The timing of muscle recruitment alters series elastic function during lengthening contractions

During eccentric contractions muscles are actively lengthened to dissipate energy. While eccentric contractions are physiologically common, muscle injury and soreness are often associated with actively lengthened muscle fibers. It has been suggested that series elastic elements (tendons and aponeuroses) may act as mechanical buffers to mitigate these potentially damaging outcomes. During eccentric contractions, strain energy is initially loaded into series elastic elements before tendon recoils stretch the muscle fascicles. By temporarily storing elastic energy, tendons can slow the rate of stretch applied directly to fascicles and can therefore function in attenuating power. Here we examine how the timing of muscle activation relative to muscle lengthening may alter the effective utilization of tendons in attenuating power. Using an in vitro muscle–tendon preparation, we test the prediction that muscle recruitment in anticipation of lengthening can reduce the rate and magnitude of stretch applied directly to muscle fascicles. Plantar muscles of Ranidae (bullfrog) were instrumented with sonomicrometry crystals to measure muscle fascicle length. MTU length, force and power were measured by a servomotor. The MTU was lengthened at a constant speed while being stimulated at either 50ms before (early–start), concurrent with, or 50ms after (late–start) MTU lengthening. We find that the magnitude and rate of stretch applied directly to the fascicles decreased when the muscle was stimulated in advance of lengthening (early–start). We conclude that motor control strategies used during energy dissipating tasks can determine the degree of power attenuation by series elastic elements. Supported by NSF grant 1051691.

Craniofacial ontology in turtles; the role of bone morphogenetic protein in the loss of palatal shelves

Turtles are an enigmatic group of vertebrates whose divergent skull morphology is still at the forefront of scientific discussion. While turtles pass through a conserved stage of primary palate development found in all amniotes, we have found that turtles diverge during secondary palate ontogeny. The typical condition for amniotes is to form outgrowths from the medial sides of the maxillary prominences called palatal shelves. In mammals, the shelves fuse in the midline and form a bony hard palate that completely separates the nasal and oral cavities. In birds and squamates, palatal shelves develop on the lateral sides of the oral roof but remain unfused, leaving a natural cleft. Here, we conclusively excluded the presence of vestigial palatal shelves at any time during the ontogeny of the craniofacial complex in two branches of turtles, a side–necked turtle (Emydura subglobosa) and a sea turtle (Lepidochelys olivacea). Additionally, through comparative analysis of avian and testudine (E. subglobosa) craniofacial gene expression patterns, we have identified a distinct lack of mesenchymal Bone Morphogenetic Protein 2 (BMP2) expression in the maxillary prominences of E. subglobosa. In previous work we showed that when BMP signaling is blocked in the chicken embryo maxillary prominence, a complete loss of palatal shelves occurred. These intriguing avian data suggest that loss of BMP expression in the turtle at an early time in their evolutionary history contributes to the loss of palatal shelves. This work is supported by an NSERC grant to JMR. JA holds an NIH Ruth L. Kirschstein PDF.

Determining the relationship between vertebral morphology and burst swimming performance

Ectothermic aquatic vertebrates are particularly sensitive to the effects of environmental conditions during early development, which can significantly impact vertebral morphology, performance, and survival. Previous research has highlighted the sensitivity of diverse groups of amphibians and fishes to the effect of temperature during early development on vertebral morphology. Vertebral morphology has also been shown to significantly impact an individual’s swimming performance, which is a crucial aspect of their survival. In this study, we investigated the relationship between the effect of temperature on vertebral development and the subsequent effect of any discrepancy on burst swimming performance in two model aquatic vertebrates, zebrafish (Danio rerio) and axolotls (Ambystoma mexicanum). Embryos of both species were collected and evenly distributed between a range of species appropriate temperatures prior to the onset of somitogenesis. Following development, startle responses were recorded and individuals were analyzed for either vertebral number or muscle fiber composition. Our results indicate that, in both species, small fluctuations in temperature can significantly influence an individuals vertebral development, such that individuals reared in higher temperatures develop a lower number of total vertebrae and a less favorable ratio of pre–caudal to caudal vertebrae for maximum performance. As a result of these morphological discrepancies, the swimming performance of these was significantly impacted and these individuals were found to have decreased burst swimming performance. We are expanding this study to determine whether individuals with decreased burst swimming performance have decreased survival when confronted with a native predator.
The role of natural frequency in a jumping robot

Many animals and robots jump to reach higher ground, to escape from predators, and even as a primary mode of locomotion. At a basic level, jumping involves transient bursts of actuation of a mass coupled with internal elastic elements to generate movement. A hypothesis, then, is that this systems natural frequency, , (from mass and elasticity) should play a crucial role in maximizing jump performance. While there have been many models created to simulate jumping, these often have many parameters and multi-link legs, making it a challenge to analyze the dynamics of such systems. To probe in detail how natural frequency affects jumping performance, we study a simple robot comprising a periodically actuated mass–spring arrangement. The actuator frequency and phase are systematically varied to find optimal performance. If forced for N=2 or more cycles, robot lift–off is achieved optimally at resonance. However, for the fastest lift–off, (N=1), maximal jump heights surprisingly occur above and below (but not at) . A simple model reveals how jumping, which occurs at transient time scales, is optimized less by resonant build up and more by proper timing and phasing. Two distinct jumping modes emerge: a simple jump, which is optimal above , is achievable with a squat maneuver, and a stutter jump, which is optimal below , is generated with a counter–movement. The stutter jump is slow but uses less power, while the single jump has a fast time to takeoff but requires higher power input. We propose that animal musculoskeletal systems can target these different jumping templates to make situation–appropriate tradeoffs between time–to–takeoff and internal power.
African lungfish (Protopterus annectens) and tetrapods share fundamental features of their limbed locomotion. Previous study of pelvic fin kinematics emphasized the fishes ability to produce rotational movements around the joint between the fin and the pelvis, as well as the ability to lift the body from the substrate, undetected by the lack of a sacrum and digitated limbs. Despite similarities in limb movement, which for sprawling tetrapods, can require nine muscles, the lungfish uses only two muscles that surround the femur and lateral pelvis. These muscles called the pelvic fin protractor and retractor muscle are separated by ventro–medial and dorso–medial running connective tissues. They originate on the medial margin of the pelvis and insert on the distal femur of the fin. The modest morphology of P. annectens is strikingly different from the muscles surrounding the pelvic girdle in terrestrial terapods, where they are often robust and span multiple joints. Here we examine the muscular control of lungfish pelvic fin movement via EMG and fin kinematics to explore specific functions of the protractor and retractor muscles. We hypothesized that these muscles are functionally subdivided and activate synergistically to generate the range of movements observed. EMG records indicate solitary activation of localized regions of both the retractor and the protractor as well as coordinated activation of regions within these muscles to produce a full range of pelvic fin rotation. Our data suggest that functional subdivision within these muscles is fundamental to pelvic fin rotation, which allows lungfish to produce limb coordination similar to those of tetrapods utilizing only two muscles.

Using sequence capture of UCEs and flanking regions to resolve phylogenetic relationships within actinopterygian fishes

Ray–finned fishes constitute the dominant radiation of vertebrates with over 30,000 species. Although molecular phylogenetics has begun to discern major evolutionary relationships within this vast section of the tree of life there is as yet no widely available approach for efficiently collecting phylogenomic data within fishes, leaving much of the enormous potential of massively parallel sequencing technologies for resolving major radiations in ray–finned fishes unrealized. Here we provide a genomic perspective on longstanding questions regarding the diversification of major groups of ray–finned fishes through targeted enrichment of ultra–conserved nuclear DNA elements (UCEs) and their flanking sequence. Our workflow efficiently and economically generate data sets that are orders of magnitude larger than those produced by traditional approaches. Analysis of the UCE data set recovers a well–supported phylogeny at magnitude larger than those produced by traditional approaches. We also discuss progress towards developing larger UCE–based data sets.

Evidence that Perkinsus marinus is acquired by oysters during rejection of waterborne particles as pseudofeces

One of the most common mechanisms for vector transmitted parasites to reach the internal host environment is through feeding. In this study, we investigated the mechanisms of oyster host colonization by the Alveolate Perkinsus marinus and focused on how oysters process infective waterborne P. marinus cells during feeding in an attempt to reveal the portal and mechanisms of entry of this parasite to its host. We also compared the uptake of freely–suspended P. marinus with that of aggregated parasite cells to link changes in particle processing by the feeding organs with infection success and route. Finally, we evaluated the effect of oyster secretions (mucus) covering the feeding organs on P. marinus physiology because these host factors are involved in the processing of waterborne particles. The ensemble of results shows a unique mechanism for infection by which P. marinus is mostly acquired during the feeding process, but not via ingestion. Rather, infection occurs during the rejection of material as pseudofeces before reaching the mouth. The pseudofeces discharge area, a specialized area of the mantle where unwanted particles are accumulated for rejection as pseudofeces, showed significantly higher parasite loads than other host tissues including other parts of the mantle. Aggregated P. marinus cells caused significantly higher disease prevalence and infection intensities when compared to freely–suspended parasite cells. Mucus covering the mantle caused a quick and significant increase in parasite replication rates suggesting rapid impact on P. marinus physiology. A new model for P. marinus acquisition in oysters is proposed.
In 'Sprawling' locomotion (e.g., lizards and salamanders), 3D limb kinematics appear more important than the more planar motions of 'upright' animals. In particular, due to the highly abducted proximal limb segment forward motion can be achieved both by its retraction and long–axis rotation (LAR) – the ‘double-crank’ mechanism. This is observed in both pectoral and pelvic limbs of salamanders, but it's significance in lizards and other 'sprawlers' is not fully known. Here, we use simultaneous measurement of 3D kinematics (XROMM) and limb endpoint forces in a representative lizard (Iguana iguana) to quantify joint rotations, torques, powers, and contributions to overall body velocity. In support of previous hypotheses, we find that the importance of the ‘double crank’ to locomotor progression is much greater in the pectoral than the pelvic limb of I. iguana. However, rather than a simple ‘double crank’, we find complex patterns of 3D pectoral girdle, shoulder and elbow rotations all contribute to forward velocity and power at different points during stance. In contrast, progressive power in the pelvic limb is provided mainly by planar flexion and adduction at the hip and carpal joints – while significant non–planar torques and rotations are found, these appear to be associated with braking and control of ground reaction torques rather than progression. Detailed 3D kinematics for sprawling animals are only recently available via the XROMM method, and so the distribution of such differential mechanisms of pectoral/pelvic limb progression cannot yet be assessed across Lepidosauromorphia. It is possible that this represents a similar fore/hind support/power differentiation to that seen in mammals, although by acting as a 'wheel' rather than a 'strut', the forelimb may be better able to also provide locomotor power.

Animals have evolved a diversity of defense mechanisms including cryptic and startling displays and flight responses to escape their predators. Arguably one of the most bizarre of these is autotomy, the voluntary shedding of a limb or body part. This behavior is beneficial in the immediate escape of the animal and leaves behind a potential distraction for the predator. However, organisms may incur long term costs to activities where the lost limb played a vital role. Reptiles, echinoderms, and arthropods are known to lose specific body parts and provide evidence for increased survival in autotomizing individuals. Several studies in these skeletalized taxa have also shown that autotomy decreases locomotor performance. We studied a soft–bodied organism, Abdopus aculeatus, an octopus known to autotomize and regenerate its arms. More than 50% of the 48 individuals observed in the Philippines were found with one or more arms lost or regenerated. Additional arms were autotomized in the lab and were found moving and suctioning to surfaces for up to three minutes without stimulation. Stimulated arms continued to move for more than one hour, attaching to surfaces at the base and repeatedly curling at the tip. These results suggest that autotomized arms have evolved behaviors that distract the predator as the octopus escapes. Preliminary locomotion studies also suggest that there is no difference in the kinetics of how autotomized and intact individuals move. However, the type of locomotion and gait patterns may differ depending on the number of arms that are lost. With these data, more quantitative analyses of the costs and benefits of autotomy may be determined along with a better understanding of the evolution of this mechanism in octopuses.
S3-1.2 ANDERSON, P*; FRIEDMAN, M; RUTA, M; Univ. of Massachusetts, Amherst, Unv. of Oxford, UK, Univ. of Lincoln, UK; panderson@bio.umass.edu
Diversity and Disparity of the vertebrate feeding apparatus across the invasion of land
When vertebrates first colonized land, about 370 Mya, they encountered a world full of new dietary resources requiring radical changes in feeding mechanisms, not only at the water–land transition but also within the terrestrial realm. However, recent work has indicated that the earliest known limbed vertebrates had mechanical jaw systems similar to their fish relatives. Here, we extend the scope of initial inquiries by examining the functional spectrum of feeding modes in a diverse range of mostly Paleozoic, semi-terrestrial and terrestrial early tetrapods. We collected various biomechanically relevant metrics from the lower jaws of a set of Devonian–Permian taxa: stem–tetrapods (including fishes), stem–amphibians, stem–amniotes, and crown–amniotes. These data were used to construct a morphofunctional space illustrating the variety of biomechanical profiles explored by these early tetrapods. Relative disparity and morphospace occupation across taxonomic groups and stratigraphic bins document a stepwise occupation of various feeding guilds. In terms of mechanical feeding diversity, Devonian and Carboniferous stem tetrapods differ little from lobe–finned fishes. It was not until the appearance of Carboniferous and Permian stem amphibians and amniotes that terrestrial vertebrates began to expand into new regions of biomechanical morphospace. Our data support the hypothesis of a lag in the origin of tetrapod herbivory: the first excursion into herbivore–gulps space does not occur until the latest Carboniferous. These results suggest that the conquest of land was a protracted event, lasting 80 My, during which vertebrates developed the repertoire of jaw mechanics necessary to fully exploit available terrestrial resources.

70.4 ANDERSON, D.A.*; SOUTHWOOD WILLIARD, A.; SCHARF, F.S.; University of North Carolina Wilmington; dao2211@uncw.edu
Osmoregulatory disruption due to acute cold stress in a juvenile estuarine fish
Marine fishes rely on active transport of ions to maintain osmotic homeostasis. Impaired function of the renal ion pumps, such as Na+/K+ ATPase, at extremely low temperatures may result in a disruption in osmotic and ionic balance that could ultimately lead to death. We tested the temperature sensitivity of Na+/K+ ATPase in red drum (Sciaenops ocellatus), a dominant sport fish that encounters extreme cold temperatures during the first winter of life at the northern extent of its range. In a controlled laboratory setting, juvenile red drum were exposed to water temperature treatments of 1, 3, and 5°C, which represented within–range minima, with a 10°C control treatment. Tissue was then collected from cold–stressed and control fish for analysis of enzyme function, water content, and internal ion concentration. We used kinetic assays to compare Na+/K+ ATPase activity in gill tissue with and without ouabain, a Na+/K+ ATPase inhibitor, for each treatment group. Assays were run at both 15 and 25°C to identify enzyme temperature sensitivity within treatments. Results indicate that enzyme activity is positively correlated to the severity of thermal stress (i.e., highest activity at the coldest treatment temperature), and activity increased at the higher assay temperature within each treatment group. In order to complement our assessment of thermal effects on ion transport, we measured water content of muscle tissue and ion concentration of muscle tissue via atomic absorption spectroscopy. Measuring the effects of acute cold stress on osmoregulatory function offers insight to seasonal shifts in physiology and causes of mortality for juvenile red drum.

129.1 ANDERSON, C.V.*; TOLLEY, K.A.; University of South Florida, Tampa, South African National Biodiversity Institute, Cape Town; cvanders@mail.usf.edu
Contrasting thermal effects on movements powered by elastic recoil and muscle contraction in chameleons living along a temperature gradient
Temperature has a strong effect on muscle contractile velocity, and thus movement performance, but elastically powered tongue projection in chameleons has been shown to be less thermally dependent than the associated muscle–powered retraction. Adaptation and acclimation to low muscle temperature are known to mitigate thermal effects in muscle–powered movements at low temperature, but natural selection might act differently on movements that benefit from lower thermal dependence (i.e., elastically powered movements). We hypothesize that between closely related chameleon taxa found along an environmental temperature gradient, performance of muscle–powered movements (tongue retraction) will be higher at lower temperatures for taxa found in colder environments than for taxa found in warmer environments. Conversely, performance of elastic recoil powered movements (tongue projection) will vary significantly less between the taxa. We imaged three taxa living along a strong elevation and temperature gradient in South Africa feeding at 15–35°C. We found that tongue projection performance for the taxa from the coldest environment was the most robust between 15 and 25°C (Q10 < 1.04). Among the examined taxa, however, relative thermal effects on performance did not show altitudinal gradation, with the mid–elevation taxa maintaining the highest degree of performance for both tongue projection and retraction at 25°C. These results indicate that thermal effects on both elastic recoil and muscle–powered movements vary between species living in different thermal environments but that other environmental variables may aid in driving these performance curves.

1.7 ANDERSON, R.A.; Western Washington University; Roger.Anderson@wwu.edu
Proximal causes of diet of in the lizard Phrynosoma platyrhinos in a northern desert scrub
Knowing the spatiotemporal patterns, causes, and consequences for both predator and prey has been a persistent challenge for ecologists. Testing hypotheses about prey use and prey availability under field conditions has been problematic. A useful system for such work includes using desert ants as prey and the ant–eating specialist lizard, the Desert Horned Lizard, Phrynosoma platyrhinos. The lizard and its prey are abundant in the Great Basin desert scrub in southeastern Oregon, and have been studied for several weeks each summer over the past decade on a 9 ha area in the Alvord Basin. Four species of ants comprise 96% of the diet by number, as analyzed by fecal pellet analyses. These ants tended to be the largest and most common ants captured by pitfall trapping, about 87% of the total ants by number. Annually 10–12 lizards were radiotracked and powdertracked, and were observed to spend most of their activity period in the open and near plant perimeters where the colony entrances to three of the four common prey species were located. Phrynosoma platyrhinos were most active in mid–morning at the same time ants were most abundant near colony entrances. Based on powdertrack trails, we inferred that the lizards knew where the colonies were. These lizards seemed to be relatively efficient foragers, judging from the length of their activity periods and their daily feeding rates.
Can temperate insects take the heat? Physiological and behavioural responses suggest high extinction risk with climate change

Insects in temperate regions are predicted to be at low risk of climate change owing to high thermal safety margins (low optimal performance temperature relative to habitat maxima) and/or high warming tolerance (high thermal tolerance relative to habitat maxima) relative to more tropical species. However, these assumptions have been generally poorly examined and such forecasting typically fails to account for microclimatic variation and behavioural optimization of insects. Here, using *Iridomyrmex purpureus* meat ants from Armidale, NSW, we show that ants regularly forage for short periods (minutes) at soil temperatures well above their upper thermal limits determined over slightly longer periods (hours) and do not show any signs of a classic thermal performance curve in voluntary locomotion across 10–55°C. Generally close associations of ant activity and performance with microclimatic conditions, possibly to maximise foraging times, suggest *I. purpureus* display highly opportunistic thermal responses and readily adjust behaviour to cope with extremely high trail temperatures. Increasing frequency or duration of high temperatures is therefore likely to result in an immediate reduction in foraging efficiency. These results for a key functional group suggest that (1) soil-dwelling temperate insects may be at higher risks of extinction with increased frequency or duration of high temperatures resulting from climate change than previously thought; and (2) that indices of climate change–related extinction are strongly influenced by the scale of climate metrics employed.

