A Flying Fish Robotic Model Organism: Design, Fabrication and Experimental Evaluation

A robotic model organism (RMO) is a physical model of a living system used to test biological hypotheses about the organism's locomotion and enables the exploration of the biological parameter space beyond what is observable in nature. Herein, we present the design, fabrication, and experimental evaluation methods of a flying fish RMO. The design of the flying fish RMO consists of a body, caudal fin, deployable pectoral fins, and pelvic fins. The pectoral fin and pelvic fin profiles are approximated from the literature on flying fish. The caudal fin mechanism is designed to approximate the carangiform swimming exhibited by flying fish. The fuselage and caudal fin are designed based on published sketches and photos to generate a biologically relevant form. The RMO design is modular to accommodate water channel and free swimming experiments. Water channel experiments are performed to characterize the hydrodynamic performance of the RMO, including the thrust generated by the caudal fin and the drag of the RMO, and the effect of asymmetrically deploying the pectoral fins on the hydrodynamic moments.

1681 Yu Yang, Dominic Yared, Noah Cowan

Sensorimotor Adaptation to Novel Dynamics in Weakly Electric Fish

It is well known that animals can adapt to changes in sensorimotor feedback, but from a control theory perspective, it remains unclear the way animals learn novel controllers and the benefits of that learning. We investigated how the fish learns to compensate for novel dynamics by fundamentally altering the closed-loop dynamics of the weakly electric fish Eigenmannia virescens refuge tracking system; specifically, we fed fish position back to the input with a high-pass filter in real time and combined it with a pre-defined sum-of-sines signal. Starting from open-loop "baseline", we gradually increased the gain of the high-pass feedback in order to destabilize the entire system in an effort to elicit learning. Finally, we abruptly ceased the artificial feedback to assess after effects. We found that fish ($N = 8$) learned to increase sensorimotor gain and add phase lead to their Frequency Response Functions (FRFs) as the system was gradually destabilized. We also discovered that the learned controller not only maintained a robust stability margin (counteracting the destabilization of the novel dynamics), but also reduced sensitivity to disturbances at low frequencies. Lastly, fish retained their learned sensorimotor controllers after feedback was removed, and this retention "washed out" within 15 minutes. We hope this project sheds new light on animal sensorimotor control and builds toward a comparative understanding of how animals adapt their closed-loop interactions with the environment.

1753 Shannan Yates, Wayne Wang, Alex Gunderson

Is it too cold? Investigating evolutionary change in cold tolerance of two Anole species

One of the consequences of global climate change is an increase in frequent extreme temperatures, which can include colder winters in certain regions. For example, in the winter of 2018, New Orleans, Louisiana saw a record -6 C, the coldest since -5 C in 1977. This extreme cold can cause major impacts on the physiology of animals, especially ectotherms. That said, understanding how organisms will respond to the changing climate has become a major goal for biologists interested in thermal physiology and evolution. Rapid evolutionary changes in cold tolerance in response to a single extreme winter event have been documented in some ectotherms, including several anoles species, to show possible evolutionary responses.To fill this gap in our knowledge, we measured the cold tolerance of both Anolis sagrei, an introduced species, and Anolis carolinensis, a native species in the south, from Fall 2020 to Spring 2022. We found no increase in cold tolerance for both species from 2020 fall to spring 2021, this result could indicate that there was no cold tolerance selected for during the previous extreme winter event in 2018. We also found that the cold tolerance of A. sag in Fall 2021 had a bounce-back effect, where the cold tolerance was lower than in previous years, this could be due to relaxation of selection during the summer or phenotypic plasticity.

1706 Huanying Yeh, Yu Yang, Noah Cowan

Luminance modulates sensorimotor delay in refuge tracking of Eigenmannia virescens

The weakly electric glass knifefish, Eigenmannia virescens, readily tracks a one-degree-of-freedom moving refuge. During refuge tracking, the fish integrates both vision and electrosense, generating precise movements in response to the refuge, and those responses can be characterized by its frequency response. At low frequencies, the fish tracks nearly perfectly, but the gain and phase "roll off" at increasing frequencies. To examine how this sensorimotor transform changes as a function of visual salience, we used a sum-of-sines (0.1 – 2.05 Hz) input to the refuge motion, and quantified the fish's frequency response function (FRF) as a function of luminance (1.15 Hz), suggesting an increase in temporal integration time (delay), as has been found previously in hawkmoths (Sponberg et al., 2015). We also found that at luminance values near 8 lux, slight increases in luminance led to sharp decreases in phase lag, suggesting a "luminance threshold" where the fish switches sensing modes and achieves better synchronized tracking.

1797 George Yi, Matthew Penn, Mario Martinez-Groves-Raines, Simon Watkins, Mohamed Abdulghani, Shane Windsor

Flight configurations of hang flying kestrels in a turbulent wind tunnel

Hang flying is a non-flapping mode of wind hovering, where birds soar orographically while keeping their head stationary relative to the ground. Kestrels are able to hang fly and keep their head very steady even under turbulent conditions. To understand how kestrel's flight configurations in hanging flight contribute to this steadiness, two nankeen kestrels (Falco cenchroides) were trained to hang fly in a wind tunnel at varying levels of turbulence. Over 500 wind hovering episodes from each bird (mean episode duration: 1 second, head movement < 3mm, body movement < 30mm) were analysed to understand this flight behaviour. Using motion capture data it was found that the birds flew with diminishing wing anhedral angle as turbulence increased, but that they flew with a significant body yaw angle (up to +/- 45 degrees) regardless of increasing levels of turbulence. The body yaw bias, or sideslip, during hanging flight, correlated negatively with tail roll, which provided lateral control complemented by asymmetric wing sweep and wing angle of attack. The yaw of the birds correlated with where they focused their gaze and we hypothesize that the yawed flight configuration is related to their regions of visual acuity. These results also provide insight into rudderless steady flight morphology and mechanics for flight at a wide range of yaw angles.

565 Julia York

Texas leafcutter ant antennal transcriptomes and patterns of expression along a thermal transect

The Texas leafcutter ant (Atta texana) is the most northern distributed leafcutter species and has evolved with their obligate fungal symbiont Leucocoprinus gongylophorus. This mutualistic fungus limits the northern range of the ants, but the most recent populations at the northern edge of the range have increased their cold tolerance compared to ancestral populations in the Rio Grande Valley (Mueller et al., 2011; Smith et al., 2019). We hypothesized that the adjustment in cold tolerance of the fungus would be supported by shifts in thermal preference behaviors and temperature sensor expression in the ants. We compared transcriptomes of the antennae from ants across a transect from north to south Texas. Given that temperature sensitive neurons are present in the antennae of congeners, we expected that candidate genes responsible for temperature preference shifts would vary in expression, splicing, or mutations. We found no consistent pattern in the temperature sensitive TRP channel gene family, and more in-depth analysis of the transcriptomics are forthcoming.

135 Zaphillia Yost, Paul Larson, Jason Macrander

Population genetics of the Florida fighting conch (Strombus alatus)

The Florida fighting conch (Strombus alatus) is a marine gastropod (Family: Strombidae) that resides in the soft sediments of shallow waters throughout the Carolinas, Florida, the Gulf of Mexico. They are unique among marine gastropods in that they have serrated, curved operculum that is used to evade predators and challenge other male fighting conches. These conch are also of commercial interest due to their aquaculture potential as an alternative food source to the endangered queen conch (Strombus gigas). Despite their distribution, unique life history, and commercial potential, they are often subjected to anthropogenic driven contamination and stressors in the forms of eutrophication and near shore pollution. There is little known about connectivity throughout their range and population wide distribution. Using two mtDNA markers (cytochrome oxidase subunit I (COI) and cytochrome b (Cyt-b)) our preliminary investigation into population structure of the Florida fighting conch from around Florida and nearby waterways indicated that they exhibit high connectivity with very low distinct population structure, indicative of high rates of genetic exchange along Florida's east and west coastlines. To our knowledge, this is the first investigation into the population structure of this species and will aid in future management and conservation decisions surrounding the Florida fighting conch and other abundant nearshore species.

145 Vanessa Young, Robin Verble

Symposium Intro: Current landscape & perspectives from a researcher and a field station director

Field sites and/or field stations and marine laboratories (FSMLs) are often the primary data collection sites for STEM professionals. They represent necessary components of research training for many early-career scientists and important components of undergraduate curricula in many university STEM programs. However, despite the formative role that field work can play in STEM professional development, the field environment presents challenges to safety and accessibility for scientists with diverse identities. While in the field, scientists may have poorly defined domestic and professional separation. Such an environment presents opportunity for collaboration and collegiality; however, the potential for abuse of power dynamics and harassment also exist as a result of these conditions. Field work often presents higher risks of racial or sexual harassment from residents and law enforcement in areas where field work is conducted, particularly for researchers with disabilities, LGBTQ+, Black, and other historically excluded identities. Despite efforts to create more socially responsible workplaces, discrimination and harassment continue to be widespread in academic settings, including field research environments. This symposium brings together diverse scholars to initiate a cross-disciplinary conversation that highlights diversity, equity, inclusion, and safety issues in field settings, identifies strategies to combat discrimination and harassment in the field, and promotes cultural change that will result in a more welcoming and diverse field environment for STEM scholars.

211 Jesse Young, Christopher Mayerl, Alekhya Mannava, Tianhui Fan, Christopher Mamone, Nicole Schapker, Angela Mossor, Rebecca German

Balance development in an infant pig model of preterm birth

Preterm infants account ∼10% of babies born in the USA. Approximately half of preterm infants show delayed motor development and compromised motor performance. However, the proximate mechanisms underlying preterm infant motor dysfunction remain poorly understood. Here, we use an infant pig model to investigate the influence of preterm birth on balance development, given that postural stability forms the foundation for all subsequent locomotor development. We assessed balance performance in 8 fullterm and 15 preterm pigs (delivered 6 days early via C-section; equivalent to a 32-week human infant). We quantified static balance by tracking the movements of the center of pressure (CoP) while pigs were standing on a force platform, finding that preterm pigs were characterized by significantly more random CoP movements than fullterm infants (i.e., greater approximate entropy; pp?0.03). Altogether, our results suggest that preterm birth significantly impacts balance performance in infant mammals, with likely sequelae for locomotor development overall. Ongoing research is focused on identifying the upstream neural and musculoskeletal factors leading to compromised balance performance in preterm infants. Supported by NIH R01 HD096881 and NEOMED.