Heat tolerance of embryos limits the geographic range of *Sceloporus undulatus*

To predict the effects of global warming will affect species, ecologists have focused primarily on the increase in mean temperature and its impact on juveniles or adults. Yet, this focus ignores two factors that ecologists must consider to make accurate forecasts. First, future climates will impose acute heat stresses as well as chronic stresses. Second, embryos are most susceptible to acute stress because they cannot behaviorally thermoregulate to the same extent as can juveniles and adults. We quantified the degree to which lizard embryos from four geographically separated populations tolerated acute warming; tolerance was inferred from cardiac performance and survival probability. At a realistic rate of warming, embryos from all populations exhibited cardiac arrest at 45–47°C. By exposing embryos to various diel cycles of temperature, we identified a threshold for survival between 40 and 42°C. In other words, a single brief exposure to 42°C killed all embryos from the four populations, while daily exposures to lower temperatures killed few embryos. Using an individual–based model that considers embryonic survival and development, we predict that environmental warming will affect the distribution of *S. undulatus* in more complex ways than previously predicted.

Global metabolite profiles as predictors of physiological traits in bivalve larvae with genetically-determined differential growth rates

High variance in growth rates is typical for larvae of marine organisms, even when reared under similar environmental conditions. Part of this phenotypic variation within a species can likely be attributed to differential performance of specific genotypes. We conducted factorial crosses using purebred parental lines of the Pacific oyster (*Crassostrea gigas*) to produce larval families with contrasting growth phenotypes. Fast- and slow-growing larvae were analyzed for differences in metabolic rates, protein synthesis rates, and protein content. Additionally, metabolomic analyses were conducted to identify (i) biochemical pathways that contribute to genetically-determined differences in growth rate, and (ii) biomarkers that might predict growth phenotype. Size-specific respiration and protein synthesis rates were similar for contrasting growth phenotypes. Protein growth and depositional efficiency (ratio of protein growth to protein synthesis) were higher in faster-growing larvae. Metabolomic analyses identified over 200 different metabolites in larvae. The amounts of several essential (leucine, methionine, phenylalanine, threonine, valine), and non-essential (tyrosine) amino acids, as well as amino acid derivatives (N6-acetyllysine, 5–oxoproline, 5–methylcysteine) were lower in the free amino acid pools of faster-growing phenotypes relative to slower-growing larvae. The lower amounts of proteinogenic amino acids in faster-growing larvae corresponded to lower protein turnover (i.e., higher depositional efficiencies) and support the proposal of differential protein turnover as a mechanistic basis for genetically-determined variance in growth. Further, these metabolites are putative biomarkers with the potential to predict growth phenotype.

Reconstructing the Diel Activity Patterns of Fossil Nonmammalian Synapsids

The majority of extant mammals are nocturnal, and it has been assumed that this trait characterized the earliest mammals. It also has been hypothesized that the shift to nocturnality caused a fundamental reorganization of the circadian system in mammals. However, the diel activity patterns (DAP) of the nonmammalian synapsid ancestors of mammals have never been examined in detail, even though this could provide insight into whether nocturnality is characteristic of mammals or a deeper lineage, and whether nocturnality evolved multiple times among synapsids. Eye dimensions are correlated with light sensitivity, and eye shape can be used to effectively discriminate anniotes of different DAP. Orbit and scleral ring dimensions are reliable skeletal proxies for eye shape, and can be used to extend reconstructions of DAP into the fossil record. Extant mammals lack scleral rings, but they are present, although infrequently preserved, across much of nonmammalian synapsid diversity. We compiled a data set of 40 specimens from 28 synapsid species. We used previously published data on scleral ring and orbit dimensions of extant squamates and avians with known DAP to establish classification rules with a linear discriminant analysis. Using prior probabilities derived from proportions of DAP among extant anniotes, we classified fossil synapsids (species averages) into diurnal, nocturnal, and cathemeral categories. Our results suggest that diurnality was the most common DAP in the analyzed sample. However, nocturnality was present in several clades, including Varanopidae, Sphenacodontidae, Therocephalia, and Cynodontia. Nocturnality likely evolved multiple times within synapsids, with its earliest appearance in the Permo-Carboniferous.
9.3 ARMSTRONG, AP*; BLACKBURN, HN; ALLEN, JD; University of California, Davis, College of William and Mary; frarmstrong@ucdavis.edu
Delay of hatching in the sand dollar Echinarchnium parma in response to reduced salinity
Hatching plasticity occurs in response to a wide range of stimuli across many animal taxa including annelids, arthropods, flatworms, molluscs, and chordates. Despite the prominence and long history of echinoderms in developmental biology, environmentally-cued hatching plasticity has only been described in a single species: the sand dollar Echinarchnium parma. Following our initial observations of hatching plasticity, we conducted detailed experiments on the effects of temperature and salinity on hatching plasticity in three male/female pairs. We tested how temperature, salinity, and their interaction affect time-to and stage-at hatching. While all factors had a significant effect, salinity had the largest effect on hatching plasticity in E. parma. Embryos of E. parma delayed their time to hatching more than two-fold in response to a salinity reduction from 32 psu to 26 psu while maintaining an otherwise normal developmental schedule. Embryos that experienced the greatest delay in hatching time emerged from the fertilization envelope as 4-armed plateus larvae rather than hatching as blastulae or early gastrulae. We observed high variability in hatching time and stage both within and among clutches, suggesting intraspecific variation in developmental responses to salinity. A delay in hatching may provide embryos short-term protection from a harmful environment. The simplicity of the manipulation and the reliability of the results suggest that hatching plasticity may be a common occurrence in sand dollar development. The wealth of data on echinoid development, combined with the molecular and genetic tools available, may make sand dollars and sea urchins a valuable model system for future studies of the mechanisms underlying hatching plasticity.

133.3 ARTACHO, P*; LE GALLIARD, JF; Univ. Austral de Chile, Valdivia, Univ. Pierre et Marie Curie, Paris; paulinaartacho@gmail.com
Correlational Selection on Resting Metabolic Rate and Body Mass in the Common Lizard
Phenotypic selection, the differential survival or reproduction of individuals with different phenotypic characters, is widely accepted as the primary cause of adaptive evolution in natural populations. Its impact on evolutionary dynamics has been documented profusely during the last decades for both simple morphological characters and life-history traits. Comparatively, the strength and shape of selection acting on more complex functional properties (e.g. physiological traits), still remain poorly investigated. Further, most current studies of phenotypic selection have been performed by analyzing phenotypic traits separately or in a small subset of functional traits. However, behavior, morphology, physiology and performance traits should evolve in concert and their interactions should affect fitness significantly. This study wished to address these issues by performing a field phenotypic selection experiment on locomotor performance, thermal behavior and energy metabolism using as a model the common lizard, Zootoca vivipara. We captured 200 individuals (males and females of different ages) in field for measuring body mass (M), resting metabolic rate (RMR), maximal sprint speed and preferred body temperature at the laboratory. After measurements, animals were released in outdoor enclosures between the end of one reproductive season and the end of the next one, after which they were recaptured and its survival evaluated. The dataset was analyzed with logistic regression which indicated a complex picture with a combination of positive correlational selection between Mb and RMR, and disruptive selection on RMR. In conclusion individuals that showed high Mb and high RMR were promoted by selection, but also individuals that had low RMR. This is one of the few studies that have demonstrated correlational selection on a proxy of energy expenditure.

148.6 ARMSTRONG, T E*; LILLIE, M A; SHADWICK, R E; Univ. of British Columbia; trishuarm@gmail.com
Stiffness of Mature Aortic Elastin and its Possible Relation to Aortic Media Structure
Aortic elastin allows arterial expansion on systole and subsequent elastic recoil during diastole, providing crucial capacitance and associated dampening of the cardiac pressure pulses. The structure and mechanical properties of the aortic wall are not uniform along its length due to the varying hemodynamic conditions to which it is exposed, but elastins contributions to this variation are not well studied. The artery wall is a composite of two main structural proteins: elastin and collagen. Autolavating an intact aorta removes the collagen and produces a mechanically competent vessel consisting of purified elastin, which can be used to study elastins contribution to arterial mechanics. Although it is generally assumed that elastins material stiffness is constant, a recent study in pigs found that it increased 30% along the thoracic aorta. We hypothesize that this increase in elastin stiffness is caused by a difference in the orientation of the elastic lamellae (EL) or in the EL connections to interlamellar elastin fibres (IEL) and smooth muscle cells. Uniaxial tensile testing of autolavsed mouse aortas showed elastins stiffness also varies along both the thoracic and abdominal aortas in mice, allowing the mouse aorta to be used as a model to investigate this surprising variation in elastin stiffness. Elastin structure within the thin mouse aortic walls is being imaged with multiphoton laser scanning microscopy to identify any variation in the EL or IEL structure that could cause the variation in stiffness.

4.5 ARY, WJ*; CRANFORD, T; BERTA, A; KRYSL, P; San Diego State University, Univ. of California, San Diego; williamjamesarya@gmail.com
Form and Function of the Odontocete Ear
Toothed whales (odontocetes) have a sound reception apparatus that is specialized for underwater hearing and works in tandem with their biosonar system. The apparatus is composed of the internal acoustic pinnae and the bony tympanoperiotic complex (TPC). The internal pinnae are made of special acoustic fats and other tissues that form a waveguide, bringing sounds from the environment to the TPC, which contains the middle ear bones. The sound reception apparatus functions to filter and/or amplify incoming sounds depending on their utility to the animal. Across species, odontocete TPCs have a variety of shapes. These shapes are linked to function. We CT scanned TPCs from 8 species across the Odontoceti. Geometric Morphometrics techniques characterized the shapes of the TPCs. Vibrational analysis based on finite element models provided a family of "natural" or resonant frequencies for each TPC. These resonant frequencies provide insight into the animals sense of hearing and the potential effects of anthropogenic sound.
6.2 ASTLEY, H. C.*; ROBERTS, T. J.; Brown University; henry_astley@brown.edu

**Where's the catch? Examining the catch mechanism in anuran jumping using inverse dynamics.**

Many animals use catapult mechanisms to produce extremely rapid movements for escape or prey capture, resulting in power outputs far beyond the limits of muscle. In these catapults, muscle contraction loads elastic structures, which then recoil to release the stored energy extremely rapidly. Many arthropods employ exoskeletal elements as a catch mechanism to lock the joint in place during the loading period, which can then be released to allow joint motion via elastic recoil. However, catapult mechanisms in vertebrates lack a clear anatomical catch. Several vertebrate catch mechanisms have been proposed, including a variable mechanical advantage at the ankle. In this mechanism, the muscle contracts at low mechanical advantage at first, which limits joint motion while the tendon stretches, followed by a transition to high mechanical advantage, which allows the tendon to recoil. To test this hypothesized catch mechanism, we collected simultaneous kinematics via XROMM and single-foot forces during the jumps of three *Rana pipiens*. We calculated joint mechanical advantage, torque, work, and power using inverse dynamics. Preliminary results show an increase in mechanical advantage at the ankle immediately prior to ankle extension, consistent with the variable mechanical advantage catch mechanism.

71.1 BABONIS, L.S.*; MARTINDALE, M.Q.; Kewalo Marine Lab, Univ of Hawaii; babonis@hawaii.edu

**Examining a cnidarian novelty: form and function of the nematosomes in Nematostella vectensis**

Sea anemones in the genus *Nematostella* are unique among cnidarians in their possession of autonomous, motile, cell masses called nematosomes which circulate throughout the body cavity. Although they were first described many decades ago, neither the form nor the function of nematosomes has been studied in great detail. Using a combination of electron microscopy (TEM and SEM) and molecular biology we build on previous studies to describe the cellular composition of the nematosomes from *Nematostella vectensis*. Although nematosomes are thought to arise from mesenterial tissue, preliminary results suggest that these motile cell masses are composed of several cell types, potentially including cell types found only in the tentacles of *N. vectensis*. In light of these observations, we compared the cellular composition of nematosomes with that of the mesenteries and isolated tentacles. Using EdU (a BrdU analog), we demonstrate that some nematosomes undergo proliferation while inside the gastric cavity. We use the combined results of these studies to develop hypotheses regarding the origin and function of nematosomes in *N. vectensis*.
Sex–bias in egg–laying order is a seemingly evolutionary impossible combination of precision, complexity, context–dependency, and reversibility. Yet, it is a common occurrence and a frequent starting point for a wide range of adaptive ecological and evolutionary phenomena – from the onset of behavioral strategies to the speed of acquisition of morphological adaptations. Such adaptive sex–bias is unlikely to be a product of coordinated genetic evolution of multiple players in the processes of egg production and sex–determination as this requires unrealistic expectations of evolutionary rates and population sizes and is not a desirable outcome for the process that needs to retain substantial environmental sensitivity. Recurrent deployment of conserved hormonal regulators throughout oogenesis can overcome some of these constraints, but introduces new ones – the necessity to reconcile general effects of hormonal regulation with required directionality and precision during particular stages. I will examine whether self–regulatory and emergent processes that govern the dynamics of oogenesis can produce non–random coordination of oocyte growth, ovulation order, and sex–determination under routine perturbations of shared physiological mechanisms, thereby significantly simplifying the evolutionary pathway to complex, precise, and reversible adaptations in sex–bias.

Valveless tubular hearts transport hemolymph in many invertebrates with open circulatory systems. Tunicates such as Ciona intestinalis rely on bidirectional valveless pumping through a U–shaped heart tube. Research related to valveless fluid transport has described pumping in tubular hearts as either peristalsis (characterized by a linear frequency–flow relationship and active contractions down the length of the tube) or dynamic suction pumping (characterized by a nonlinear frequency–flow relationship and a localized region of active contraction). The immersed boundary method will be used to simulate the fully–coupled fluid–structure interaction problem. Corresponding experiments will be performed using dynamically scaled physical models of peristalsis and dynamic suction pumping. Womersley number and other parameters will be matched to the heart tube of Ciona intestinalis and other tunicates. The fluid transport efficiencies of each mechanism will be described over this parameter space. A new pumping mechanism that includes features of both traditional peristalsis and dynamic suction pumping will be introduced that incorporates the electrophysiology of the tubular heart.

The cost of performance: power cost and aerodynamic force generated by varying wingbeat kinematics

Bats display a wide range of flight behaviors, including steady flight, rapid acceleration, sharp turns, and load carrying. These behaviors require different combinations of lift and thrust, which are achieved by varying wing kinematics. Although the kinematics associated with different flight behaviors have been studied, it has not been possible to directly relate specific kinematic parameters to force production because flapping animals change multiple parameters simultaneously. To isolate the effect of specific kinematic parameters on aerodynamic force, and measure the energetic cost associated with each flapping motion, we designed, built, and tested a multi–articulated robotic bat wing that was instrumented to measure net lift, thrust, and mechanical power. During testing in a wind tunnel, we varied five kinematic parameters: four affecting wing motion (wingbeat frequency, wingbeat amplitude, stroke plane, downstroke ratio), and one affecting dynamic morphology (wing folding on upstroke). For each kinematic parameter, we described its relationship with net lift, net thrust, and mechanical power as the parameter varied across most of the range observed in the model bat species, Cynopterus brachyotis. Each parameter affected lift, thrust, and power in a different manner. For example, increasing amplitude produced additional force at a lower power cost than increasing frequency. Wing folding on the upstroke increased net lift and decreased power cost albeit with reduced thrust. The different relationships between kinematic parameters with lift, thrust, and power can inform modeling of how all the kinematic parameters can collectively be varied to produce the combination of forces required for different flight behaviors.

Mechanical Properties of a Shark Jaw Support Structure

The upper jaws of elasmobranchs (sharks, skates, and rays) are not fused to the cranium as they are in tetrapods. Instead, they are suspended by 0–3 ligaments (none in skates and rays) anteriorly and a skeletal element, the hyomandibula (HY) posteriorly. The HY connects the cranium to the jaw joint and can have many orientations, shapes, and sizes depending on the clade. We know how the HY moves during feeding and, from bite force estimates and measurements we can estimate the forces acting on the HY. Here we present data on how well these elements withstand the stresses associated with the loads seen during feeding. We determined the mechanical properties of the HY of four species of sharks with different jaw orientations and feeding styles (bamboo shark, a suction feeder; smoothhound shark, a biter; sandbar shark, a biter; and dogfish, both suction feeder and biter. We used sonomicrometry to track local strain in the direction of loading and at 90 degrees to the loading direction. This allowed us to estimate both the stiffness of the material and its Poissons ratio. We also measured the cross sectional shape and the percent area of calcified cartilage to predict how well the element handles force in different directions. Our results show that despite large differences in size and shape, there is little difference between the effective mechanical properties of the HY in different species. It appears that to withstand larger forces the HY’s increase in size without a changing in mechanical properties. This is in contrast to analogous results from the pelvic girdles of cartilaginous fishes. However, differences in the shape of the cross–sectional area and relative mineralization levels among species may lead to differences in the response among species to bending or tensile load.
Avian Adaptive Immune Responses to Buggy Creek Virus (Togaviridae: Alphavirus) and its Arthropod Vector, the Swallow Bug (Oeciacus vicarius)

Life history decisions such as reproduction, growth, and development result in variability in physiological responses among avian species and likely impact a birds immune response to both macro and microparasites. Here we examine the adaptive, humoral immune responses of a native bird and an invasive bird to an arbovirus (Buggy Creek virus; Togaviridae; Alphavirus), and its ectoparasitic arthropod vector (swallow bug; Oeciacus vicarius). Swallow bugs are closely associated with the native, colonially nesting cliff swallow (Petrochelidon pyrrhonota) and the introduced house sparrow (Passer domesticus) that occupies nests in cliff swallow colonies. We measured levels of BCRV—specific and swallow bug—specific IgY levels before nesting (prior to swallow exposure) and after nesting (after swallow bug exposure) in house sparrows and cliff sparrows in western Nebraska. Levels of BCRV-specific IgY increased significantly following nesting in the house sparrow, but not in the cliff swallow. Additionally, house sparrows displayed consistently higher levels of swallow–bug specific antibodies both before and after nesting compared to cliff sparrows. These results indicate that significant differences in the immune response to this arbovirus and its arthropod vector exist between these two avian species. These immune response differences may be influenced by the life history characteristics of these avian hosts, and may help to explain the differences in disease susceptibility that exist between these two species.

Evolution of Two Genomes: Impact of Sequence Divergence on Mitochondrial Function

We are investigating the divergence in oxidative phosphorylation (OxPhos) metabolism among populations of Fundulus heteroclitus. The OxPhos pathway occurs in mitochondria and uses oxygen to produce the majority of ATP in a cell. This pathway consists of 5 large enzyme complexes with 45 to 4 proteins per complex and is the only pathway in which the proteins involved are coded by both mitochondrial and nuclear genomes. F. heteroclitus populations have sequence divergence in OxPhos genes in both mitochondrial and nuclear genomes. These populations are distributed along a steep thermal cline on the east coast of the United States and have evolved by natural selection to adapt to this clinal variation in temperature. Thus, F. heteroclitus serve as a model species to enhance our understanding of the impact of nucleotide divergence on physiological function. The initial studies of OxPhos function used 96 individuals from six different populations of F. heteroclitus, and differences in mitochondrial respiration were measured using a high-resolution respirometer (Oxygraph–2k, Oroboros Instruments, Innsbruck, Austria). The fish from each population were acclimated to both 12°C and 28°C. Hearts were isolated from each population and temperatures will provide insights into the evolution and adaptation of natural populations.

Anti–bat behavioral strategies and evolutionary routes in the escalation of the bat–moth arms race

Bat–insect interactions date back millions of years, and the shared evolutionary history between echolocating bats and nocturnal insects have resulted in a suite of unique defensive strategies. Tiger moths have escalated the arms race by beaming ultrasonic response signals back at bats. In tiger moths, these sounds have been shown to warn bats of bad taste, function in acoustic mimicry complexes and jam bat biosonar. We will discuss our recent discovery that hawkmoths also produce ultrasound in response to bat attack. Unlike tiger moths, hawkmoths are not chemically defended, only males produce ultrasound and the structure of the sound–producing organ varies greatly across the family. This raises the prospect that anti–bat ultrasound production may be linked to multiple additional behavioral strategies, including cross–family acoustic mimicry, advertisement of physical defenses and/or evasive flight; and that hawkmoth ultrasonic reply to bat attack has multiple independent evolutionary origins. We will consider data from three main technical approaches: 1) high–speed filming experiments of bat–moth interactions in the lab, 2) playback of bat echolocation attacks to moths in the field and 3) construction of an evolutionary tree built on molecular (DNA) data that we are using to examine the historical transitions of anti–bat ultrasound production.

Circadian rhythms in free–living arctic ground squirrels

In indigenous arctic reindeer and ptarmigan, circadian rhythms are not expressed during the constant light of summer or constant dark of winter, and it has been hypothesized that a seasonal absence of circadian rhythms is common to all vertebrate residents of polar regions. Here we show that, while free–living arctic ground squirrels do not express circadian rhythms during the heterothermic and pre–emergent euthermic intervals of hibernation, they display entrained daily rhythms of body temperature (Tb) throughout their active season which includes six weeks of constant sun. In winter, ground squirrels are arrhythmic and regulate core body temperatures to within ±0.2°C for up to 18 days during steady–state torpor. In spring, after use of torpor ends, male but not female ground squirrels, resume euthermic levels of Tb in their dark burrows but remain arrhythmic for up to 27 days. However, once activity on the surface begins, both sexes exhibit robust 24–h cycles of body temperature. We suggest that persistence of daily rhythms through the polar summer enables ground squirrels to minimize thermoregulatory costs. However, the environmental cues (zeitgebers) used to entrain rhythms during the constant light of the arctic summer in these semi–fossorial rodents are unknown.
The delineation of the fourth walking leg segment is temporarily linked to posterior segmentation in the mite Archegozetes longisetosus (Acari: Oribatida, Trhypochthoniidae)

Acari (mites and ticks) lack external segmentation, with the only indication of segmentation being the appendages of the prosoma (chelicerae, pedipalps, and four pairs of walking legs). Acari also have a mode of development in which the formation of the fourth walking leg is suppressed until the nymphal stages, following a hexapodal larva. To determine the number of segments in the posterior body region (opisthosoma) of mites, and to also determine when the fourth walking leg segment is delineated during embryogenesis, we followed the development of segmentation in the oribatid mite Archegozetes longisetosus using time–lapse and scanning electron microscopy, as well as in situ hybridizations of the A. longisetosus orthologues of the segmentation genes engrailed and hedgehog. Our data show that A. longisetosus patterns only two opisthosomal segments, indicating a large degree of segmental fusion or loss. Also, we show that the formation of the fourth walking leg segment is temporally tied to opisthosomal segmentation, the first such observation in any arachnid.

Interpopulation variation in throat color morphs in an incipiently speciating lizard: From blue to white and back again?

Both color polymorphism and alternative reproductive tactics are associated with accelerated rates of speciation in several taxa. We document discrete variation in throat color, an important sexual signal, in the mesquite lizard (Sceloporus grammicus) species complex. Some populations within this complex exhibit orange, yellow, and blue color morphs in males, which are similar to color morphs that are associated with alternative reproductive tactics in related lizard species. However, several other populations of the S. grammicus species complex instead exhibit orange, yellow, and white throat color morphs in males. We previously found both types of color variation to be associated with variation in male aggressiveness, but the effects of blue and white coloration are opposite. Here, we place this interpopulation color variation into a phylogeographic context and discuss how it relates to previous hypotheses regarding speciation processes within the S. grammicus complex.

The effects of day length, hibernation, and hibernaculum temperature on tooth morphology in the Turkish hamster (Mesocricetus brandti)

Ever-growing rodent incisors deposit dentin one of the tissues comprising mammalian teeth on a circadian basis; these daily dentin layers are visible both in histological cross section and on the medial surfaces of incisors. Hibernation disrupts the normal pattern of dentin deposition, and distinct hibernation marks have been documented in the incisor dentin of several rodent species. Little, however, is understood about the factors that influence hibernation mark morphology. We tested the effects of day length, hibernation, and hibernaculum temperature on incisor surface morphology in Turkish hamsters housed in one of four conditions: long days (LD) at 22°C, short days (SD) at 22°C, SD at 5°C, and SD at 13°C. Body temperature and torpor use were monitored with implanted radio transmitters, and teeth were examined postmortem. Teeth of SD hamsters had narrower, less distinct circadian increments than teeth of LD hamsters, and hibernation at both 5°C and 13°C was associated with very narrow, sharply defined increments. At 5°C the number and cumulative width of hibernation increments were related to number and cumulative duration of periodic arousals, although this relationship was not detected at 13°C. This investigation adds to a growing body of work on the effects of hibernation on hard tissue morphology, and has implications for the study of hibernation behavior in evolutionary and historical contexts.
BATTLELE, Barbara−Anne; Univ, of FL, Whitney
Limulus max), 10−11 months of
see at night nearly as well as during the day, and
in the yellow stingray,
BECK, M. L.*; HOPKINS, W. A.; HAWLEY, D. M.; Virginia
sebebus@memphis.edu beckmic@vt.edu
BEBUS, SE*; SMALL, TW; SCHOECH, SJ; University of
). However, sedation with the anesthetic, tricaine
max
Battelle@whitney.ufl.edu
Limulus

may have subtle physiological effects on nestlings but that
exposure to residual trace elements following remediation efforts
but that following handling restraint the induced and fold−increase in
nestlings did not differ among reference and contaminated colonies
marina. We found that basal corticosterone concentrations of
remediated and one reference colony that was disturbed by a nearby
body size and body condition prior to fledging. Exposure to a period
not affect clutch size and fledging success and did not affect nestling
species. Exposure to these low concentrations of trace elements did
cause adverse physiological and developmental effects in other
remediated colonies had element concentrations below levels that
coal−fly ash spill in TN, USA. Most eggs and nestlings in the
and aberrant reproductive behavior in wildlife. We examined the
Exposure to elevated concentrations of these elements can cause
trace elements that pose health risks to humans and wildlife.
Coal combustion waste contains elevated concentrations of numerous
spill

The effects of trace element exposure on tree swallow reproductive
success and stress response following remediation of a coal−fly ash
spill
Coal combustion waste contains elevated concentrations of numerous
toxics that pose health risks to humans and wildlife. Exposure to elevated concentrations of these elements can cause
teratogenic effects, reproductive failure, altered hormonal responses, and aberrant reproductive behavior in wildlife. We examined the
reproductive success of adult tree swallows and the morphology and stress response of their nestlings following remediation of a large
coal−fly ash spill in TN, USA. Most eggs and nestlings in the
remediated colonies had element concentrations below levels that
cause adverse physiological and developmental effects in other
species. Exposure to these low concentrations of trace elements did
not affect clutch size and fledging success and did not affect nestling
body size and body condition prior to fledging. Exposure to a period
of unseasonably cold weather negatively affected reproductive
success across colonies but these effects were greatest at two
remediated and one reference colony that was disturbed by a nearby
marina. We found that basal corticosterone concentrations of
nestlings did not differ among reference and contaminated colonies
but that following handling restraint the induced and fold−increase in
corticosterone concentrations was suppressed in nestlings from some
contaminated colonies. Taken together, our results suggest that
exposure to residual trace elements following remediation efforts
may have subtle physiological effects on nestlings but that
reproductive success of nestlings is not being adversely affected.

BECK, M. L.*; HOPKINS, W. A.; HAWLEY, D. M.; Virginia
sebebus@memphis.edu beckmic@vt.edu
BEBUS, SE*; SMALL, TW; SCHOECH, SJ; University of
). However, sedation with the anesthetic, tricaine
max
Battelle@whitney.ufl.edu
Limulus

may have subtle physiological effects on nestlings but that
exposure to residual trace elements following remediation efforts
but that following handling restraint the induced and fold−increase in
nestlings did not differ among reference and contaminated colonies
marina. We found that basal corticosterone concentrations of
remediated and one reference colony that was disturbed by a nearby
body size and body condition prior to fledging. Exposure to a period
not affect clutch size and fledging success and did not affect nestling
species. Exposure to these low concentrations of trace elements did
cause adverse physiological and developmental effects in other
remediated colonies had element concentrations below levels that
coal−fly ash spill in TN, USA. Most eggs and nestlings in the
and aberrant reproductive behavior in wildlife. We examined the
Exposure to elevated concentrations of these elements can cause
trace elements that pose health risks to humans and wildlife.
Coal combustion waste contains elevated concentrations of numerous
spill

The effects of trace element exposure on tree swallow reproductive
success and stress response following remediation of a coal−fly ash
spill
Coal combustion waste contains elevated concentrations of numerous
toxics that pose health risks to humans and wildlife. Exposure to elevated concentrations of these elements can cause
teratogenic effects, reproductive failure, altered hormonal responses, and aberrant reproductive behavior in wildlife. We examined the
reproductive success of adult tree swallows and the morphology and stress response of their nestlings following remediation of a large
coal−fly ash spill in TN, USA. Most eggs and nestlings in the
remediated colonies had element concentrations below levels that
cause adverse physiological and developmental effects in other
species. Exposure to these low concentrations of trace elements did
not affect clutch size and fledging success and did not affect nestling
body size and body condition prior to fledging. Exposure to a period
of unseasonably cold weather negatively affected reproductive
success across colonies but these effects were greatest at two
remediated and one reference colony that was disturbed by a nearby
marina. We found that basal corticosterone concentrations of
nestlings did not differ among reference and contaminated colonies
but that following handling restraint the induced and fold−increase in
corticosterone concentrations was suppressed in nestlings from some
contaminated colonies. Taken together, our results suggest that
exposure to residual trace elements following remediation efforts
may have subtle physiological effects on nestlings but that
reproductive success of nestlings is not being adversely affected.
69.6 BEERS, J.M.; Stanford University; jbeers@stanford.edu

**Relationships between hemoprotein expression and cardiovascular physiology of Antarctic notothenioids: form, function, and future implications.**

Antarctic notothenioid fishes have been exploited by scientists for decades as classic Krogh–style models with which to study cold–adapted physiological traits. Some of the most fascinating discoveries have come from studies focused on one particular group of notothenioids, the white–bleded icefishes (Family: Channichthyidae). Noted for their complete lack of hemoglobin, and also myoglobin in some species, these animals have partially compensated for the loss of oxygen–binding proteins by utilizing several enhanced cardiovascular features. One such characteristic is the presence of vast blood vessel networks, evidenced most strikingly in the eyes. Findings have shown that retinal vascular densities are inversely correlated to the amount of hemoglobin in the blood, thus suggesting a relationship between heme protein expression and oxygen supply/demand in the highly aerobic retina. Interestingly, data indicate that the development of the elaborate vascular patterns that we see in the eyes of present day icefishes may have arisen via a cellular route of nitric oxide–mediated angiogenesis. Implications for this finding hold importance because this cell signaling pathway is fundamental to most, if not all, vertebrate animals, and thereby allows us to explore questions that may have potential biomedical applications. Furthermore, the unique cardiovascular physiology of icefishes may prove costly because the adaptations for life in the stably cold, well–oxygenated waters of the Southern Ocean might reduce the tolerance of these fish to high temperature. Indeed, icefish have significantly lower thermal tolerance than their red–bleded counterparts, which could place these animals in a precarious position with regard to future climatic warming.

36.2 BENNETT, M.M.*; OWINGS, A.; YOCUM, G.; RINEHART, J.; GREENLEE, K.; North Dakota State University, Fargo, United States Dept. of Agriculture, Fargo, United States Dept. of Agriculture, Fargo; meghan.bennett@ndsu.edu

**Flight metabolic rate as an expression of quality in temperature stressed alfalfa leafcutting bees, Megachile rotundata.**

The alfalfa leafcutting bee, *Megachile rotundata* F. (Hymenoptera: Megachilidae) is a solitary species that develops inside a maternally constructed brood cell. Pre–pupal *M. rotundata* diapause over winter and resume development as ambient temperatures increase. Environmental cues are known to initiate biological processes in many insects, allowing better survival of anticipated stressors, such as temperature fluctuations. However, insects are limited in their ability to deal with extreme temperature fluctuations when not in a diapauing state. To better understand how temperature fluctuations during juvenile development affect adult physiology, we exposed pupal *M. rotundata* to one of three temperature treatments and assessed changes in adult flight physiology. Pre–pupae were reared normally at 29°C for 14 days. At that point, some insect development was interrupted for 1 week by placement in either constant 6°C or 6°C with a 1h daily pulse of 20°C (FTR). Pupae were returned to 29°C and allowed to develop to adulthood. Because insect flight is metabolically expensive and is essential for success for the next generation, flight metabolism was used to indicate quality. Flight metabolic rates were measured using flow through respirometry. When compared to uninterrupted or FTR development, females from constant 6°C had higher metabolic rates, while males from constant 6°C had lower metabolic rates. Surprisingly, 53% of bees from the 6°C group were unable to fly and had morphological defects. These data suggest that interrupting bee development with placement in a constant 6°C, a common rearing method, negatively affects adult bee physiology.

119.4 BEN–HAMO, M.*; BURNS, D.J.; BAUCHINGER, U.; MUKHERJEE, S.; EMBAR, K.; PINSHOW, B.; Ben–Gurion University of the Negev, University of KwaZulu–Natal; miri.benhamo@mail.huji.ac.il

**Behavioral and Physiological Responses during Feather Replacement in House Sparrows.**

All birds lose feathers, whether during molt or by accident, and replace them by processes that are energetically demanding. We hypothesized that house sparrows, *Passer domesticus biblicus*, use both physiological and behavioral mechanisms to reapportion their resources among competing functions that change when feathers are lost. We tested two predictions: 1) Sparrows growing new feathers adjust their behavior to minimize the energy costs of foraging and to increase net energy gain from their food; and 2) since house sparrows are known to carry limited energy reserves, when regrowing lost feathers they use facultative nocturnal hyperthermia to save energy. To test these predictions we divided sparrows into three groups: 1) Plucked – sparrows from which we plucked 15 specific feathers; 2) cut – sparrows in which the same 15 feathers were cut off at the calamus below the barbs; and 3) control – unmanipulated sparrows with plumage intact. We recorded the amount of seeds the sparrows ate when they foraged in artificial food patches, and continuously recorded their body temperatures (Ts) by telemetry. We found that plucked sparrows growing new feathers adjust their foraging behavior by decreasing vigilance and increasing their effective encounter rate with seeds. However, these sparrows did not use facultative nocturnal hyperthermia. In fact, their nighttime Ts increased significantly compared to the cut and control groups. We attribute the increase in nighttime Ts to increased metabolism during feather regrowth.

62.1 BENTLAGE, B; University of Maryland; bastian.bentlage@gmail.com

**Species distributions in the open oceans: integrating distribution models and population genomics.**

Population genetic and phylogeographic studies have uncovered strong population structuring and previously unrecognized amounts of cryptic sibling species in many marine habitats. In the open oceans, most studies have investigated patterns of population structuring and species diversity for the uppermost parts of the water column. These patterns can be explained using present–day environmental discontinuities of water masses. The deeper parts of the open ocean water column (the mid–water) have been largely neglected due to the difficulties of sampling this environment. I present a case–study integrating three–dimensional correlative ecological niche modeling with population genomics that investigates population genetics of hydrozoan jellyfish (Cnidaria: Medusozoa) that inhabit the open oceans, in particular mid–water habitats. Ecological niche modeling was employed to predict the ranges of suitable habitat in the open oceans to make predictions about present–day geographic distributions of hydrozoan jellyfish and the sub–structuring of their populations. Population genomic data are then used to test these geographically explicit hypotheses of population structure. Preliminary results suggest that species inhabiting deep waters display little genetic differentiation among distant populations while shallow water inhabiting species display strong population genetic structuring.
146.1 BENTLEY, GE*; PERFITO, N; CALISI, RM; UC Berkeley; gb7@berkeley.edu
Season− and context−dependent sex differences in melatonin receptor activity in a forebrain song control nucleus: comparison of data from the laboratory and a semi−natural environment
There are dense populations of melatonin receptors in large areas of the songbird brain, in particular in the visual system and the song control system. Melatonin has therefore been implicated in neuroplasticity of the song control system. Previously we demonstrated extremely large changes in activity of melatonin receptor in Area X, a forebrain song control nucleus that is important for song learning and production. In a laboratory environment, melatonin receptor activity was drastically down−regulated in male and female European starlings during photostimulation (a simulated breeding season). The functional significance of this large change in Area X is unclear, so we sought to elucidate it by tracking melatonin receptor activity in male and female starlings housed in a semi−natural environment and permitted to breed. Males and females all exhibited high melatonin receptor activity in Area X during short days at the start of the breeding season, and maintained this high activity during photostimulation until females laid eggs. At this point the females down−regulated melatonin receptor activity in Area X, whereas the males maintained high activity until later on in the breeding season. Overall, we observed a gradual termination of melatonin receptor activity in Area X as the breeding season progressed, but the timing of the termination was different between the sexes. Our data contrast with those collected in a laboratory environment, and highlight the need for studying brain and behavior of wild species in as natural an environment as possible if we are to understand the significance of any observed effects.