373 Becca Young, Andres Romero-Carvajal

The transcriptional basis of embryonic diversification in frogs

The impressive diversity in reproductive adaptations that exist across amphibians poses challenges to embryo development. Apart from the ancestral water-developing embryos, multiple amphibians have evolved independently and repeatedly complex nesting behaviors like nest building, parental care, and the concealing of embryos in body cavities. Challenges of diverse developmental environments are associated with changes to egg properties (e.g., egg size and yolk abundance), embryo architecture, timing and rate of development. Notably, gastrulation – or the rearrangement of cell layers towards the differentiation of ectoderm, mesoderm and endodermal layers – 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., Dendrobatids). Yet, the signaling molecules and transcription factors regulating gastrulation are largely conserved across vertebrates. How these conserved molecular mechanisms are differentially deployed to generate diverse gastrulation patterns is unknown. Here, we characterize gene expression in early, middle, and late gastrula in two Dendrobatid species (Epipedobates machalilla and Hyloxalus nexipus) and compare expression to canonical patterns described in Xenopus to identify modifications in key signaling and transcription factor genes of gastrulation. Further, we leverage temporal clustering and gene co-expression analysis to identify co-expression modules and novel candidate genes associated with shifts in the relative timing of gastrulation processes. Our results shed light on how conserved molecular mechanisms can be differentially deployed and reorganized to generate diversity.

1492 Melody Young, Edwin Dickinson, Daniel Tanis, Nicolas Flaim, Alexander Lopez, PD Dr.-Ing. Andrada, John Nyakatura, Michael Granatosky

Beak-iation expands the locomotor repertoire of birds

Arboreal species frequently move with their bodies below the substrate. Such suspensory behaviors (e.g., inverted quadrupedalism, brachiation) have been described extensively in mammals. Parrots (Order: Psittaciformes) are also highly arboreal and face similar challenges of suspension to arboreal mammals. While assessing patterns of suspensory movement in rosy-faced lovebirds (Agapornis roseicollis), we observed the adoption of a rapid (∼0.09 m/s) alternating gait pattern in which: 1) the beak grasps the support; 2) the two hindlimbs release synchronously; 3) the center of mass swings forward, pivoting about the beak; 4) the hindlimbs reengage further along the substrate; and 5) the beak assumes a new grasping position in front of the hindlimbs. Based on patterns of isolated beak and limb forces, rosy-faced lovebirds load their craniocervical system with equivalent body-weight magnitudes (∼150% of body weight) to the forelimbs of brachiating gibbons, spider monkeys, and douc langurs. Further, out-of-phase fluctuations in gravitational potential and kinetic energy suggest that rosy-faced lovebirds are moving below branches using some level of pendular movement. However, energy recovery during beak-swinging is lower (∼21%) compared to what is observed during inverted quadrupedalism in two-toed sloths (∼36%) or brachiation in gibbons (∼90%). “Beak-i-ation” is a novel discovered locomotor mode that allows rosy-faced lovebirds to expand their potential foraging sphere, and highlights how behavioral innovations allow broader locomotor repertoires that could be predicted by morphology alone.

1504 Melody Young, Edwin Dickinson, Nicolas Flaim, Daniel Tanis, Alexander Lopez, Michael Granatosky

Climbing is hard (at least for humans).

Climbing represents a challenge of gaining height whilst overcoming gravitational acceleration. As such, the mechanical cost of climbing is driven by inescapable accumulation of potential energy. However, natural selection has produced a wide array of anatomical and behavioral variation among climbers, and it seems impossible for all species to have truly optimized the costs of vertical climbing. In this study we compare the mechanical costs of climbing, as derived from classic center of mass movement protocols, across four disparate taxa: Australian green tree frogs, Indo-Pacific geckos, rosy-faced lovebirds, and humans ranging in body size from 0.012-80kg and practicing distinct modes of gripping during climbing. Climbing costs were driven by potential energy, but all species experienced at least some kinetic energy fluctuations that added to the overall cost, which were greatest in humans and lowest in tree frogs. Irrespective of phylogeny, body size, or anatomical specialization, all species performed close to the possible mechanical minimum of vertical ascent. Across species, we demonstrate that reducing oscillations in the tangential position of the center of mass during a stride is the best strategy in reducing climbing costs. From a mechanical perspective, the costs of climbing are constrained by basic physical laws, and despite anatomical variation and varying degrees of arboreal specialization, animals adopt behavioral strategies to limit unnecessary costs during climbing.

1473 Nour Yousry, Paige Henderson, Jordanna Sprayberry

The effect of fungicide odor-pollution on floral search and selection in bumblebees

Over three quarters of all angiosperms and more than a third of all crops grown require active pollination efforts. Bumblebees are valuable generalist pollinators, with Bombus impatiens serving as one of the main pollinators in eastern North America. However, micro- and macro-stressors on bumblebees negatively impact both foraging efficiency and pollination efficacy. Agrochemical odor-pollution has been shown to hinder floral-odor learning and recognition in Bombus impatiens via an associative odor-learning assay. Building on this prior work, our study aims to determine the effects of fungicide odor pollution on bumblebee foraging in a more active foraging environment. These experiments investigate whether the presence of a background fungicide odor (Reliant® Systemic Fungicide) impacts ability and time to locate a learned floral resource in a wind tunnel. Experiments are repeated with and without early-access to visual cues to determine if fungicide odor pollution is more impactful on bees that are engaged in ‘floral-search’ rather than ‘floral-selection’ behavior.