112.3 BERGMANN, P.J.*; MCCELROY, E.J.; Clark University, College of Charleston; pbergmann@clarku.edu
Many−to−many mapping of phenotype on function, and the F−array
Relationships between phenotype and function are often complex, involving trade−offs, facilitations, redundancies, and traits that influence only one aspect of function. In systems with multiple phenotypic parts and multiple functional capacities, phenotype−function relationships are frequently very complex. For example, trade−offs, facilitations, redundancies, and unique relationships can interact with one another, influencing the rate of evolution of the various phenotypic and functional traits, and creating functional lines of least resistance to evolution. Although it is well known that trade−offs limit the rate of functional and phenotypic evolution, and it has been shown that redundancy can ameliorate these trade−offs, we find that facilitations and unique phenotype−function relationships also play roles in ameliorating trade−offs, sometimes more effectively than redundancy. We term the complex relationships between multiple aspects of phenotype and multiple aspects of function many−to−many mapping. We apply the F−matrix approach for relating basic limb morphology to locomotor performance in a series of Phrynosomatine lizards to illustrate this concept. We also make suggestions for dealing with the problem of multicollinearity in functional morphology datasets, and for placing the F−matrix approach in a comparative context.

129.5 BERG, O*; HOLZMAN, R; BROWN, M D; OLAIVAR, A F; MULLER, U K; California State University, Fresno; Tel Aviv University; umuller@csufresno.edu
Fluid mechanics of the bladderwort feeding strike: 0 to 60 mph in 1 millisecond
The aquatic bladderwort Utricularia gibba captures zooplankton in mechanically triggered underwater traps. With characteristic dimensions less than 1 mm, the trapping structures are among the smallest known that work by suction mechanism that would not be effective in the creeping−flow regime. In order to understand the adaptations that make suction feeding possible on this small scale, we have measured several dozen U. gibba suction events by digital Particle Image Velocimetry. The spatial distribution of fluid speed identifies the external flow as inviscid, as generally observed for adult fish. We have furthermore characterized the internal flows by tracking particles at frame rates up to 50 000 per second. These results diverge from observations in fish: the fluid is accelerated from rest at an extraordinarily high rate (up to 25 000 m/s) to reach a peak speed of 5 m/s, ensuring that the internal flow is also inviscid. Thus the short duration of the strike out−paces the development of a boundary layer, creating a fast and energy−efficient inward jet. The dynamics are well described by a time−dependent Bernoulli equation in which the action of the trap door is represented by a step increase in driving pressure. The limiting flow speed is shown to depend only on this pressure, while the initial acceleration is determined by pressure and channel length. The flow is effectively inviscid because less than 20% of steady−state power is lost to friction. Frictional losses increase rapidly with decreasing channel diameter, setting a lower limit on practical bladderwort size.
24.4 BERGSTROM, C.A.*; PACHECO, J.; FRITZ, T.; University of Alaska Southeast; cbergestrom@sas.alaska.edu

Functional morphology and swimming performance in flounder: are left–sided fish faster?

Performance consequences of morphological variation within species set the stage for ecological selection to occur. In fishes, variation in body shape is known to affect swimming performance, leading to changes in ecological interactions such as predator avoidance and prey capture. However, performance consequences of one of the most conspicuous forms of body shape variation, direction of asymmetry in flatfishes, are poorly understood. Starry flounder (Platichthys stellatus), is a flatfish species that is polymorphic for asymmetry direction. The proportion of sinistral (left–sided) and dextral (right–sided) morphs exhibits a geographical cline across the species range. Differences in morphology (head shape, tail size, body depth) and stable isotope signatures between sinistral and dextral morphs suggest that they may differ in locomotor performance as well as prey acquisition. Here we tested if there were also differences between morphs in prolonged swimming endurance and fast−start velocity and acceleration. Two categories of swimming performance were tested: endurance was measured as the amount of time required to exhaust a fish swimming at constant speed in a flow chamber, and fast−start performance was measured from video of fish stimulated to induce a startle response in still water. Sinistral fish had superior performance over dextral fish in both categories, and preliminary data suggests they may also have an elevated metabolic rate. These data add to evidence of ecological segregation between asymmetry flounder morphs, implicating selection as a potential mechanism maintaining the geographical cline in their distribution.

24.5 BERNARDO, J.*; SPOTILA, J.R.; AGOSTA, S.; Texas A&M Univ., Drexel Univ., VA Commonwealth Univ.; jbernardo@tamu.edu

Thermal sensitivity of metabolic rates explains range properties: towards a cause–and–effect understanding of climate change vulnerability

Understanding the causes of species distributions has been a central goal of ecology for more than a century, but our current understanding is surprisingly unsophisticated. Most current evidence is based on correlations among abiotic factors and range properties (limits, extents) but does not examine species biology directly. Macroecological, and macrophysiological approaches do consider correlations between species traits and range properties, but they are often weak and lack a concrete mechanistic, cause–and–effect explanation. Here we test macro−scale predictions of The Oxygen− and Capacity−Limitation of Thermal Tolerance Model (OCLM), a mechanistic model based on detailed analysis of cellular and sub−cellular processes assayed in vivo as organisms are thermally challenged. The OCLM, developed using marine animals, finds that deterioration of whole organism performance with increasing temperature past optimal performance reflects an inability to satisfy oxygen demands of metabolism, and the concomitant onset of anaerobiosis. Using a salamander model system, we show that the rate at which metabolic performance deteriorates with increasing temperature explains a substantial amount of interspecific variance in lower elevational limits and in the latitudinal extent of geographic ranges. These results provide (1) one of the strongest empirical explanations of interspecific variance in range properties in any system, (2) the first interspecific comparative support of the predictions of the OCLM, and (3) the first demonstration of the relevance of the OCLM to terrestrial organisms. Our results also have important implications for evolutionary models of species range determination.

112.2 BERMAN, G.J.*; CHOL, D.; BIALEK, W.; SHAEVITZ, J.W.; Princeton University; gberman@princeton.edu

Quantifying inter−species variations through the automated discovery of stereotyped behaviors

In recent years, the scientific community has learned a great deal about morphological evolution through making comparisons between closely−related species, discovering, for instance, that significant physical alterations between species can occur through a potentially reversible accumulation of single nucleotide substitutions. Applying these ideas towards the evolution of behavioral traits, however, has proven much more challenging. Much of this difficulty arises as a result of our inability to quantify behavior with the same fidelity and richness that exists in the study of morphology. In this talk, I will describe the novel metrics we have developed to quantify stereotyped movements — behaviors that an animal performs frequently and with great similarity. Using the fruit flies of the Drosophila melanogaster species subgroup as model organisms, we find that it is possible to mine high−speed movies of an animal moving in a structureless environment for such behaviors. This is achieved using a novel method that draws from ideas in information theory, non−linear dynamics, and unsupervised learning. Our method creates a well−defined statistical definition of what it means for an animal to perform a stereotyped motion, allowing for the rigorous construction of new behavioral metrics. Moreover, we show that using these quantifications, it is possible to make meaningful comparisons between these species’ behaviors, thus opening the door for further insight into the interplay between genes, neurons, and behavior.

118.6 BEZAUULT, E*; RENN, S; Reed College, Portland (OR); ebezault@reed.edu

ANALYSIS OF COPY NUMBER VARIATION ACROSS AFRICAN CICHLID GENOMES

Structural variation has been shown to be a major source of evolutionary novelty. The African cichlids, known as one of the most explosive radiations of adaptive radiations, offer an excellent model to study the genetics of adaptation and diversification in Vertebrates. The sequencing of the genome of 5 species and their annotation (Cichlid Genome Consortium & Broad Institute) provide key genomic resources to study their evolution. The interest of array−based Comparative Genomic Hybridization (aCGH) to study Copy Number Variation (CNV) is widely accepted, yet challenging when conducted across distantly related taxa. To analyze CNV at the whole genome level across African cichlids lineages, we have developed a high−density multi−species microarray platform (12plex 135K NimbleGen array). To ensure high hybridization efficiency at a wide phylogenetic scale among African cichlids, the probes have been selected based on the consensus sequence from the multiple genome alignment of the 5 cichlid species sequenced. Furthermore this exon–focus array includes 70K probes targeted on the Ensembl tilapia genome annotation, specifically representing ~24K predicted−genes. At the overall genome level, this array presents an average probe interval of 6Kb, which could expectedly allow the detection of structural variation of 30–60Kb. We first used this array to analyze CNV among the 5 species previously sequenced, representing 3 major evolutionary lineages of African Cichlids: Oreochromines, Neolamprologines and Haplochromines, with representatives of 2 different lake radiations and 1 non−radiating riverine species. We therefore compared the results obtained from aCGH with the ones derived from genome sequencing. The aCGH approach will be extended at population level as well as broader phylogenetic scale within African cichlids, to identify CNV associated with adaptation and diversification.
The evolution and development of the archosaurian head and the origin of the bird skull

The bird skull is a highly specialized structure that has diverged considerably from the ancestral cranial plan of the archosaurian "ruling reptiles," whose modern representatives are birds and crocodilians. We investigated the developmental mechanisms underlying this divergence on several scales. On a broad scale, we propose that the heterochronic mechanism of progentic paedomorphosis explains many seemingly disparate transitions from a more ancestral archosaurian skull to an avian skull. The bird lineage was juvenilized in several steps relative to ancestral forms, an insight obtained using a geometric morphometric analysis that included both phylogenetic and ontogenetic breadth. Early avialins in particular clustered with the juveniles and embryos of other archosaurs, with more crownward taxa moving farther and farther backward along a trajectory corresponding to ontogenetic progression. Definitionally, these results describe paedomorphosis, but the particular mechanism of progensis was strongly supported by corresponding decreases in body size and in time to sexual and somatic maturity. Furthermore, some modularity exists in the heterochronous transformations here identified, notably in that the premaxilla, which forms the distinctive bird bill, grows peramorphically against a global paedomorphic background in which the orbits and brain become relatively larger and the maxillary region smaller. Given a broad evolutionary developmental mechanism for major changes in skull form toward birds, we have subsequently undertaken investigations of the specific molecular mechanisms behind the transformations elucidated by our phylogenetic/ontogenetic morphometric work, with some success in testing hypotheses of gene function using manipulation of model organisms.

Epigenetic regulation of myogenesis in a growth paradigm—specific manner.

Piscine growth is unique in that many species exhibit patterns of muscle growth opposite that of mammalian species. Many teleosts exhibit hyperplastic muscle growth throughout their lives, while most mammals only exhibit hyperplasia during fetal growth or following trauma. Recently, we have characterized closely related fish species that exhibit different growth types: zebrafish (determinate-like) and giant danio (indeterminate). The zebrafish (Danio rerio) has been used extensively as a model system for developmental studies but, unlike most teleost fish, it grows more determinately. A close relative, the giant danio (Devario cf. aequipinnatus), grows indeterminately, displaying both hyperplasia and hypertrophy in muscle as an adult. Interestingly, the adult giant danio exhibits a significant increase in body mass following growth hormone treatment, while the adult zebrafish fails to respond with more than a 10% increase in growth. To better understand the underlying mechanisms of growth paradigm differentiation, we have begun to characterize potential methods of epigenetic regulation of myogenic regulating factors between these two opposing growth types. Methylation of lysine residues on histone 3 (H3) has been shown to repress muscle—differentiation—specific gene promoters in mammals. Here we demonstrate differential patterns of epigenetic regulation between closely-related fish species exhibiting opposing growth paradigms, where hypermethylation of several lysine residues is associated with the Myf5 promoter in myogenic precursor cells (MPCs) from adult giant danio myotomal tissue. Giant danio MPCs do not express Myf5 protein during in vitro myogenesis, suggesting that epigenetic regulation may play a pivotal role in growth paradigm potential.

Fixational eye movements in the earliest stage of metazoan evolution

Fixational eye movements in vertebrate vision prevent sensory adaptation by refreshing the retinal image. Without fixational eye movements an animal would be rendered blind during visual fixation until the time the eyes were moved voluntarily or the world moved in front of them. Box jellyfish face the same sensory adaptation problem as vertebrates and a counter strategy is necessary to prevent image fading, but unlike vertebrates these animals do not have motor control of their eyes. Here we present the first evidence that vertebrate fixational eye movements have evolutionary parallels in Cnidarians, the first phylum to develop a central nervous system. We have proven that the bell contractions in the box jellyfish Tripedalia cystophora induce a swinging of the eye—carrying rhopalia which, in amplitude and duration, matches the spatio-temporal resolution of the lens eyes. Video recordings of free swimming and tethered animals determined the spatio-temporal relationship between the rhophalial swinging and the visual physiology of T. cystophora, and the findings were further confirmed by performing extracellular electrophysiological recordings on transected rhopalia exposed to comparable visual stimuli in vitro.

Dynamic climbing of near-vertical surfaces with a legged robot

Geckos are able to ascend challenging, smooth vertical surfaces with speed and robustness to perturbations that robot designs have yet to match. Studies of these animals reveal that they have fluid, efficient body dynamics during climbing as well as adhesives that are capable of providing very large adhesive forces relative to body mass. We have developed a 10 cm, 19 gram legged robot that we are using to study the effects of foot design, adhesion, and body dynamics on climbing ability on smooth, hard surfaces. The robot uses a microstructured rubber adhesive with shear-induced adhesion qualitatively comparable to that seen in geckos. A bio-inspired ankle and tendon system is used to promote conformation with a surface as well as engagement without generating peeling moments. Automated foot testing shows the feet are capable of normal adhesive loads of 0.37N with a shear load of 1N with only minor performance degradation when the feet are significantly misaligned with the climbing surface. Early climbing trials on a hard near-vertical surface show that the maximum velocity possible while climbing decreases as the incline increases. The robot demonstrated climbing speeds of 10 cm per second on 70-degree inclines and was limited to inclines of 75 degrees and below. A fundamental model describes the effect of incline on climbing speed. Other evidence also shows that this performance limit is due to body dynamics and adhesive limitations. New models and system modifications, and engagement methods are leading to improved climbing performance and robustness of the robotic platform.
**114.1 BIRN-JEFFERY, AV*; HUBICKI, C; BLUM, Y; HURST, J; DALEY, MA; Royal Veterinary College, UK, OSU, Oregon; abirnjeffery@rvc.ac.uk**

Don't break a leg: injury prevention, robustness and stability of legged locomotion

In uneven terrain, legged animals must avoid falling and exceeding tissue safety factors to prevent injury. Simple models of locomotion highlight a potential trade-off between stability and injury avoidance. To investigate scaling effects on leg control for stability, we studied obstacle negotiation in ground birds spanning a 50-fold body mass range. We expected larger, straight-legged animals to prioritize reduction of peak forces, leading to lower robustness and stability compared to smaller species. Unexpectedly, we observed that body and leg dynamics during obstacle negotiation are similar. Furthermore, force trajectories remained similar to level terrain across species. These results suggest a common control policy, regardless of body size. We noted an asymmetry in the stance force trajectory across birds, with peak force around 30-40% of stance, which is not predicted by current models. We demonstrate that minimum-work actuation applied to an intrinsically damped leg model correctly predicts these force characteristics and suggests higher intrinsic damping in smaller species. Despite similar peak forces across terrains, the birds achieve remarkably high robustness and stability, maintaining 50% leg length obstacles with little variation in speed, and limit fall risks to only 8 in 10,000. Animals prioritize injury and fall avoidance over steady dynamics. The experimental data is consistent with a control policy involving feed-forward swing-leg control to minimize changes in passive-dynamics of stance phase. Consistent trends across a 50-fold range in body size suggest general principles which may be useful for the control of legged robots.

---

**88.1 BISHOP, K.L.*; ONEILL, M.; SCHMITT, D.; Florida International University, Stony Brook University, Duke University; kristin.bishop@fiu.edu**

Comparison of walking mechanics in an arboreal and a terrestrial primate

Animals have several mechanisms available that may reduce their metabolic cost while walking. One is the movement of center of mass to exchange potential and kinetic energy needed to lift and accelerate the center of mass. Alternatively, animals can reduce the energy lost through redirecting the path of the center of mass, known as collisional energy loss. Previous work has shown that some animals use the inverted pendulum mechanism less effectively than others, but it is not known whether those animals accept a higher cost for locomotion or compensate by using other energy saving mechanisms such as reducing collisional energy loss. Arboreal animals may be unable to use the inverted pendulum mechanism, and if so, they may compensate by reducing collisional losses. In this study we compare the walking mechanics of two species of lemurs, *Lemur catta*, the most terrestrial of the lemurs, and *Eulemur fulvus*, an exclusively arboreal species. Individuals of both species were videorecorded while walking across a force plate that was either flat or had a pole attached, simulating arboreal locomotion, to record the kinematics and kinetics of their locomotion. We found that *L. catta* was capable of having very high energy recovery, with a maximum energy recovery of 71%, comparable to that found in dogs and humans. Recovery values were high in this species for both ground and pole. *E. fulvus* had lower energy recovery on both ground and pole, with a maximum recovery below 50%. Thus the use of an arboreal support does not drive mechanical patterns, but arboreal adaptations appear to have an import effect suggesting that effective arboreal movement may be inconsistent with energy recovery. Kinematic analysis and comparisons of collision fraction were used to explain the differences in energy recovery between the terrestrial and arboreal species.