1410 An-Ping Yu, Mihika Kozma, Donald Mykles

Gene expression of insulin-like peptides (ILP) across the molt cycle of the blackback land crab

Crustaceans regularly undergo growth and regeneration through the molt cycle. Four stages of the crustacean molt cycle are controlled by levels of circulating ecdysteroids, which are synthesized by Y-organs (YO). Insulin-like peptides (ILPs) are members of the insulin superfamily known to regulate growth and development in arthropods. ILPs have been characterized in insects, but their role in the molt cycle of crustaceans is unknown. An insulin receptor (InsR) was previously detected in the YO transcriptomes of the blackback land crab, Gecarcinus lateralis. InsR was differentially expressed in YOs when the molt cycle was manipulated using a mTOR inhibitor. In Drosophila, an ILP secreted by damaged imaginal discs inhibits ecdysteroid synthesis and delays metamorphosis. Correspondingly in crustaceans, molting can be suspended in early premolt if regenerating limb buds are damaged. Thus, ILPs may activate signal cascades that regulate ecdysteroidogenesis. This study aims to characterize gene expression of ILPs across molt stages. Two putative ILPs (ILP-1; ILP-3) were identified in eyestalk ganglia and YO transcriptomes of G. lateralis through phylogenetic analyses. Using transcriptomics and PCR, these ILP genes are examined across several organs of G. lateralis including YO, hepatopancreas, eyestalk ganglia, and regenerating limb buds at different developmental stages. By characterizing any differential gene expression, the specific role of ILPs in limb regeneration and molt regulation can be further explored. Support: NSF (IOS-1922701) and CSU Honors Program.

172 Jisoo Yuk, Anupam Pandey, Leena Park, Willy Bemis, Sunghwan Jung

How foxes dive into snow

Some mammals plunge-dive or dig out snow to catch prey hidden beneath the snow. Among them, arctic foxes and red foxes are known to be great hunters that catch small animals by snow diving. Here, we investigate the morphological characteristics of snow-diving foxes and the dynamics of snow diving to understand how they penetrate snow. First, we scanned dry skulls of a series of species in Felidae (cats and allies) and Canidae (dogs and allies, including foxes) to analyze key geometrical features such as snout length and width. In comparison with the bobcat and puma in the Felidae, the fox's snout is noticeably longer and narrower, thereby having a higher curvature. Next, we evaluated the benefits and dynamics of the structural differences between cats and foxes when diving into snow. To measure the impact force, we dropped 3D-printed skulls of cats and foxes into a container filled with snow. We also tested artificially snout-shortened 3D-printed models of foxes. When the snout is reduced in length by 25%, it generates twice the impulse compared to the original fox snout. Similarly, the bobcat generates a greater force during the impact phase. These results imply that the fox's sharp and long snout helps to quickly approach prey when diving through snow with less impact force.

146 Ellianna Zack, Stephanie Smith, Kenneth Angielczyk

From Fairies to Giants: impacts of body size and ecology on trabecular bone of Xenarthran vertebrae

Trabecular bone is a spongy bone tissue that serves as a scaffolding-like support inside many skeletal elements. Previous research found allometric variation in some aspects of trabecular bone architecture (TBA) and bone microstructure, whereas others scale isometrically. However, most of these studies examined very wide size and phylogenetic ranges or focused exclusively on primates or lab mice. We examined the impact of body size on TBA across a smaller size range in the mammalian clade Xenarthra (sloths, armadillos, anteaters). We μCT-scanned the last six presacral vertebrae of 23 xenarthran specimens (body mass 120g-35kg). We collected ten gross-morphology measurements and seven TBA metrics and analyzed them using phylogenetic and non-phylogenetic methods. Most metrics had similar allometries to previous work. However, because ecology and phylogeny align closely in Xenarthra, the phylogenetic methods likely removed some covariance due to ecology; clarifying the impact of ecology on TBA in xenarthrans requires further work. Regressions for Folivora had high p-values and low R-squared values indicating that the extant sloth sample either is too limited to determine patterns or that the unique way sloths load their vertebral columns causes unusually high TBA variation. The southern three banded armadillo sits far below the regression lines, which may be related to its ability to roll into a ball. Body size, phylogeny, and ecology impact xenarthran TBA, but parsing these effects is highly complex.

828 Jessica Zehnpfennig, Matthew Graham, Andrew Mahon

Are you my mother? Investigating reproductive patterns within Pycnogonida (sea spiders)

Sea spiders (Pycnogonida; Chelicerata) are a speciose clade of benthic invertebrates found in all oceans. Reproduction in the vast majority of the group involves mechanisms exclusively focusing on paternal care after egg production by the mothers. The female sea spider produces eggs, transfers them to the male, who fertilizes and adheres them to his ovigerous legs in clusters, carrying them until they hatch. Sea spider mating systems are vastly understudied, with previous work primarily focusing on life history, morphology, ontogeny and phylogeny. Of the few investigations utilizing molecular data to examine genetic mating in natural populations of sea spiders, only three species have been investigated using microsatellites. Recent molecular advances have shown that single nucleotide polymorphisms (SNPs) developed from restriction site-associated DNA sequencing (RAD-seq) protocols are substantially more powerful and advantageous than microsatellite loci at assigning paternity and relatedness among individuals. We applied these tools to identify SNPs and investigate sea spider kinship. From our SNP discovery and genotyping, we assigned parentage and investigated relatedness within two species of Antarctic sea spiders (Nymphon australe and Ammothea gigantea). Male specimens carrying multiple egg clutches from the same geographic location were selected and SNPs from each male and multiple eggs within each of the clutches were analyzed. We will present information on the relatedness between egg clutches and discuss the potential for polygynandrous mating in Pycnogonida.

1167 Miriam Zelditch, Donald Swiderski

Modularity of mandible shape, part I: Methodological considerations

Modularity and integration are widely recognized as fundamental properties of organisms and central to theories of complex adaptation. Empirical analyses now commonly analyze modularity and integration of shape, which are valuable for the information they provide about the geometry and spatial structure of modules. However, a recent study contends that a necessary method in shape analysis, the Procrustes superimposition, leads to spurious inferences of modularity and integration and even more so when semilandmarks are slid. We reexamine those claims, conducting more thorough and statistically more rigorous analyses that use current methods and are also reproducible, extending them to evolutionary integration and modularity as well. Using two designs for simulating random variation of shape, we find that neither the Procrustes superimposition nor sliding semilandmarks to minimize the Procrustes distance increases the strength of variational modularity or integration above that present in the simulated data. Only sliding to minimize bending energy does. The same results are obtained for evolutionary modularity, but not for evolutionary integration. In the case of evolutionary integration, the evolutionary model leads to very high evolutionary integration in the simulated random data, prior to superimposition. Even so, the strengths of variational and evolutionary modularity and integration estimated from empirical data far exceed the 95% confidence intervals obtained from the simulations.

1476 Haolin Zeng, Noah Egan, Ram Avinery, Shengkai Li, Daniel Goldman, Takao Sasaki

Building dynamics of self-assembly pontoon bridges in the fire ant, Solenopsis invicta

Ants are among the few groups of terrestrial animals who can build functional structures using their own connected bodies, exemplifying how biological complexity can arise from lower-level individual actions. Here we show that fire ant (Solenopsis invicta) workers are able to self-assemble floating bodily connections across the water to reach food in a slime mold fashion. In our experiment, we presented food placed in the center of a petri-dish filled with water to a starved colony. Proto-bridges were consistently expanding, decaying, and regenerating but always resulted in a single bridge connecting the shore and the food within a few hours. To understand the dynamics of the bridge-building process, we tracked the bridge expansion speed and coherence under various conditions. Proto-bridges were extended by ants joining the pontoon from the shore as well as from floating groups. When an air current was blown over the food and water arena, ants always built bridges against the incoming airflow, indicating that ants were motivated by the scent of the food. Additionally, hungrier ants are less efficient at bridge building, which supported predictions from agent-based model simulations. Overall, we showed that bridge building in fire ants is a novel and efficient laboratory study system for understanding the mechanisms of self-assembly structures.

744 Maya Zepeda, Laura Grossner, Riley Wincheski, Kiri Stauch, Charles Abramson

Cap Pushing Responses of Honey Bees (Apis mellifera) with Associated Weight Preference

Honey bees are vital pollinators for many land ecosystems. However, the current colony collapse disorder phenomena has threatened their species. This puts even more pressure on humans to understand honey bee behavior and their social networks to help understand this collapse. Components of bee foraging behavior include searching, memorizing, identifying, carrying food, and communicating with other bees. This comparative psychology experiment provides insight into studying honey bees' unique learning mechanisms through a cap pushing response (CPR) technique. CPR was used to analyze behavioral responses where free-flying bees were trained to push a cap and reveal a reward. Previous research has been conducted using CPR with physical punishment, shaping, recall, and scent through observation. These manipulated techniques allowed researchers to identify honey bee weight preferences using CPR. The current experiment looked at choice preference between heavy versus light weighted caps to obtain a food reward. Collected experimental data on CPR experiments looked to see if there was a significant preference for a bee pushing a lighter cap. Overall, the results were significant for all tested groups meaning that honey bees had no choice preference when choosing to push a heavy or light cap to obtain a reward. These findings tell us that honey bees are able to adapt and have no preference between different weighted caps, being able to push an object thirty times their weight.

1676 Saba Zerefa, DEBOJYOTI BISWAS, Yu Yang, Noah Cowan

Decoding Active Sensing via Tracking Behavior in Weakly Electric Fish

Active sensing is the process of using movements to improve sensory information. However, its connection to task-level control is relatively unexplored. To understand this interplay, we study the refuge tracking behavior of the weakly electric glass knifefish, Eigenmannia virescens. The fish's natural refuge seeking behavior allows for a useful model for analyzing its sensorimotor system, and consequently, its active sensing and task-level controllers. Previous work (Biswas et al. 2018) found that E. virescens regulates active sensing by maintaining a constant root-mean-square (RMS) sensory slip; however, the prior work did not examine the task-level control component in the sensorimotor system. In our experiment, the fish (N = 3) tracked a moving refuge following a reference trajectory, while we artificially modified its reafferent feedback (5 replicates for each of 6 augmented feedback gains). The reference trajectory was a sum-of-sines function, where the frequencies of the sine functions were prime multiples up to 41; this signal was used due to its "noisy", unpredictable nature, and its large frequency bandwidth, which is ideal for interrogating the task-level controller. We found that all three fish systematically changed their task-level controller depending on the modified reafferent gain and, simultaneously, adjusted their active sensing to maintain a constant RMS sensory slip, even during task-level control. These new findings shed light on how animals simultaneously manage active sensing, while using sensory information for task-level control.