---

**144.5 BLACK, C.R.*; BERENDZEN, P.B.; Univ. of Northern Iowa; corinthi@uni.edu**

The Effect of Phylogeny on Morphological Characteristics of the Skeleton in Pleuronectiformes

Pleuronectiformes, commonly known as flatfishes, are a highly specialized order of fishes displaying obvious asymmetrical morphologies. When a flatfish hatch, they are symmetrical. As development continues, one eye migrates dorsally to the other side of the head. This causes morphological changes to occur simultaneously, resulting in an asymmetric fish. These changes include asymmetry of paired fins, dentition, and pigmentation of the body. The skeletal structure undergoes morphological changes as development continues. Of these skeletal structures, the frontal complex of the skull illustrates the greatest transformation. Although all Pleuronectiformes undergo similar developmental changes, there are significant differences in morphology of these characters across the phylogeny. This study focuses on examining the morphological diversity of several skeletal characteristics including the shape of the frontal complex, fin insertion points, and the spinal flexure using geometric morphometrics. Radiographic images of at least one representative of every genus available, in the order of Pleuronectiformes, were digitized by placing 32 landmarks across the skeleton. Landmarks were standardized, a principal component analysis was performed, and the ancestral phylomorphospace was reconstructed using the most recently published molecular phylogeny. Preliminary results will be presented.
Material effects on cloning frequency, larval development and juvenile size in the sea star Asterias forbesi
A fundamental life-history trade-off occurs between the size and number of offspring that a female produces. Traditionally, biologists have assumed that there is a species-specific optimal egg size, the value of which can fluctuate with changing environmental parameters. However, in unpredictable environments a bet-hedging strategy resulting in variable offspring sizes may be favored. The sea star Asterias forbesi produces eggs that vary more than two-fold in volume within a single clutch (110µm – 150µm diameter). In addition, the larvae derived from these eggs have frequently been observed to produce clones. To test for maternal effects on cloning frequency and larval development we sorted sibling embryos at the blastula stage into large (190µm mean diameter) or small (140µm mean diameter) size classes. Previous studies have shown that exogenous cues can alter the frequency of cloning, but it is unclear whether endogenous reserves might also influence the asexual production of larvae. Our results suggest that despite an initial disadvantage in energy reserves, small treatments produced clones at frequencies similar to their large siblings. Since little is known how maternal investment affects juvenile quality in sea stars, we continued to follow these larvae and examined the effect of maternal investment on time to and size at metamorphosis. Small treatments took about 2 additional days compared to large treatments before settling as juveniles, a 63% increase in developmental time. Because the experiment ended early, our estimate of the developmental period for larvae from small eggs is highly conservative. Size at metamorphosis did not appear to be affected by maternal investment and varied greatly within treatments.

Structure–function relationships in the pectoral fin of freshwater stingray Potamotrygon orbignyi
To achieve the characteristic undulations of rajiform locomotion, the pectoral fins of batoid fishes must be flexible and well-controlled, to generate, accommodate, and modulate the propulsive wave. Batoids have dramatically diverged from their osteichthyan ancestors in both fin use and structure, but lack the mechanical linkages that provide control in the pectoral fins of actinopterygian fishes. By integrating an understanding of 3-D swimming kinematics with the pectoral fin morphology of freshwater stingray Potamotrygon orbignyi, I connect aspects of structure and function in the fin of an undulatory rajiform swimmer. The morphology of skeletal and muscular fin elements differs across fin chord and span, creating regional variations that correlate with the swimming kinematics of P. orbignyi. Anterior regions of the pectoral fin, which form a stable leading edge during swimming, are structurally stiffened by a more robust fin skeleton, with the potential for active stiffening from a pennate arrangement of muscle fibers. Structure predisposes mid–disc and posterior regions of the fin to greater flexibility; these same regions show the greatest amplitudes during undulation. Comparisons with the fins of a representative actinopterygian fish (bluegill sunfish Lepomis macrochirus) and shark (dogfish Squalus acanthias), reveal structural convergence between stingrays and actinopterygians in fin ray branching and segmentation. The repetition of fin elements during the evolution of batoid pectoral fins created the potential for this convergence, as well as for regional specialization within the fin, with structural features connecting pectoral fin morphology and undulatory performance.

The impact of taxonomic progress on knowing the Tree of Life: an example from amphibians
Since 1985, taxonomic research on the diversity of living amphibians has increased species diversity by ~60% (from 4014 in 1985 to 7000+ in late 2012). We evaluate the impact of nearly thirty years of species-level taxonomy on our knowledge of the Amphibian Tree of Life. Using a recently published study based on DNA sequence data for nearly 2900 amphibian species, we explore the impact of post-1985 taxonomy (i.e., after the 1985 publication of Amphibian Species of the World, ed. D.R. Frost) on our present-day knowledge of evolutionary relationships and patterns of diversification. We present both qualitative and quantitative comparisons based on phylogenies generated by (1) pruning recently published trees to circa 1985 taxonomy and by (2) reanalyzing matrices in which post-1985 taxa are removed from the analysis. We ask to what extent our knowledge of the Amphibian Tree of Life is dependent on taxonomic research and species discovery since 1985. In a general sense, would we have known then what we know now if only we had DNA sequence data in 1985? We highlight analyses based on tree shape statistics that reveal general themes likely true for our present-day understanding of other organisms.
Change in resource allocation patterns in response to variation in food acquisition provides a mechanistic basis for understanding observed life history responses to variation in food availability. Organisms respond differently to changes in food quantity vs. quality, as demonstrated empirically and theoretically, using conceptual structures such as resource congruence, stoichiometry and the geometric framework. Here we examine the life history effects of realistic changes in the quantity of food available and connect lab experiments to field observations, using butterflies as a model system. Variance in per capita flower availability results from weather and land use patterns, and can lead to prolonged nectar limitation. In butterflies, adult food limitation generally does not affect lifespan, but can lead to reduced fecundity. We extend work on allocation to reproduction under nutrient stress by asking how such stress affects fecundity, egg mass and composition as a function of age in two species with contrasting life histories, hence physiological demands. The larvae of Speyeria mormonia diapause without feeding and hence the eggs are expected to have a greater energetic provisioning requirement than eggs of Colias eurytheme. Likewise, S. mormonia has a higher use of adult food in egg production. Consistent with these traits, under laboratory conditions, S. mormonia eggs are heavier, and fecundity decreases to a greater extent under nutrient stress. Nonetheless, S. mormonia does not defend egg mass or egg energy stores under nutrient stress, although C. eurytheme does. We also compare female performance under stress in the lab with that in the field for S. mormonia.

Despite their lack of muscles and neurons, sponges are capable of propagated contractile events, known as contractile waves. These contractions have been studied mostly in demosponges with the typical leuconoid canal design. This present study presents novel time−lapse examinations of contractions in live calcareous sponges with simpler canals: Leucosolenia botryoides (asconoid canals) and Sycon ciliata (syconoid canals). Particular attention was paid to contractile events here termed debris coughs, in which clouds of debris were ejected from excurrent oscules during a contractile wave. Debris coughs occurred in both asconoid and syconoid sponges: syconoid sponges were observed to cough more frequently and in apparently greater volumes than was seen in asconoid sponges. Debris fields (presumably ejected by a cough) also were seen occasionally with Sycon sponges: these deposits were composed of small round cells of uncertain nature, but they were in the same size range as choanocytes. Putative ingredients of the ejected debris clouds could be sponge cells and/or the residue of organisms (victims of predation and filtration) trapped and consumed in the canals of these highly spiculose sponges.

The Southeastern Coastal Plain of North America is a refuge for many divergent lineages of freshwater vertebrates. However, this region was submerged by a marine transgression throughout the Eocene, so the modern Southeastern Coastal Plain and its communities are relatively young. Using the fossil record and a multi−locus nuclear phylogeny, we examine divergence times and body size evolution of aquatic salamanders from North American coastal plains since the Mesozoic. At least five salamander families occurred on the extensive Western Interior Coastal Plain, which existed from the Upper Cretaceous through the Eocene. Four of these families subsequently colonized the Southeastern Coastal Plain by the early Oligocene to late Miocene. The oldest divergences among extant species from Southeastern Coastal Plain endemic clades occurred during the Miocene, indicating that most of the current diversity arose from a single lineage of each family that colonized the Southeastern Coastal Plain after the Eocene marine regression. Body size is highly labile in these four families, which show at least one or more major size shifts since the early Cenozoic, including two recent size reversals in endemic Southeastern Coastal Plain clades. This has resulted in continuous shuffling of the size order of aquatic salamander lineages on this shifting refuge since the Late Cretaceous. Therefore, while the environmental niche parameters of these aquatic salamanders may be highly conserved, size related ecological factors (eg, trophic interactions) have likely been highly labile across space and time.

Stomatopods, or mantis shrimps, possess the most spectrally diverse retinal photoreceptor array yet described. Their photoreceptors are maximally sensitive to sixteen discrete wavelengths of light between 310 and 700 nm, as well as to linearly and circularly polarized light. The spectral tuning mechanisms at work in these photoreceptors have been well described within the human visible range, above 400 nm, showing that this surprising diversity of photoreceptor types is achieved through unique arrangements of visual pigments and long−pass optical filters in receptor sets of reticular cells 1 to 7 (R1−R7). However, stomatopods also have R8 photoreceptors sensitive to at least five different wavelength ranges of ultraviolet (UV) light, but little is known about their spectral tuning. Here we present molecular and physiological evidence that polychromatic UV vision in the stomatopod Neogonodactylus oerstedii is achieved by the elegant pairwise combinations of one of typically two visual pigments, absorbing at 330 nm and 380 nm respectively, with four novel UV−specific short− and long−pass optical filters. Modeling of photoreceptor spectral sensitivity from the absorbance spectra of these filters and pigments closely matches previous electrophysiological recordings from the R8 receptor cells. Furthermore, various species of stomatopods utilize different complements of these components, producing a diversity of UV receptor suites throughout the order. The sophisticated composition of stomatopod UV photoreceptors suggests an essential role for this capacity in their visual ecology.

Debris fields (presumably ejected by a cough) also were seen occasionally with Sycon sponges: these deposits were composed of small round cells of uncertain nature, but they were in the same size range as choanocytes. Putative ingredients of the ejected debris clouds could be sponge cells and/or the residue of organisms (victims of predation and filtration) trapped and consumed in the canals of these highly spiculose sponges.
The role of the stress axis in coping with chronic uncertainty

The adaptations animals have in the natural world are solutions to ecological problems to which they have a long evolutionary history. The stress axis is a vital regulator of that adaptation. Animals in nature experience periods of long-term uncertainty because of lack of food, severe weather, high predator threat, social conflict, and so on. However, only some species are chronically stressed by these factors showing chronic changes in their physiology, reproduction, and condition; others deal with a stressor acutely and then go back to the business of living. I will present evidence that the stress axis in the first group continues to function remarkably well. The difference between chronic and acute responses of the two groups may be related to their life history. Though the biomedical literature and most of the literature on natural populations regard chronic stress-induced changes as pathological, I will argue that these changes are adaptive and ultimately promote an animal’s survival and reproductive success.

The feeding apparatus of first feeding European eel (Anguilla anguilla) larvae: a functional morphological approach

The European eel (Anguilla anguilla Linnaeus 1758; Actinopterygii, Anguillidae) is faced with a severe decline (up to 99%) in its natural populations over the last 40 years. Due to the absence of knowledge regarding the exact cause for this decline, a lot of effort is recently put in obtaining a complete artificial breeding program for this endangered, but still globally traded species. Unfortunately, the artificially reared eel larvae are, at present, unable to stay alive for more than three weeks after hatching. Since the larval mortality rate peaks at the onset of active food uptake, and literature regarding the larval feeding capacities, strategies and natural prey preferences is rather scarce, a functional morphological analysis of the feeding apparatus of first feeding larvae is performed. This analysis includes modeling the theoretical bite force by using a graphical 3D-reconstruction of the musculoskeletal system of these extremely small organisms (<1 cm). Based on the acquired 3D data of joints, levers and muscle insertions, as well as muscle data, very small bite forces (10⁻⁷ N) are obtained for these European eel larvae. Additionally, preliminary data on kinematics (from video recordings) of jaw and hyoid movements in pre-feeding larvae demonstrates a rather limited ability of jaw movement by both ligaments and muscles. Combining both results, rather small and soft food items are suggested to be preferable in both natural and artificial environments, which appears to be in line with the existing hypothesis that these larvae feed on either small and/or gelatinous prey items in nature (Hydrozoa, Thaliacea, Ctenophora, Polychystenia) and, additionally, may be useful information to optimize the artificial breeding program.

The younger games: flies compete for oviposition sites that benefit their young

We used game theory to predict how fruit flies (Drosophila melanogaster) should compete for oviposition sites. Although flies prefer to lay their eggs within a particular range of temperatures, the potential for competition among offspring should cause females to accept warmer or cooler sites when preferred sites become crowded. To look at this problem, I observed where flies chose to lay eggs under various densities of competing females. In each trial, 1, 5, 10, or 20 flies were placed within a thermal gradient of potential oviposition sites, (a grape agar media ranging from 21°C to 37°C). Additionally, I also ran a trial where I added a single fly at a time to the thermal gradient to see if effects on behavior resulted from the presence of other females or the presence of eggs on the media. After 9 hours, I counted the eggs laid in each portion of the gradient and analyzed how the distribution of eggs was affected by the density of females. By drawing on game theory to make quantitative predictions, this research builds on previous empirical studies of competition between thermoregulating animals.

The integrative phylogeny approach applied to Porifera: a case-study the Homoscleromorpha

The two main scientific tasks of taxonomy are species delineating and classification. These two tasks are often treated differently, with species classification accomplished by newly-developed phylogenetic methods, often based on molecular sequences, while species delimitation is conducted by what is often considered as an old-fashioned typological approach based on a morphological description. A new integrative taxonomy approach has been recently proposed (Dayrat, 2005) maintaining that species delimitation should be a multidisciplinary undertaking combining several independent datasets. Here we argue that the same principle is relevant to species classification. In the last 20 years we assembled various datasets based on external morphology, anatomy, cytology, spicule shapes, geography, reproduction, genetic sequences and metabolomics of homoscleromorph sponges. We show how we used these datasets to describe new species of homoscleromorph sponges and to elucidate their phylogenetic relationships and their phylogenetic position within the phylum Porifera.
**S5−1.2 BOWDEN, R.M.*; CLAIRARDIN, S.G.; PAITZ, R.T.; II.
St. Univ.; rmbowde@ilstu.edu**

**Early hormonal influences on temperature dependent sex determination in turtles**

In reptiles with temperature dependent sex determination (TSD), treatment with exogenous steroids, particularly estrogens, during the middle third of development have well documented effects on sex determination. Less well understood are the effects of maternal or endogenous steroids on development, despite the fact that eggs have a rich supply of maternal steroids at oviposition. Because embryos are exposed to steroids very early in development, understanding the fate of those compounds, and potential effects on development are critical to revealing the link between early exposure to steroids and steroid effects. To this end, we have been investigating embryonic metabolism of maternal steroids, how timing of exposure influences steroid effects, and more recently, the effects of endocrine disrupting compounds during early development in the red−eared slider turtle *Trachemys scripta*. We have found that the embryo and its associated membranes are responsible for the metabolism of maternal steroids, and that estradiol is converted to several estrogen sulfates that are present in both the yolk and albumen egg compartments. Interestingly, at least some of these sulfonated products are capable of influencing sex determination, as we have demonstrated with exogenously applied estradiol sulfate. When the endocrine disruptor Bisphenol−A is applied to eggs, the rate and end products of estrogen metabolism, and sex determination are altered. The metabolism of maternal estrogens is important to modulating the influence of steroids on development, and disruption of this process may help explain how the estrogenic effects chemicals such as Bisphenol−A are elicited.

**22.1 BOYER, SL*; BAKER, CM; POPKIN−HALL, ZR; LAUKO, DI; WIESNER, HA; KOZAK, KH; LUXBACHER, AE; Macalester College, University of Minnesota; boyer@macalester.edu**

**Immunochallenge and terminal investment in female house wrens (Troglodytes aedon)**

The reproductive costs associated with up−regulation of the immune system have been well−documented and arise from a trade−off between reproductive effort and self−maintenance. However, some recent studies that activated the immune system of breeding individuals found that parents actually increased, rather than decreased, reproductive effort following immunostimulation, suggesting terminal parental investment as prospects for future reproduction declined. We tested the trade−off and terminal investment hypotheses in a free−living population of house wrens (*Troglodytes aedon*) by challenging the immune system of breeding females with an antigen, lipopolysaccharide. Immunized females showed no evidence of subsequent reproductive costs associated with the immunostimulation; instead, they produced offspring of higher phenotypic quality, but in a sex−specific manner. Relative to control offspring, sons of immunized females had increased body mass and their sisters enhanced cutaneous immune responsiveness to phytohaemagglutinin injection. Further study suggests that immunostimulation leads to an increase in both pre−hatching resource allocation to eggs and post−hatching maternal effort when provisioning live young.

**99.1 BOWSHER, JH*; ANG, Y; FERDERER, T; MEIER, R; North Dakota State University, National University of Singapore; julia.bowsher@ndsu.edu**

**Deciphering the evolutionary history and developmental mechanisms of a complex sexual ornament: the abdominal appendages of Sepsidae (Diptera)**

Male abdomen appendages are a novel trait found within Sepsidae (Diptera). Here we demonstrate that they are likely to have evolved once, were lost three times, and then secondarily gained in one lineage. In order to establish the developmental mechanism for appendage formation, we studied the development of the sternites in males and females for three species with and one species without the appendages. For each species and sex the number of cells in all sternites regardless of sex. All species with appendages have elevated cell counts for the fourth segment, which gives rise to the appendages. In *Perochaeta dikowi*, which reacquired the trait, the female also has an elevated cell count on the fourth segment despite the fact that females do not develop appendages. This difference suggests that *P. dikowi* has evolved a different developmental mechanism for appendage formation.

**62.3 BOYER, SL*; BAKER, CM; POPKIN−HALL, ZR; LAUKO, DI; WIESNER, HA; KOZAK, KH; LUXBACHER, AE; Macalester College, University of Minnesota; boyer@macalester.edu**

**Historical biogeography of mite harvestmen from the Wet Tropics of Australia**

The Wet Tropics of Queensland, Australia have emerged as a model system for understanding the evolutionary effects of climate change on rainforest animals. In vertebrates whose species distributions span the Wet Tropics, contraction and fragmentation of forest habitats during the Last Glacial Maximum has resulted in population−level divergences whose genetic signatures are apparent today. In contrast to vagile vertebrate species, the dispersal−limited leaf−dwelling mite harvestmen (Arachnida, Opiliones, Cyphophthalmi) have tiny species distributions (~50km in diameter). As a result, the consequences of habitat fragmentation and contraction are expected to differ from what has been documented in vertebrates. Currently, our knowledge of the diversity and distribution of mite harvestmen across the Wet Tropics is in its infancy, but significant progress has been made and historical biogeographic patterns have begun to emerge. We present new species and new locality data, ecological niche models and hindcasting, and a preliminary phylogeny for the mite harvestman genus *Austroparcella*.
When and how do Tree Swallow chicks die during cold weather?