85 Yangfan Zhang, George Lauder

Fish schooling dynamics: reduced use of aerobic capacity and anaerobic energy

Schooling is a collective behaviour common to numerous fish species that is proposed to reduce the energy required to swim, but how energy is conserved remains elusive. We hypothesize that schooling dynamics reduce total energy expenditure in fishes exhibiting active directional schooling compared to the energy used by solitary fish, especially at higher speeds where there is a premium on energy conservation. To evaluate this hypothesis, we directly measured aerobic and anaerobic metabolic contributions to schooling energy use over a speed range of 0.3–8 body length s-1 in giant danio (Devario aequipinnatus). Locomotor kinematics were recorded simultaneously. We show a reduction in energy used per tail beat by fish in schools of up to 126% compared to solitary fish. Schooling fish used a smaller proportion of their aerobic capacity to swim and reduce the need for anaerobic metabolism, which lowered the total energy expenditure and cost of transport by up to 112% at higher speeds. Fish schools achieve an aerobic energetic minimum at 1 body length s-1, a value that agrees with the long-distance swimming speeds recorded by acoustic tags placed on migrating fish. Therefore, we suggest that energy conservation may be a key driver for the evolution of active directional schooling behavior in fishes.

228 Chi Zhang, Stephen Mather, A. Murat Maga

An open-source photogrammetry pipeline for acquiring 3D biological models

Acquiring accurate 3D models of biological specimens efficiently and economically is critical for data collection and analysis. Here we present a structure-from-motion (SFM) photogrammetry pipeline and protocol based on open-source tools and an affordable camera for achieving accurate 3D models with realistic texture. SFM photogrammetry is a relatively new technique that registers 2D images for reconstructing camera positions. It then generates a dense point cloud for detailed meshing and texturing. Our pipeline is based on the open-source package Open Drone Map (ODM), which is commonly used for landscape and architecture modeling based on aerial photography. Our sample comprises a list of Aplodontia rufa (mountain beaver) skulls. Photos were taken automatedly by syncing the shutter of a regular DSLR camera with a turntable. Reconstructed models were visualized, scaled, and measured using 3D Slicer and MeshLab. Using models acquired from CT scanning as the reference, our results show that the geometry of the models is sufficiently accurate for morphometric analysis. It also offers realistic surface texture for detailed evaluation, which cannot be achieved by CT scanning. We present detailed protocols and instructions, such as those for camera setup and photo taking, for users to apply our pipeline in biological and evolutionary data collection.

300 Yufeng Zhang, Amberleigh Henschen, Elina Thomas, James Adelman

Effects of acute and long-term mycoplasma gallisepticum infection on mitochondrial function in house

Mycoplasma gallisepticum (MG) causes respiratory disease and conjunctivitis in house finches (Haemorhous mexicanus). This study aimed to evaluate the acute and long-term effects of MG infection on suppressing mitochondrial function and immune responses in house finches. Our data from experimental inoculations in captivity showed that mitochondrial function and density largely differ between acute and long-term MG infection. MG affected mitochondrial complex II driven respiration in acute infection, which could be one of the mechanisms underlying MG's ability to suppress early immune responses via the succinate-regulated pathway. Both mitochondrial function and density decreased after long term infection. More importantly, 32 days after infection, finches no longer showing any clinical signs of infection showed similarly reduced bioenergetic capacity compared to finches still showing clinical signs. These results indicate that the bioenergetic effects of MG differ between infection stages, and that reduced mitochondrial function after MG infection could have long term fitness consequences even after symptoms resolve.

753 Margaret Zhang, Andrew Schulz, Cassie Shriver, Joseph Mendelson, David Hu, Young-Hui Chang

In-vivo work loop analysis of the African Elephant Trunk

Elephant trunks, tongues, and octopi's arms are the three primary examples of muscular hydrostats, structures composed mainly of muscles with no skeletal support. The dense collection of muscles allows these appendages to maneuver through nearly any obstacle, but we understand very little about their mechanical force generation. In this experimental study, we report the first in-vivo work loop analysis done on the muscular hydrostat. Working with Zoo Atlanta, we studied the force-length relationship of the African elephant trunk using an elephant-sized tug-of-war device. We discuss the mechanical understanding of the trunk and the future work that will be done to expand this to other hydrostats to help understand the physical limitations of these hydrostats.

1064 Bingyang Zhang, Philip Anderson

Modeling biological puncture: on the mechanics, energetics, and scaling

Biological puncture systems utilize a variety of morphological tools to penetrate soft target tissues. Despite being highly diverse in form, scale and function, these systems are united by a set of underlying physical rules which dictate their mechanics. While previous studies have illustrated form-function relationships in individual systems, these underlying rules have not been formalized and generalized. A knowledge gap exists between puncture tool morphology and material response and how their effects impact the scaling of puncture systems. We present a mathematical model for biological puncture events based on energy balance in soft materials to determine how the initial energy applied by a puncture tool is split into three contributions during puncture: elastic strain energy, work to fracture, and work to overcome friction. General scaling relationships of different orders are found between these energy contributions and a characteristic failure length scale, which postulate an optimal shape for the biological puncture tool. We demonstrate through FE simulations the significant role of puncture tool geometries in determining puncture energies. Further results from dynamic puncture tests at different velocities reveal that the sensitivity of puncture damage to tool geometry variations decreases as the puncture speed increases. These findings highlight the complex interplay between morphology, material response, and other mechanical processes during biological puncture. They offer a timely approach to biomechanically contextualize and systematically characterize existing biological puncture systems.

1755 Liyuan Zhang, Teagan Mathur, Yuhe Cui, Aimy Wissa, Marianne Alleyne

Launching Engineered Prototypes to Study the Factors that Influence Click-Beetle Jump Capacity

In nature, click-beetles use a unique hinge structure between their prothorax and mesothorax that acts as a power amplifier to produce a high acceleration while jumping. This structure enables them to jump the height of several times their body length without using legs. In addition to investigating the material, interior, and exterior properties of the hinge structure, it is necessary to study beetle jump trajectories to inform the design of novel jumping mechanisms. For better control over variables, we designed a special launching platform and simplified beetle prototypes to simulate the latching and release of the hinge. This launcher design uses a quick-reaction release mechanism and magnetic actuator to simulate the unlatching process and uses a spring to simulate the stored elastic energy. Through the design of different simplified prototypes, we are able to compare the jumping trajectories of live click beetles and constructed prototypes. This study will help reveal how variables such as the center of mass, spring elasticity, elytron curvature, weight, and body length affect the beetles' jumping capability. Our findings provide further insight into the design and fabrication of legless jumping robotic mechanisms.

91 Grace Zhong, Laurel Kroo, Manu Prakash

Thermotaxis in an apolar, non-neuronal animal

Neuronal circuits are hallmarks of complex decision making processes in the animal world. How animals without neurons process information and respond to environmental cues promises a new window into studying precursors of neuronal control and origin of the nervous system as we know it today. Robust decision making in animals, such as in chemotaxis or thermotaxis, often requires internal symmetry breaking (such as A-P axis) provided by a given body plan. We report the discovery of robust thermotaxis behavior in Trichoplax adhaerens - an early-divergent, enigmatic animal with no anterior-posterior symmetry breaking (apolar), and no known neurons or muscles. We present the first quantitative, robust behavioral response assay in Placozoa. By exposing T. adhaerens to a thermal gradient under a long-term imaging setup, we observe robust thermotaxis occuring over timescale of hours, independent of circadian rhythms. We quantify that T. adhaerens detects thermal gradients of at least 0.1 °C/cm for baseline temperatures ranging from 17-22.5 °C, with motility trajectories well-described by a Lévy distribution. Interestingly, T. adaerens does not maintain a fixed orientation while performing thermotaxis. We demonstrate a critical animal size above which thermotaxis is hindered. Several TRP family homologs have been reported to be conserved in metazoans, including in T. adhaerens. We discover naringenin (known TRPM3 antagonist) inhibits T. adhaerens thermotaxis. The discovery of robust thermotaxis in T. adhaerens provides a tractable handle to interrogate information processing in a brainless animal.

1252 Baxi Zhong, Juntao He, Shengkai Li, Eva Erickson, Kelimar Diaz, Tianyu Wang, Daniel Soto, Daniel Goldman

Self-propulsion via slipping: frictional swimming in multi-legged locomotors

Locomotion is typically studied either in continuous media where bodies and legs experience forces generated by the flowing medium, or on solid substrates dominated by friction. In the former, centralized coordination is believed to facilitate appropriate slipping through the medium for propulsion. In the latter, slip is often assumed minimal and thus avoided via decentralized controls. We discover in laboratory experiments that terrestrial locomotion of a meter scale multi-segmented/legged robophysical model resembles undulatory fluid swimming. Experiments varying waves of limb stepping and body bending reveal how these parameters result in effective terrestrial locomotion despite seemingly ineffective isotropic frictional contacts. Dissipation dominates over inertial effects in this macroscopic-scaled regime, resulting in essentially geometric locomotion akin to microscopic-scale swimming. Theoretical analysis demonstrates that the high-dimensional multi-segmented/legged dynamics can be simplified to a centralized low-dimensional model, which reveals an effective Resistive Force Theory with an acquired viscous drag anisotropy. We extend our low-dimensional, geometric analysis to illustrate how body undulation can aid performance in non-flat obstacle-rich terrains and also use the scheme to quantitatively model how body undulation affects performance of biological centipede locomotion (the desert centipede S. polymorpha) moving at relatively high speeds (~0.5 body lengths/sec). Our results could facilitate control of multilegged robots in complex terradynamic scenarios.

1115 Elaine Zhou, Abraham Lineaweaver, Kenddra Buresch, Jean Boal, Roger Hanlon

Mechanotactile 3D shape discrimination by octopus arms suckers

Octopuses have multisensory mechanisms that allow them to recognize objects in their environment. Foraging octopuses use a combination of chemo- and mechano-receptors located on their arm suckers to distinguish prey, but the relative importance of each of these sensory mechanisms in relation to foraging has not been studied in detail. Previous experiments in our lab revealed that octopuses are clearly able to discriminate prey from non-prey using only contact chemosensory information. The current study isolates the mechano-sensory capabilities of Octopus bimaculoides arm suckers and aims to determine whether 3D shape mechano-sensing is sufficient to discriminate prey from non-prey. We collected video from 10 octopuses interacting with a control cube and four experimental 3D-printed shapes representing prey and non-prey (i.e., bumpy rock, crab, sea star, and mussel). The objects were introduced to the animals inside a rock dome and were only accessible using their arms, eliminating visual confirmation of each object. The octopuses' interaction with each object was graded on the contact time with the object and the maximum recruitment of adjacent arms to the object. The data revealed that the octopuses were not able to clearly discriminate 3D printed shapes made to resemble prey shape vs. non-prey. The study of octopuses' behavioral response based on isolated sensory mechanisms provides a greater understanding of their chemical and mechanical prioritization in prey-based interactions.