Temperate-breeding aerial birds face strong selection to breed early with the consequence that chicks experience periods of inclement weather that both increase thermogenic stressors and reduce their food supply. Tree Swallows (Tachycineta bicolor) are aerially-foraging cavity-nesting insectivores that frequently suffer complete or partial nest failure during cold weather. We studied individual-level chick mortality risk in a population of Tree Swallows near Ithaca, NY during 2010. Using weather and food data collected locally, we measured environmental conditions chicks experienced between hatching and fledging. We also characterized the development of chicks at days 3, 6, 9, and 12 by weighing, measuring feather cover, capacity for endothermy, and body composition using quantitative magnetic resonance (QMR). During periods of cold weather, we weighed and conducted additional QMR scans daily, and determined chick fate. Two cold snaps occurred during the study, and due to nesting asynchrony, cold weather affected chicks at all stages of development. Of the 140 chicks we followed (32 nests), 65 (from 19 nests) died during or immediately following periods of cold weather. Mortality risk was highest for 6-9 day-old chicks. At this age chicks have a moderate capacity for endothermy but have incomplete insulation from growing feathers. Chicks died with an average 9.6% fat which is 3.6% more fat than lean females carry at the end of the breeding. After controlling for body composition change with chick age (linear decrease in proportion of mass accounted for by fat), the last measurements prior to death revealed slightly higher fat loads than on chicks that survived. Our data suggest that chicks are most vulnerable midway through development, and that they do not die because they have exhausted their energy stores.

Reduction of an aposematic signal: the role of microhabitat in North American black widows (Latrodectus)

An aposematic signal may warn a predator of the signaler's dangerous capabilities. While much work has focused on the evolution and form of aposematic signals, few studies have examined why they may be lost or reduced. Ancestral trait reconstruction suggests that two species of North American black widows (Latrodectus mactans and L. hesperus) exhibit a reduction of aposematic coloration. While these species still possess the black widow's iconic ventral red hourglass, they usually lack the dorsal coloration seen in congeners. To examine why L. mactans may have reduced its coloration, we present microhabitat comparisons between it and a sympatric black widow, L. variolus, that has retained its dorsal coloration. We found that the dorsally all-black L. mactans (N=21) tends to prefer lower microhabitats than that the dorsally colored L. variolus (N=27, p<.05). We suggest that when considering microhabitats, the differences in coloration between the species may represent a cost-benefit tradeoff between signaling to predators and avoiding presenting a queue to eavesdroppers. Because L. mactans is found close to the ground with its hourglass pointed upwards, it is less likely that a predator will view its dorsal side than for L. variolus. However many prey still approach from below, and reducing dorsal coloration may improve L. mactans foraging ability.

The Effects of Chronic Cortisol on Appetite in Tilapia Oreochromis mossambicus

Stress in fish has been shown to impair growth, reproduction, immune function and overall health. Stress is managed along the hypothalamic-pituitary-interrenal axis, resulting in the release of cortisol. In the brain, appetite regulating hormones include ghrelin, neuropeptide Y (NPY) which both stimulate appetite and corticotropin releasing hormone (CRH) which acts to decrease appetite. Cortisol has been shown to decrease food intake and growth in several species of fish. Whether cortisol is altering the neuroendocrine regulators of food intake is poorly understood in fish. The current study was designed to investigate the effect of chronic cortisol treatment on food intake and the endocrine regulators of appetite in tilapia. Tilapia were fed one of the following treatments: 0 mg/kg (control), 50 mg/kg, and 500 mg/kg cortisol-laden feed. For 32 days fish were fed a known amount of excess feed twice a day, at 0900 and 1600h, and allowed to feed for 1h at which point remaining food was collected to determine food consumption. At 32 days fish were sacrificed and brain and stomach were collected. The high cortisol dose significantly reduced food intake and growth compared to controls. In both the telencephalon and hypothalamus regions of the brain, there was a significant decrease in NPY expression in both the low and high cortisol dose treated fish compared to controls. Interestingly, there was no change in ghrelin expression in the hypothalamus and stomach but ghrelin expression in the telencephalon was significantly decreased in the low cortisol dose. There was no change in CRH levels across treatments in the telencephalon or hypothalamus regions. These data suggest that chronic exposure to cortisol may decrease appetite by decreasing expression of appetite stimulating hormones in the brain.
68.2 BRAZEAU, M.D.; Naturalis Biodiversity Center; martin.brazEAU@gmail.com
Taking a step back: computational problems for morphological data revisited
Although no longer as prevalent as molecular sequence data, morphological data remain an important source of phylogenetic and comparative data. Without them, it is impossible to place fossils in the tree of life or have a complete picture of the evolution of phenotypes. However, morphological characters are hierarchical, violating the assumptions of character independence in popular phylogenetic algorithms. Morphological character datasets may thus contain characters that are inapplicable to a subset of the taxa. Existing algorithms and software do not account for this, forcing researchers to develop workarounds at the level of character matrix construction. All these workarounds present computational problems. Possibly the most widely accepted approach to dealing with character inapplicability in morphological datasets is to score inapplicable taxa as missing data. However, it is well known that this approach may artificially add steps to tree scores, potentially discarding optimal solutions during the search process. Here I show modifications to the Fitch parsimony procedure that returns correct counts when non-applicable data are distinguished from missing data, but not considered a separate character state. A preliminary implementation examining published datasets shows that considerable resolution of published morphological trees may owe to computational artefacts owing to non-applicable data. The problem is further explored in light of parametric methods, such as maximum likelihood and Bayesian posterior probability, and possibilities for improving their applicability to morphological data. It is hoped that these considerations and developments can lead to improved algorithms for handling morphological data.

20.6 BRIGHT, J.A.*; COBB, S.N.; MARUGAN−LOBON, J.; RAYFIELD, E.J.; University of Bristol, Hull York Medical School, Universidad Autonoma de Madrid; j.bright@bristol.ac.uk
Morphological, dietary and phylogenetic convergence in the diurnal birds of prey
Birds are one of the most diverse clades of modern vertebrates, and have historically been regarded as a classic group in which to study adaptation through evolution. Different lineages of birds often display remarkable convergence in their cranial and beak morphologies, frequently presumed to be associated with similarity in dietary niche. We tested this assumption by performing Geometric Morphometric (GMM) analyses within a subset of neognathous birds, the diurnal birds of prey. Recent molecular phylogenies have classified this group as polyphyletic. There are therefore multiple examples of convergence within this subset of birds, for instance between the falcons (Falconidae) and hawks (Accipitridae), or between the Old World vultures (Accipitridae) and New World vultures (Cathartidae). Three−dimensional landmarks and semi−landmarks were collected from the beaks and skulls of diurnal raptors. Principle Components Analysis shows that carrion feeders (the Old and New World vultures) tend to cluster together in morphospace regardless of phylogeny, indicating strong morphological as well as dietary convergence. However, despite obvious dietary convergences, Falcons plot separately to all other Accipitrids. Thus it seems that although dietary niche may be predicted based on cranial morphology in some families, ecology alone is insufficient to explain the variety of forms seen in the diurnal birds of prey. This may reflect the fact that many raptors hunt and kill with the talons not the beak, meaning that talon morphology may additionally predict dietary ecology. Further functional analysis of the range of talon and beak forms will aim to test this.

67.1 BRAZEAU, KR*; HAHN, TP; UC Davis; krbrazeal@ucdavis.edu
Comparing the effects of testosterone treatment on onset and continuity of plumage molt between two species of cardueline finch
All birds must replace their feathers each year in order to survive, but species vary in their flexibility of timing the transition from breeding to molt. Past studies have established that high levels of sex steroids (e.g. estradiol and testosterone associated with breeding) can delay the onset of molt. Differences in responsiveness to sex steroids may be responsible for variation in molt timing among species. This study compared the role of testosterone in regulating molt timing in two species of cardueline finches. House finches and pine siskins are both seasonal breeders, but the latter are considered more flexible in their reproductive timing because they will sometimes arrest their molt if conditions become favorable for late summer breeding. Wild caught birds of both species were brought into captivity and treated with testosterone via silastic implants administered either prior to molt or during the middle of molt. We found that pine siskins were more sensitive to testosterone than house finches; testosterone completely inhibited molt in the siskins until the implants were removed, while many of the house finches were able to slowly molt a limited number of feathers during the treatment period. However, house finches given testosterone during the middle of molt arrested molt more abruptly than did pine siskins. These results help to clarify mechanisms by which different species coordinate transitions from one life cycle stage to the next.

S10−1.7 BRISCOE, Adriana*; YUAN, Furong; University of California, Irvine; abriscoe@uci.edu
Physiological genomics of color vision in butterflies
Butterflies evolve mimetic wing coloration under selection from predators. Unless butterfly eyes have adaptations for discriminating mimetic color variation there is a risk of confusing mimics from potential mates for the butterflies themselves. The genus Heliconius, composed of 43 species, is of particular interest because unpalatable species form Müllerian mimicry rings throughout the Neotropics. We have discovered that Heliconius eyes express recently duplicated ultraviolet (UV) opsin mRNAs, and provided evidence that this gene duplication may be an adaptation for species recognition of mimetic colors, via enhanced UV color vision. Little is known, however, about the correlated changes in vision gene expression accompanying the evolution of a new UV–photoreceptor type. We report the results of a large−scale visual transcriptome study. Our results suggest that natural and sexual selection on the compound eye has varied considerably over the evolutionary history of the genus and that tradeoffs exist in evolving increased visual complexity.
Ontogeny of navigational responses to regional magnetic fields in loggerhead sea turtle hatchlings

Hatching loggerhead sea turtles (Caretta caretta) from the east coast of Florida enter the ocean and immediately begin a long distance migration lasting several years. During this time, many of the turtles circle the Sargasso Sea before eventually returning to the North American coast. Young loggerheads are known to begin their migration with a magnetic map in which regional magnetic fields existing along the migratory route serve as open-sea navigational markers and elicit changes in swimming direction at critical points in the migration. Little is known, however, about whether the magnetic fields turtles experience early in their migration influence orientation responses to subsequent regional magnetic fields. As a first step toward investigating, we tested the orientation responses of two groups of turtles with different magnetic histories to a field that exists near northern Portugal (north of the normal migratory route). Turtles that had previously swum only in the magnetic field of their home beach failed to show a consistent directional preference when tested in the north Portugal field. In contrast, turtles that had previously swum in a magnetic field that exists near South Carolina (a location along the early migratory pathway) responded to the same north Portugal field by swimming approximately southwest, a direction that might help them remain within the warm-water migratory pathway. These results suggest that experience with magnetic fields that exist along the migratory route can influence subsequent responses to regional magnetic fields under at least some conditions.
The Synergistic Nature of the Behaviors and Mechanisms that Support Effective Burrowing in the Mantis Shrimp Squilla empusa

The mantis shrimp Squilla empusa is a charismatic marine crustacean known for its powerful strike, keen sense of vision, and chemosensory abilities. These benthic creatures create extensive burrows that are important in feeding, reproduction, and protection from predation. Through field observations of a population located in Great Harbor in Woods Hole, MA this species of mantis shrimp has been observed to construct burrows faster and makes more alterations than previously recorded. To understand the mechanics of these burrowing behaviors, mantis shrimp were filmed making burrows in the lab using high-speed videography. S. empusa used two markedly distinct methods of burrowing: pleopod fanning and maxilliped bulldozing. Pleopod fanning consists of a swift posterior power stroke, followed by a slower recovery motion towards the anterior. During the power stroke the pleopods are fully extended, while during the recovery phase the pleopods curl up, reducing drag. In the other form of burrowing, the maxillipeds dig into the substrate, rotate to hold the sediment in a basket, and then deposit the contents outside of the burrow. To understand the fine structure of the mantis shrimps pleopods and maxillipeds, analysis of the appendages was performed using a Zeiss dissecting microscope. Through this series of observations and analyses we are starting to understand how pleopod anatomy and kinematics work synergistically to create an effective burrowing system. This work was supported by NSF DBI-1005378 REU Site-Biological Discovery in Woods Hole, the Lucy B. Lemann Fellowship Fund Award, and the Laura and Arthur Colwin Endowed Summer Research Fellowship Fund Award.

Support Effective Burrowing in the Mantis Shrimp Squilla empusa

The Synthesis of the Burrow

To understand the fine structure of the mantis shrimp Squilla empusa burrow, we observed and filmed the burrowing behavior in the lab. The mantis shrimp was observed to use two distinct methods of burrowing: pleopod fanning and maxilliped bulldozing. Pleopod fanning involves a swift posterior power stroke, followed by a slower recovery motion towards the anterior. During the power stroke, the pleopods are fully extended, while during the recovery phase, the pleopods curl up, reducing drag. In the other form of burrowing, the maxillipeds dig into the substrate, rotate to hold the sediment in a basket, and then deposit the contents outside of the burrow. To understand the fine structure of the mantis shrimp’s pleopods and maxillipeds, we performed an analysis of the appendages using a Zeiss dissecting microscope. Through this series of observations and analyses, we are starting to understand how pleopod anatomy and kinematics work synergistically to create an effective burrowing system. This work was supported by NSF DBI-1005378 REU Site-Biological Discovery in Woods Hole, the Lucy B. Lemann Fellowship Fund Award, and the Laura and Arthur Colwin Endowed Summer Research Fellowship Fund Award.

Non-genetic transgenerational modifications of offspring phenotype are increasingly evident in physiological studies. Indeed, this phenotype is emerging as a potential source of variation in comparative physiology. Here we focus on non-genetic transgenerational transfer of morphological, physiological, and behavioral traits in the zebrafish (Danio rerio) and the water flea (Daphnia magna). The experimental design was similar in both studies (Ho and Burggren, 2012; Andrewartha and Burggren, 2012). Essentially, parents were chronically exposed to hypoxia and then exposed to severe hypoxia and their responses recorded. A control population stayed in normoxia. The subsequently produced offspring (6–18 dpf) were assessed and compared with control populations. In Danio, larval offspring had longer body length when derived from adults that had been exposed to hypoxia for 2, 3 or 4 weeks. Hypoxic resistance (measured by time to loss of equilibrium) 6–18 dpf was ~15% lower in those larvae from parents that had been exposed to 1 week of chronic hypoxia, but longer exposures (2.5 or 4 weeks) significantly increased larval resistance by ~24–30%. CTMin (~39.5°C) and CTMax (~10–12 °C) were unchanged by parental hypoxic exposure. Neonatal Daphnia from hypoxic-exposed adults had a significantly smaller body mass and unchanged by parental hypoxic exposure. Neonatal Daphnia from hypoxic-exposed adults had a significantly smaller body mass and unchanged by parental hypoxic exposure. In the water flea, the response to hypoxic exposure was similar, with ~24–30% lower hypoxic resistance in larvae from hypoxic-exposed parents. These effects dissipated with further development within a brood and with subsequent broods. Parental hypoxic exposure thus can be revealed as a factor in larval phenotype through non-genetic transgenerational mechanisms.
Feeding patterns and their implications for energy budgets in tropical limpets

Energy budget models are often used to understand and predict the metabolic responses of species to environmental variation, such as global warming. The robustness of these models is based on an understanding of patterns of energy gain and expenditure of the modeled organisms, but such measurements can be imprecise for species with complex or poorly understood behavior patterns. Applying these models to keystone species can help predict community–wide responses to environmental variation, especially in the intertidal zone, where many species live near lethal limits of stress. Limpets (*Cellana* spp.) are keystone grazers in the high intertidal zones of the tropics. Most intertidal grazers forage while submerged or splashed, so their activity patterns are closely limited by the tidal cycle. These constraints have been incorporated into behavior models of *Cellana*, but little is known of their feeding rates and ingestion, remaining a blackbox in the models. Using an accelerometer–based contact microphone, we recorded the feeding patterns (rasping sounds) of *Cellana* on the shore over several tidal cycles. Limpets fed at a rate of 80–100 rasps per minute (rpm) while moving up with the flooding tide, became inactive near slack tide, and then fed again at 80–100 rpm while moving down the shore with the ebbing tide. These data are consistent with the prediction of a model of digestion mechanics that limpets are volume–limited grazers, rather than energy–limited foragers. Refining estimates of energy intake using field–based measurements of foraging can help tailor energy budget models, such as Dynamic Energy Budget Models (DEBM), to specific species and improve our ability to forecast energetic consequences of environmental change.

Different strokes for different folks: Comparing motion across and within swimming species

Modeling swimming biological systems hinges on accurately representing the shape of the system in time. We present a method of describing the complex kinematics of an organism using only a few parameters. This low–order representation of the organisms stroke is suitable for fast and effective comparison of different motions performed by the individual, by other individuals and by other species. Using images from videos, we extract optimal basis modes in the curvature space for various species. We use this characterization of the swimmers shape to model and predict the swimming speed and trajectory. For a given species, we use the optimal set of basis modes to model the system in an idealized fluid environment. We find the maximum efficiency stroke for the model system and compare it to the stroke observed in situ. Studying basis modes across species allows us to rationalize biological kinematics and draw conclusions about how different organisms interact with their environment.

The effect of prenatal steroids on citrate synthase activity in the fetal guinea pig scalenus muscle

Glucocorticoids are commonly administered to women considered at risk for preterm birth to speed up fetal lung development and reduce infant mortality. Although these steroids aid lung development in preterm infants, their effects on ventilatory muscles are not well documented. In this study, the effect of betamethasone, a glucocorticoid, on the activity of the oxidative enzyme citrate synthase (CS) in the scalenus muscle of fetal guinea pigs will be examined. Previous histological research demonstrated that NADH (oxidative enzyme) concentrations were greater in the scalenus muscles of betamethasone–treated guinea pig fetuses. Thus, we hypothesize that CS activity will be greater in the muscles of fetal guinea pigs treated with betamethasone compared with control fetuses. Pregnant guinea pigs were injected with either betamethasone (0.5 mg/kg) or sterile water twice a day, 24–hours apart, at 65%, 75%, and 85% gestation. Muscles samples were collected, homogenized, and diluted to a predetermined optimal dilution factor with buffer. A reaction mixture (50 mM imidazole, 0.25 mM DTNB, 0.4 mM acetyl CoA, and 0.5 mM oxaloacetate, pH 7.5 at 37°C) was added, and the maximum reaction rate (Vmax) of CS was measured with a microplate reader at 412 nm. The Vmax values were converted to units of enzyme activity (pmol/min·g wet muscle mass) and the average CS activities of the control and treated muscles were compared. If our hypothesis is supported, infants treated with glucocorticoids could potentially have higher oxidative capacities in their ventilatory muscles than their untreated counterparts. This change would lead to greater fatigue resistance and allow treated infants to better respond to ventilatory challenges.
78.4 BUXMAN, C.L.*; WESTNEAT, M.W.; University of Chicago, Field Museum of Natural History; cmcchord@uchicago.edu

How do triggerfish eat? The evolution of variable feeding behavior in balistid fishes

Muscles in many vertebrates have become repeatedly subdivided, yielding multiple actuators for biomechanical systems. Muscle subdivisions may, with evolutionary change in origin, insertion, or contractile physiology, increase the potential range of behavioral repertoires. The highly subdivided adductor mandibulae muscles of triggerfishes (Teleostei: Balistidae) are an ideal system for investigating the functional significance of a subdivided musculature. Here, we investigated the behavioral consequences of multiply subdivided jaw closing muscles through a series of feeding experiments. Feeding sequences from several morphologically and phylogenetically disparate species were filmed during bouts with different prey items of dissimilar material properties. Video sequences were digitized using 14 landmarks to assess the biomechanically relevant kinematics of the cranium. Kinematic variables were calculated from landmark data, phylogenetically corrected, statistically analyzed and compared across treatments and taxa, and mapped onto the balistid phylogeny in order to identify potential patterns of evolutionary change in feeding behavior. Our results indicate that triggerfishes modulate feeding behavior (low stereotypy and high flexibility). Furthermore, variation in kinematic profiles is only somewhat consistent with phylogenetic disparity. Taken together, our results suggest multiple independent origins of feeding behavior strategies in the triggerfish lineage. Future work will add in vitro and in vivo muscle properties, and several measures of triggerfish jaw performance that, along with the behavioral analyses discussed here, will provide insight into the evolutionary relationship of form and function in this group. Supported by NSF IGERT No. DGE-0903637 and DEB-0844745.