1740 Haodong Zhou, Cassandra Donatelli, Kaelyn Gamel, Henry Astley, Odette Laneuville, Emily Standen

Feel it in Your Bones: Differences in the Skeletal Anatomy of Terrestrial and Aquatic Mudskippers

Mudskippers are a group of amphibious fishes in the family Oxudercidae, whose species inhabit a range of habitats from aquatic to terrestrial. Most of our understanding about habitat preference comes from natural history observations, particularly where individuals are collected (i.e. low intertidal vs high intertidal). Mudskippers have undergone several morphological changes to accommodate terrestrial life, including changes to the pectoral and pelvic girdles. This unique morphology gives rise to a novel gait, crutching, which Mudskippers use to move overland. Though the appendicular morphology and crutching gait has been described in some species, few studies have compared skeletal structures across the family. The fossil record shows a trend towards simplification of limb joints in fishes that evolved to move over land and functional studies show that extinct fishes may have moved with a crutching-like gait. Even so, it is impossible to determine with certainty which anatomical changes were crucial for terrestrial locomotion. In our study, we use microCT scans to compare the skeletal anatomy of sixteen species of mudskippers. We also used a custom force plate to characterize the crutching gait in two species. We found a significant difference in axial and appendicular anatomy between terrestrial and aquatic species. Understanding which adaptations are required for terrestrial locomotion has implications in both mechanical design and our understanding of the evolution of terrestrial locomotion in aquatic vertebrates.

46 Diamanda Zizis, Chris Martine, Tanisha Williams

Heading for a breakdown: Assessing evolution through the hybridization of two sexual systems

Hybridization is an important evolutionary pathway that has contributed to the world's vast biodiversity. Hybrids were acquired from crosses between Solanum dioicum (dioecious) and S. ultraspinosum (andromonoecious). The only successful hybrids from the original crosses were those derived from S. dioicum as the pollen donor and S. ultraspinosum as the pollen recipient. Due to strong maternal effects, all F1 hybrids resembled S. ultraspinosum, thus all F1 plants were andromonoecious. A series of statistical analyses were done based on morphometric data. A principal component analysis confirmed that the hybrids were distinct from both parents, but were most similar to the pollen recipient. The F2 hybrids appear to demonstrate variability in inflorescence architecture, which may be suggestive of a change in sexual system. In attempts to create an F3 hybrid generation, nearly all of our crosses have failed—suggesting that a hybrid breakdown is occurring. To determine where the breakdown is occurring, I am employing fluorescent microscopy. This may explain what mechanisms are present in nature that prevent hybridization of species with different sexual systems. This study should promote a better understanding of hybridization—a driving force in plant diversification—among Australian Solanum, a group in which hybridization is known to be widely possible but rarely confirmed in nature. Likewise, hybridization between taxa with two distinct sexual forms may shed light on the evolution of reproductive strategies in this clade.

627 Christopher Zobek, Connor Verhulst, Anmol Sethi, Alec Wilken, Casey Holliday

Protractor Muscle Diversity in Reptiles and Its Significance for Cranial Kinesis

Varying degrees of cranial kinesis are present in vertebrates, from the extremely kinetic and loosely built skulls of snakes to the akinetic skulls of crocodilians. Partially responsible for this diversity of cranial kinesis is an assemblage of jaw muscles that power the feeding apparatus. Specifically, the protractor muscles (mPPt, m. protractor pterygoideus), which attach the pterygoid to the braincase, are thought to be a primary driver of kinesis. Here we employ DiceCT (iodine-contrast microCT) and muscle fascicle tracking approaches (Avizo Xfiber) to reconstruct the protractor muscles and their architecture in a broad sample of reptiles to better understand how the muscles impact cranial function. We imaged and modeled the protractor muscles of a diverse sample of species that employ a range of cranial kinesis, including snakes (Akistrodon contortix, Morelia spilota, Pantherophis obsoletus), lizards (Anolis sagrei, Gekko gecko, Varanus exanthematicus), and birds (Megaceryle alcyon, Anas sp., Psittacus erithacus). We segmented each muscle and collected volume, attachments, resultants, fiber architecture and pennation, and moments about the otic joint as a means of exploring cranial kinesis. We found that the protractor muscles differ greatly in pennation, resultants and moments supporting our expectations that these muscles responsible for cranial kinesis are quite variable among snakes, lizards and birds and require additional study to better understand their ecological and evolutionary significance.

1353 Kendra Zwonitzer, Justin Havird

Causes of mtDNA mutations across Metazoa: Using substitution spectra to predict mutation mechanisms

Mitochondrial DNA (mtDNA) contains genes that are central to eukaryotic metabolism. Mutations in mtDNA can cause human disease and have been proposed as a significant driver of aging under the mitochondrial theory of aging. Despite the significant impact of mtDNA mutations, the primary mechanisms responsible for generating mtDNA mutations across animals remain unclear. The three most popular proposed mechanisms of mtDNA mutations are reactive oxygen species (ROS), polymerase errors, and spontaneous deamination. Each mechanism should result in a unique mutational signature, which can be estimated by examining the substitution spectrum within an evolutionary lineage. Substitution spectra include the relative frequencies of the different types of mutations (e.g., C to T vs. G to T), as well whether there is any strand-bias. We collected mtDNA sequences across multiple diverse metazoan clades including primates, nematodes, and fish and implemented ancestral sequence reconstruction to generate a substitution spectrum for each clade. These spectra were compared to the known signatures of each proposed mechanism of mtDNA mutation. We find most metazoans show evidence for spontaneous deaminations as a primary mechanism for mtDNA mutation, including an abundance of C to T changes on the lagging strand template. Some clades do show evidence for other additional causes such as ROS. Our results have implications for how mechanisms of mtDNA mutation may vary across Metazoa.