145.1 BYERS, K.J.; RIFFELL, J.A.*; BRADSHAW, H.D.; University of Washington, Seattle; jiriffell@uw.edu

Differential pollinator attraction and processing of flower scent by bumblebees

Flowering plants attract the inspection of insect pollinators using a wide variety of signals, including scent, which can recruit pollinators at a distance and draw them into visual range. We have investigated the role of floral scent in mediating differential attraction between two species of monkeyflowers (Mimulus) reproductively isolated by pollinator preference. The bumblebee-pollinated Mimulus lewisi and the hummingbird-pollinated M. cardinalis are significantly different both in the chemical composition of the volatile bouquet and in the rate of scent production. M. lewisi flowers produce a bouquet of at least 11 monoterpens, dominated by limonene, 2-myrcene, and cis-2-octene. Of these 11 monoterpenes, M. cardinalis flowers produce only limonene, released at just ~1% the rate of M. lewisi flowers. Bumblebees respond more strongly to M. lewisi as measured by gas-chromatograph-coupled single-unit recording from antennal lobe (AL) neurons, and by wind tunnel and two-choice behavioral assays. Three monoterpenes limonene, 2-myrcene, and cis-2-octene are necessary and sufficient to ensure the neural and behavioral response of bumblebees to M. lewisi. These volatiles are also found in the tergal gland of bumblebees, which mediates recruitment and foraging activation of worker bees. Indeed, AL recordings reveal that the M. lewisi floral scent and tergal gland extracts are represented similarly in the bee AL, hinting at a possible signaling co-option between the recruitment pheromone in bumblebees and floral scent in M. lewisi. In this system, floral scent alone is sufficient to elicit differential visitation, implying a strong role of scent in the origin and maintenance of reproductive isolation between M. lewisi and M. cardinalis.

S9–1.4 BYRNE, M; Univ. of Sydney, Australia; mbyrne@anatomy.usyd.edu.au

Impacts of warming and ocean acidification on growth of larval and juvenile sea urchins – from the poles to the tropics

The Temperature Size Rule states that temperature increases development rates of ectotherms faster than growth rates, resulting in smaller body sizes at life history transitions. Thus a decline in body size is predicted to be a response to global warming. Ocean acidification reduces body size in marine ectotherms as growth rates decrease with reduced carbonate availability and physiological hypercapnia. Ocean warming and acidification covary, but it is not known how they will interact to affect development, growth, size at maturity and other proxies of fitness. To address these issues, the response of sea urchin life histories from across world latitudes to warming and acidification was investigated. Exposure to stress early in development can have negative downstream effects because performance of later ontogeny depends on success of early stages. Embryos generated on ocean change conditions are sensitive to warming and may not reach the calcifying stage in the absence of parental acclimation and adaptation. Larvae are sensitive to warming and acidification. The effects of acidification in echinoplutei indicate that the stunting effect of pH/PCO2 is influenced by physiological hypercapnia and teratogenic effects. In long-term rearing of juveniles to maturation acidification reduced body size and warming mitigated this effect. Sea urchins were larger at maturity under projected warming and acidification scenarios suggesting that body size will not necessarily decrease with climate change. Reproductive potential showed a negative response to acidification with varying levels of mitigation by warming. It may be too early to make firm predictions on the effect of marine climate change on body size. The data highlight the need to examine how covarying stressors interact in long-term studies.

111.3 CAHILL, AE; Stony Brook University; acahilll@life.bio.sunysb.edu

Metamorphosis of Crepidula larvae in response to varying conspecific densities and settlement cue concentrations

It is known that larvae of Crepidula spp., like many other marine invertebrate larvae, metamorphose in response to a cue from conspecific adults. However, the relationship between adult density and larval metamorphosis is not well-characterized in C. fornicata or C. plana. On Long Island, C. fornicata occurs at much higher densities than C. plana, which has a patchier habitat. C. fornicata may therefore be less sensitive to conspecific cue than C. plana. Here, I performed a bioassay using adult-conditioned water to examine metamorphosis in both Crepidula spp. in response to cue from conspecific and heterospecific adults. Because metamorphosis in still water rarely mimics field conditions, I varied adult density and measured settlement of C. fornicata larvae in the field. Larvae in both the lab and the field metamorphosed at higher rates with increasing adult density. These results indicate that recruitment in small populations of Crepidula may be limited by the ability of larvae to detect conspecific adults, which in turn has implications for population dynamics at range edges.
The discovery of GnIH is changing the way we view the regulation of sexual behavior and reproductive function in general. GnIH inhibits gonadotropin synthesis and release in vitro and in vivo in both birds and mammals, resulting in a decrease in circulating sex steroids as well as a decrease in sexual behavior. However, the role of GnIH, if any, during the time of parental care is unknown. The transition from sexual and aggressive behaviors to parental care often involves a decrease in circulating testosterone levels that otherwise can interfere with parental care. Based on preliminary results and the negative effects of GnIH on androgen circulation, we characterized hypothalamic GnIH in male and female European starlings (Sturnus vulgaris) over the parental care phase of the breeding season. We found that GnIH−ir peptide expression changes with the first day of incubation and first day of chick care. We conducted an egg removal experiment to examine how unpredictable events (i.e. nest predation) can affect this relationship. Results revealed that GnIH−ir expression changes in response to egg loss. Thus, changes in GnIH−ir expression during these important transitions in parental care may implicate it in the mediation of such behaviors. Finally, we attempted to block GnIH expression in vivo using a recently discovered RFRP (GnIH mammalian homolog) receptor antagonist, RF9, and found that both systemic and central administration in birds does not alter LH circulation as it does in mammals, nor does systemic administration alter parental behavior, as measured by visits to nests. Thus, while RF9 may serve as a potential RFRP receptor antagonist in mammals, its actions do not appear to function similarly in birds.
118.4 CAMERON, CB*; BISHOP, C; Univ. de Montreal, St. Francis–Xavier Univ.; c.cameron@umontreal.ca
Biomineral ultrastructure, elemental constitution and genomic analysis of biomineralization–related proteins in echinoderms
Here, we report the discovery and characterization of biominerals in the acorn worms Saccoglossus kowalevskii and Ptychodera flava galapagos (Phylum: Hemichordata). Using electron microscopy, X–ray microprobe analyses and confocal Raman spectroscopy, we show that echinoderm biominerals are small CaCO₃–aragonite elements restricted to specialized epidermal structures, and in S. kowalevskii are apparently secreted by sclerocytes. Investigation of echinoderm biomineralizing proteins in the translated genome and expressed sequence tag (EST) libraries of Saccoglossus kowalevskii indicates that three members of the urchin MSP–130 family, a carbonic anhydrase and a matrix metalloprotease are present and transcribed during the development of S. kowalevskii. The SM family of proteins is absent from the echinoderm genome. We will present corresponding results from the crinoid Florometra serratisima. These results increase the number of phyla known to biomineralize and suggest that some of the gene–regulatory toolkit, if not mineralized tissue themselves, may have been present in the common ancestor to echinodermates and echiuromorphs.

78.5 CAMP, A.L.*; BRAINERD, E.L.; Brown University, Providence RI; ariel_camp@brown.edu
Hyoid kinematics and haptic muscle strain during suction feeding in largemouth bass (Micropterus salmoides)
To capture food, suction feeding fishes use their kinetic skulls to rapidly expand the mouth cavity both laterally and dorsoventrally. Ventrally, mouth volume is increased by depression and retraction of the hyoid, but the muscular cause of this motion is unclear. This ventral expansion could be produced by the sternohyoid muscle, which attaches directly to the hyoid apparatus at the urohyal. If this is true, sternohyoid muscle shortening should equal urohyal retraction. The ventral body muscles, the hypaxials, could also retract the hyoid by rotating the cleithrum of the pectoral girdle, which is linked to the urohyal by the sternohyoid muscle. In this case, hypaxial muscle shortening should equal urohyal retraction. We tested these hypotheses by measuring urohyal and cleithrum kinematics, as well as sternohyoid and hypaxial muscle shortening, during suction strikes in 3 largemouth bass (Micropterus salmoides). Bone kinematics were measured relative to a body axis plane using X–ray Reconstruction of Moving Morphology. This technique combines bone models with motion recorded from bilateral x–ray video to create 3D animations of bone kinematics. Muscle shortening was measured using fluoromicroscopy, which uses x–ray videos to measure distance changes between intramuscular markers. The urohyal moved both caudally (retraction) and ventrally (depression) relative to the body axis, and the cleithrum was retracted. Hypaxial muscle shortening was similar to urohyal retraction distance, with means of 6.2mm and 8.5mm, respectively, whereas mean sternohyoid muscle shortening was only 0.5mm. The hypaxial muscles generated hyoid depression, via cleithrum retraction, while the sternohyoid muscle acted like a ligament to transmit hypaxial shortening to the urohyal.

112.4 CAMERON, S.F.*; WILSON, R.S.; Uni of QLD, Australia; s.cameron3@uq.edu.au
Sexual dimorphism of Hemidactylus frenatus along a latitudinalcline: testing Rench’s rule in an ectotherm with intense male–male competition in lower latitudes
Rench’s rule predicts that animal populations with greater average body sizes should exhibit higher magnitudes of sexual dimorphism. As higher latitudes are commonly associated with greater average body sizes, a latitudinalcline in sexual dimorphism is also expected to follow suit. However, given sexual dimorphism is driven by gender differences in reproductive fitness, any increases in male–male competition in lower latitude populations could counteract Rench’s rule. To investigate this idea it is necessary to examine a species with intense male–male competition and quantify inter–sexual differences in both morphological and whole–animal performance traits. We used Hemidactylus frenatus as they are found along a large latitudinal range across Australia and are likely to experience intense male–male competition in lower latitudes due to a warmer climate and higher densities. We predicted the magnitude of sexual dimorphism would be stabilized along their latitudinal range due to the interacting effects of Rench’s rule at higher latitudes and increasing male–male competition in lower latitudes. We found greater average body sizes for populations from higher latitudes, however no evidence for Rench’s rule as there was no associated increase in sexual dimorphism with latitude. In contrast, whole–animal performance exhibited a negative correlation with latitude, where individuals from populations from lower latitudes had greater relative biting performances than those from higher latitudes, although no latitudinal variation in inter–sexual differences in performance was found.

35.5 CAMPOS, E.O.*; BRADSHAW, H.D.; DANIEL, T.L.; University of Washington, Seattle; ecampos@uw.edu
Exploring plant–pollinator interactions using 3D printed flowers
Pollination syndromes are suites of floral traits postulated to reflect convergent evolution among distantly related species due to selection by a shared guild of pollinators. We used a four–parameter geometric model of flower shape to construct artificial flowers using computer–aided design software and a 3D printer. The four shape parameters describe corolla curvature, corolla width, flower length, and nectar radius. Our goal is to use these flowers to test whether the shape of artificial flower populations can evolve in response to selective pressures induced by real flower–foraging animals in an experimental evolution study. To assess whether pollinator foraging performance is affected by variation in "floral" shape, we allowed individuals of the hawk moth Manduca sexta to forage freely on dimorphic arrays of 16 artificial flowers. The two morphs in an array differed in only one of the four shape parameters. We find that if the nectary radius is too large (2.5 mm), M. sexta is able to exploit artificial flowers equally well regardless of the values of other shape parameters (mean number of flowers of each morph emptied per foraging trial: 6.0 ± 0.8 SE; 4.9 ± 0.9 SE; p > 0.34). But if nectary radius is reduced to 1 mm, then flower curvature has a significant effect on foraging performance (7.6 ± 0.2; 2.1 ± 0.4; p < 0.01). These results suggest that artificial flowers could experience a selection differential based on shape as a result of visitation by moths.
Behavioral variation among tadpole populations: ecological causes and consequences

Theory predicts that intraspecific trait variation can have important ecological impacts, yet we have a poor understanding of the causes and consequences of trait variation in natural systems. Local adaptation can generate among-population trait differences, and these adaptive variants may have cascading effects on the rest of the ecosystem through interactions of these organisms with other species. Wood frog tadpoles inhabit ponds that range from low-risk (few predators) to high-risk (many predators). High-risk ponds are expected to favor lower activity levels and greater responsiveness of tadpoles to predator cues than do low-risk ponds. We reared tadpoles from a variety of ponds in mesocosms, both with and without caged predators. We measured the behavior of the tadpoles and the predator density in the source ponds. We found that responsiveness to predator increased with predation risk in source ponds while overall activity rate was unaffected. More active tadpoles should have stronger negative effects on periphyton and zooplankton (due to increased foraging), and less responsive tadpoles would result in smaller indirect effects of predators on these lower trophic levels. Preliminary evidence suggests that increased tadpole activity was associated with reductions in periphyton and increases in zooplankton. Behavior in this system varied predictably along an ecological gradient, with apparent consequences for interacting species. This work highlights the potentially important role of ecological differences among communities in shaping, and being reciprocally shaped by, intraspecific behavioral variation.

Metabolic signals differentially regulate trade-offs between the reproductive and immune systems in female Siberian hamsters

Most free-living animals have finite energy stores that they must allocate to different physiological processes. As such, when energy is limited, energetic trade-offs among these physiological systems may occur. In our study, we experimentally limited energy availability to female Siberian hamsters (Phodopus sungorus) with 2-Deoxy-D-glucose (2-DG), a non-metabolizable glucose analog that disrupts cellular utilization of glucose. We observed how treatment with a low or high dose of 2-DG affected energy allocation to the reproductive and immune systems. We predicted that limiting energy availability via 2-DG treatment would decrease reproductive and immune functions. In addition, a subset of hamsters was treated with leptin, an adipose hormone that provides a direct signal of available fat stores. We predicted that leptin treatment would provide a false signal of energy reserves and would reduce the energetic constraints imposed by 2-DG. We found that 2-DG treatment reduced, but leptin did not restore, reproductive tissue mass. Additionally, leptin treatment enhanced innate immunity, as measured by a bacterial killing assay, although 2-DG treatment had no effect on this measure. In contrast, the high dose of 2-DG decreased immunoglobulin G (IgG) production in response to a foreign antigen; however, leptin treatment did not counteract the 2-DG induced decrease in IgG levels. Rather, leptin appeared to enhance the negative effects of 2-DG on IgG levels. Collectively, these findings suggest that an animals current energy balance can affect both reproductive and immune responses but that different metabolic fuels affect energy allocation to the reproductive and immune systems in dissimilar ways.
Feeding kinematics in damselfishes (Pomacentridae): ecological diversity and repeated trophic convergence

The damselfishes represent a species–rich lineage that forms a major component of the fish fauna on all coral reefs, and as such they represent an important part of the vertebrate trophic diversity present in these communities. The evolution of the functional morphology of damselfish skulls is characterized by rapid and repeated shifts between a limited number of trophic niches, such that the adaptive diversification of their trophic ecology has primarily consisted of multiple shifts between three primary feeding niches: herbivory, planktivory and a limited type of omnivory. This pattern of evolution has resulted in repeated convergence on skull shapes that are associated with either primarily benthic–feeding niches (herbivory and omnivory) or pelagic–feeding niches (planktivory). Whether or not the skull kinematics of damselfishes in separate feeding guilds exhibit similar patterns of movement has not been previously studied. Here we examined the feeding kinematics of 5 damselfish species that represent wide coverage of the pomacentrid lineage, and which include an herbivorous species, an omnivore, and three convergently evolved planktivores. We used high–speed video recordings of feeding events from wild–caught fishes captured in the waters around Lizard Island on the Great Barrier Reef. We compare the feeding performance of damselfishes that are both trophically and morphologically diverse, as well as those that are trophically divergent, but distantly related.
8.4 CASTRO, D.A.*; PODOLSKY, R.D.; College of Charleston; diegocastro90@gmail.com

Effects of Limited Oceanic CO₂ and Temperature on Sperm Motility and Swimming Speed in Northern and Southern Populations of the Sea Urchin Arbacia punctulata

Increases in atmospheric CO₂ are raising CO₂ levels in the ocean, driving a decrease in oceanic pH through the process of ocean acidification. Several key biological processes, including calcification and cellular metabolism, are sensitive to small changes in pH. Little is known, however, about how populations evolving under different conditions have responded to variation in CO₂ or to the synergistic effects of CO₂ and other environmental parameters like temperature. Latitudinal comparisons are a powerful way to address such questions. We examined the swimming performance of sperm cells under different CO₂ and temperature conditions for sea urchins (Arbacia punctulata) collected from northern and southern populations in the western Atlantic. Prior work found that increases in CO₂ through about 2.5 times current levels, corresponding to 100 years in the future based on climate models, led to significant linear declines in both sperm motility and swimming speed. We exposed sperm from each population to each of the two respective collection temperatures (14 and 24°C) under a range of CO₂ concentrations (pre-industrial, current, 1.75 times current, and 2.5 times current). We predicted that sperm of northern and southern populations would show differences in the degree of sensitivity to CO₂ at a common temperature. Sperm from southern populations likely show greater sensitivity because a given CO₂ change leads to smaller pH changes in southern waters compared to the same CO₂ change and associated pH change in northern waters. Our results will be discussed in terms of differences expected in the solubility of CO₂ in oceanic upwelling, and in aragonite saturation levels between northern and southern latitudes.

63.3 CAUSEY, D.R.*; REYES, J.A.; WAGGONER, C.M.; HAMILTON, A.W.; ARMSTRONG, J.L.; KELLEY, K.M.; California State University Long Beach; Pacific Coast Environmental Conservancy, Orange County Sanitation District; dwight.causey@gmail.com

PROTEIN EXPRESSION SCREENING IN ENDOCRINE−DISRUPTED, CORTISOL−PRODUCING INTERRENAL TISSUE OF URBAN OCEAN FISH

Wild fish residing near wastewater treatment plants (WWTPs) in coastal southern California have previously been demonstrated to exhibit an endocrine−disrupted condition affecting function of the cortisol−producing interrenal, which is correlated with exposures of the fish to specific classes of environmental contaminants. Fish exhibiting this form of endocrine disruption do not activate a normal neuroendocrine response to stress. Studies of English sole indicate that interrenal response to ACTH is impaired when tested in vitro, and interrenal from these fish exhibit corresponding decreases in expression of steroidogenic activation regulating (StAR) and P450−11β hydroxylase. Using proteomics−based screening, interrenal proteomes were compared between control and endocrine−disrupted English sole captured from reference and WWTP locations, respectively. Analyses thus far reveal that nine proteins were negatively correlated with cortisol response (p<0.05), while twenty proteins were positively correlated (p<0.05). Identification of some of these proteins indicate alterations in expression of heat−shock protein (HSP), aldehyde dehydrogenase, peroxiredoxin, and malate dehydrogenase, suggesting responses including oxidative and cellular stress and altered cellular metabolism. Proteins were also identified that significantly correlated with cortisol response, which are candidate players in the disrupted interrenal condition. (Support from NOAA/USC Sea Grant Program in California.)
Assessing effects of starvation-induced morphological variations on swimming of larval sand dollars with a novel biomechanical model and video motion analysis

Morphylogenies of planktonic larvae of many marine invertebrates are complex and highly variable. Larval morphologies impose biomechanical constraints on vital ecological functions, including swimming. Earlier modeling studies suggest slight changes in larval morphology could compromise swimming performance. However, environmental variables such as food availability and ambient pH often induce morphological changes in larvae. These natural variations suggest the general hypothesis that environmentally-induced morphological changes are coordinated such that larval abilities to perform ecological functions are conserved. To test this hypothesis, we developed a novel protocol to extract geometric meshes representing detailed 3-dimensional larval morphologies from confocal micrographs and used this model to assess the impacts of morphological variations on larval swimming. Larval sand dollars (Dendraster excentricus) are known to be phenotypically plastic and develop longer ciliated extensions arms under food-limited conditions to enhance feeding. In this case study, using non-invasive video motion analysis and the biomechanical model, we tested the specific hypothesis that the starvation-induced morphological changes alter larval swimming. Video analysis results showed that 4-arm larval sand dollars swam in wider helices and had higher oscillatory speeds when starved. In still water, the model larvae had different passive sinking behaviors, suggesting the observed morphological variations had biomechanical implications. The observed differences in larval swimming could be a result of both changes in biomechanics and behaviors. Our results support the general hypothesis that environmentally-induced morphological variations, including starvation, are coordinated to balance ecological functions tradeoffs.

Family-level analysis of exploited and at-risk ray-finned fish species shows high potential loss of biodiversity

Commercial harvesting of ray-finned fishes is both intense and widespread. The distribution of this pervasive exploitation and its attendant risk of extinction with respect to phylogeny is not currently well-understood. Previous studies have shown that clustered extinction increases the loss of trait diversity, which have both short-term (lower yield, reduced ecosystem services) and long-term effects (lost evolutionary history, biodiversity). We used several previously published phylogenies of families with exploited species and constructed additional phylogenies using phyloWAD. Species on these phylogenies were matched to exploitation and extinction risk data collected from fishbase.org, the IUCN Red List, and the Sea Around Us Project. Our results show a highly significant clustering of extinction risk and exploitation among many of the fish clades examined. Additionally, the pattern of these clustered extinction risks would lead to a significantly increased loss of evolutionary history compared to a pattern of random extinction, maximizing the potential threat to biodiversity. We also analyzed the rate of body size evolution using auTeur, and found that in some families species that are at risk for extinction or are experiencing exploitation pressure tend to evolve a significantly faster rate of body size evolution. This finding, in conjunction with the threat of a high loss in evolutionary history, suggests that commercial harvesting of fish is pruning away particularly exceptional branches on the fish tree of life.

Comparative transcriptomes of cnidarian freshwater parasites

The myxozoan Myxobolus cerebralis and the enigmatic Polypodium hydriforme are both parasites with extremely unique life cycles and aberrant body plans specialized to parasitize certain economically relevant fish species. Both have been suggested to have phylogenetic affinity with cnidarians because of the similarity of their polar capsules to nematocysts. This has been supported by some molecular analyses. However, because they are morphologically distinct from each other and any other cnidian, their phylogenetic placement within Cnidaria is unresolved. The large scale of information provided by next generation sequencing appears promising for shedding light on some of these questions. We have sequenced, assembled, and are characterizing the transcriptomes from both of these species, in the hopes of refining the phylogenetic placement of these organisms and investigating developmental and morphological transitions which occurred in their evolution. Because these are both parasites that live among host tissue, the analysis of these transcriptomes involved the development of a post-sequencing contamination filtering method based on a series of hierarchical BLAST searches, which could be applied to other situations in which contamination before sequencing cannot be avoided. As part of this effort, we have isolated genes that appear to be homologous to nematocyst-specific genes. Obtaining transcriptomes allowed for the rapid discovery of potentially informative candidate genes for future phylogenetic and developmental studies, that will yield insight into the evolution of these highly divergent life cycles and morphologies.

Do Tropical Birds From Andean Forests Have Low Basal Metabolism?

Recent studies by Joe Williams, Popkko Wiersma, and colleagues indicate that tropical forest birds from Panama have significantly lower basal metabolic rates (BMR) compared to birds from higher latitudes. This finding was attributed to the slow pace of life of tropical species (e.g., life history characterized by long lifespan, delayed maturation, low reproductive investment). To expand these results with data from a geographically distant tropical region, we measured BMR in 120 bird species from three field stations along the eastern Andean slope in Peru. The stations (400 m, 1400 m, and 3000 m elevation) include habitats ranging from hot, humid lowland Amazon forest to cool, high-altitude cloud forest. Birds were mist-netted and measured at night under conditions appropriate for determining BMR (ambient temperature 30-34 °C, fasted for >5 h, stable and low metabolic rate, body temperature > 35 °C). We compared our BMR results to the data in Wiersma et al. (2007), and to the stringent BMR allometry generated by McKechnie and Wolf (2004). Both of the latter datasets include temperate as well as tropical species. We also tested for effects of altitude on the BMR of Andean birds, as there are substantial environmental temperature differences between the stations.
99.3 CHAVEZ, A.A.; GORMAN, C.; ERKEN, M.; MCDougald, D.; STEINBERG, P.D.; NISHIGUCHI, M.K.; New Mexico State University, University of New South Wales, University of New South Wales; nish@nmsu.edu

Predation response of Vibrio fischeri biofilms to protozoan bacteriovores

Vibrio fischeri is a bioluminescent marine bacterium found worldwide, an active member of the bacterioplankton community, and has been used as a model system to study their beneficial associations with sepialid squids. V. fischeri also proliferates in a sessile, stable, community known as a biofilm, which is one alternative survival strategy of its life cycle. Although this survival strategy is adequate protection from abiotic factors, marine biofilms are still susceptible to grazing by bacteria−consuming protozoa. Subsequently, grazing pressure can be controlled by certain defense mechanisms that confer higher biofilm−anti−predator fitness. In the present work, we hypothesize that V. fischeri exhibit an anti−predator fitness behavior while forming biofilms. Different predators, representing commonly found species in aquatic communities were examined, including the flagellates Rhynchosomans nasuta and Neobodo designis (early−biofilm feeders), and the ciliate Tetrahymena pyriformis (late−biofilm grazer). V. fischeri biofilms included isolates from both seawater and squid hosts (Euprymna and Sepiola). Our results demonstrate inhibition of predation by biofilms, specifically isolates from seawater strains. Additionally, anti−protozoan behavior was observed to be higher in late biofilms, particularly from the ciliate T. pyriformis; however, inhibitory effects were found to be widespread among all isolates tested. These results provide an alternative explanation for the adaptive advantage and persistence of V. fischeri biofilms and provide an important contribution in the understanding of defensive mechanisms that exist in the out−of−host environment.

50.5 CHAVEZ, A.A.; GORMAN, C.*; LOSTROH, C.P.; NISHIGUCHI, M.K.; New Mexico State University, Colorado College; nish@nmsu.edu

Genetic switches control host specificity in a squid−Vibrio symbiosis

Gap repair is a technique that has historically been used to clone entire operons by using the natural recombinant homologous cloning mechanism in Saccharomyces cerevisiae. By using S. cerevisiae in vivo recombination, we can manipulate and express operons from different Vibrio fischeri strains from geographically distinct squid host populations to determine if suites of genes are responsible for the specificity observed among closely related host−symbiont pairs. V. fischeri ES114 genomic DNA (isolated from Euprymna scolopes, a Hawaiian squid host) was then used as the nucleotide template; the targeted operon and the gapped vector was digested and simultaneously introduced into yeast cells allowing recombination. V. fischeri can then be transformed with the new vector by tri−parental mating to contain entire operons/regulons from the other strain, in this case V. fischeri ETJB1H (isolated from E. tasmanica, an Australian squid host). This technique allowed us to execute a detailed investigation of the importance in strain−specificity of these gene operons in vivo. Subsequently, two different squid host species (E. scolopes and E. tasmanica) were used to test colonization abilities and competition of the constructed strains. Results indicate that after mobilizing lux and pil operons from ETJB1H to ES114, colonization of the constructed strain was equivalent to the efficiency observed for the native strain; the same was observed for the msh operon, but in this case after mobilization from ES114 to ETJB1H. Thus, competitive ability based on symbiotic loci is not equal among closely related strains of Vibrio. Deciphering how the evolutionary history of specificity between closely related Vibrio strains occurred may give insight to the function of competence and inter−strain genetic specificity.

28.4 CHENEY, JA*; MIDDLETON, KM; KONOW, N; GIBLIN, EL; BREUER, KS; SWARTZ, SM; Brown University, Providence, RI; University of Missouri, Columbia; jornc.chene@brown.edu

Electromyography of bat wing membrane muscles

Bat wing membranes consist of a double layer of skin, and this architecture makes them thin, lightweight, and compliant. A number of small muscles, the plagiopatagiales, are embedded in the membrane, oriented approximately along the chord of the wing. These muscles both originate from and insert into this membrane. It has been hypothesized that the plagiopatagiales function to tense the membrane, which would reduce wing compliance and decrease wing camber. For this hypothesis to be correct, the plagiopatagiales must be active during flight. Further, we predict that if these muscles function to reduce wing camber by increasing membrane tension, their activity should occur during downstroke, when the membrane is cambered due to significant load. This activity pattern should only hold during steady flight. However, when a flight behavior must maximize lift, such as during landing, we expect that the muscle activity and intensity would change in order to maximize wing camber. To determine when these muscles are active during flight, if at all, we used fine−wire electromyography. We implanted sew−through electrodes in a single plagiopatagialis muscle in four individuals of the Jamaican fruit bat (Artibeus jamaicensis). Using a lightweight cable, we recorded electromyograms from the muscle during both steady flight and landing maneuvers in a wind tunnel. Consistent with our hypotheses, we found that, during steady flight, the plagiopatagiales were active during the downstroke, and during landing events, the periodic pattern of activity and recruitment changed. Overall, our results are consistent with the idea that the plagiopatagiales modulate wing camber during flight.

137.2 CHINA, V*; HOLZMAN, R; Tel Aviv University, The Interuniversity Institute for Marine Sciences in Eilat; victor.china@gmail.com

The crucial effect of hydrodynamics on feeding efficiency during the critical period of fish larvae

Survival of the larval stage of marine fishes has far−reaching consequences in determining their rates of settlement, population size and stability. While feeding performance is known to play a central role in determining survival, there is little information on the mechanisms of prey capture by fish larvae. The hydrodynamic forces that govern suction feeding performance are expected to change through the larvae’s ontogeny, as the larvae transition from a viscous−dominated regime to a realm of higher Reynolds numbers. We used numerical simulations, feeding experiments and high−speed video observations to test the direct effect of viscosity on larval feeding performance. Computational fluid dynamic (CFD) simulations revealed that the flow generated at small mouth sizes is characterized by shallow spatial gradients compared to that measured for high Reynolds numbers. Prey−capture rates were positively correlated with larval size and negatively correlated with viscosity; primarily due to mechanistic effects of the suction flow and reduced capture success. High−speed photography indicated that in order to feed successfully under conditions of increasing viscosity, the larvae had to open their mouths faster and wider. Starvation is considered a primary cause of mortality in the early stages of larval fishes, as suggested a decade ago in Hjorts critical period hypothesis. Our findings reveal severe hydrodynamic constraints on the efficiency of suction−feeding at the size range typically associated with that critical period. These constraints could explain starvation and low survival of larval fish and also imply an evolutionary constraint on the minimal larval size at hatching.
30.1 CHRISTY, JOHN H; Smithsonian Tropical Research Institute; christyj@si.edu

**Extreme synchrony, amplitude modulation and phase reversals in the semilunar reproductive cycle of the intertidal false limpet Siphonaria gigas on a rocky shore in Panama**

Many intertidal organisms produce gametes or larvae once or twice each lunar month when tidal conditions most favor survival of these vulnerable early life stages. On shores with semidiurnal tides, the changing phase relationship between the lunar synodic (29.53 days) and anomalistic (27.55 days) cycles modulates the amplitude between successive spring and neap tides. Approximately every 7 months the amplitude difference changes from one half--lunar phase to the other (e.g., switches from new to full moon, or first to last quarter, and then reverses 7 months later). I continuously monitored the semilunar cycle of egg production by the false limpet Siphonaria gigas for 4.5 years and found that this simultaneous hermaphroditic tracks this complex tidal pattern. Individuals attached ribbons of eggs in jelly whorls to the rock over a two--day period twice each lunar month with most eggs deposited 1 day before the lowest neap tides. Eggs hatched to veliger larvae in 4 6 days. The intensity of reproduction varied inversely with the heights of the neap tides. Consequently eggs were covered by the tide for the least amount of time before they hatched. When the difference in heights between successive neap tides was large, the limpets produced eggs only on the neap set with lower high tides. Every 7 months when the neap tide height difference shifted between the first and last quarter moons the limpets too shifted their timing, but not immediately, leading to two or more out--of--phase egg deposition cycles. Extreme synchrony and precise timing of egg deposition to correspond with the lowest tides in the month may protect eggs best from predation by fish.

34.4 CHU, K.H.*; TSANG, L.M.; WU, T.H.; The Chinese University of Hong Kong; kahouchu@cuhk.edu.hk

**High genetic divergence among Hong Kong stream faunal populations: Implications for biodiversity conservation of freshwater ecosystems**

Freshwater organisms generally exhibit much more pronounced genetic structuring than their marine counterparts. While understanding the level and spatial distribution of genetic diversity is crucial for conservation management planning, such information has received little attention until recently in highly developed cities like Hong Kong and Singapore, where local extinction caused by habitat loss and degradation is severe. Here we compared the genetic divergence in mitochondrial genes of common freshwater fauna, represented by nine species of fishes and five species of inverteterbrates, collected from more than 20 streams in Hong Kong covering a land area <1,000 km². Surprisingly, except in three species of fishes, all species exhibit pronounced genetic architecture, with population in each stream frequently having its own unique haplotypes, even though some of the streams are separated only by a few kilometers. Moreover, genetic diversity within each stream is very low, usually with a single haplotype dominating the entire population. This reflects a low effective population size commonly observed in fragmented populations. The congruence in population subdivision observed across fauna suggests long term isolation among streams. Since conservation measures are often only considered long after urban development has begun, unexpected high genetic diversity of freshwater fauna over short distances has significant conservation implications as a substantial amount of biodiversity may have already been lost due to past development. Careful conservation planning of freshwater ecosystems is needed for future development in Hong Kong and elsewhere.

62.6 CHURCHILL, C.K.C.*; ALEJANDRINO, A.; VALDÉS, A.; Ó FOIGHIL, D.; University of California, Santa Barbara, Iowa State University, California State Polytechnic University, Pomona, University of Michigan, Ann Arbor; celia.churchill@gmail.com

**Parallel sexual rekeying supports non–geographic planktonic speciation**

The relative roles of geographic and biological barriers as mechanisms of genetic isolation are highly debated in evolutionary biology, yet knowing how speciation occurs is essential to our understanding of biodiversity. In the open ocean, differentiating the two is particularly difficult because of the high levels of gene flow found in pelagic communities. The marine neuston is a promising system for investigating planktonic speciation mechanisms; located at the surface of the planets subtropical oceans, the neustons isobathic nature renders it exceptionally tractable both for sampling and understanding localized ecological variation. Here, we use molecular phylogenetics to test the hypothesis that geography is the primary isolating mechanism in a group of predatory neustonic nudibranchs with simultaneous hermaphroditic reproduction (Glaucinae). Glaucinae comprises two valid species with different distributions: *Glaucus atlantis* is circumtropical and *G. marginatus* is Indo--Pacific. Our results are the inverse of allopatric expectations: *G. atlantis* is panmictic, whereas *G. marginatus* contains four species in two clades with overlapping distributions. Within the *G. marginatus* species complex, a parallel reproductive change has occurred in each cryptic species pair: the loss of a bursa copulatrix. We hypothesize that its presence or absence affects mating behavior by changing the mechanics of penial insertion. Our results show that details of genital morphology are better predictors of latent evolutionary relationships among glaucinid lineages than biogeography, and support biological isolation as the primary driver of speciation novel result in a planktonic system.

83.4 CIELOCHA, J. J.*; YONEVA, A.; JENSEN, K.; Univ. of Kansas, Bulgarian Academy of Sciences; jjielocha@ku.edu

**Insights into spermatozoon ultrastructure of lecanicephalidean tapeworms (Platyhelminthes: Cestoda)**

Spermatozoon ultrastructural characters have shown to be informative in phylogenetic studies in many invertebrate groups. Comparative data on sperm ultrastructure among cestode orders, though information for the elasmosbranch cestode order Lecanicephalidea is limited. The only previous data on lecanicephalidean sperm ultrastructure came from a specimen of *Tetragonocephalum* (Justine, 2001). Mature spermatozoa of *Tetragonoccephalum* were described as possessing a single acrosome, crested body, and parallel cortical microtubules. Based on these data, Levron et al. (2010) postulated a spiral nucleus. Specimens of *Tetragonoccephalum* as well as three additional lecanicephalidean genera were collected from rays from the Solomon Islands and fixed for transmission electron microscopy (TEM). Posterior proglottids with well—developed external seminal vesicles were cut from the strobila of each individual and processed for TEM. Proglottids were embedded in Spurr's resin. Ultrathin sections were cut on an ultramicrotome, mounted on copper grids, double stained with uranyl acetate and lead citrate, and observed with TEM. A single acrosome, crested body, parallel cortical microtubules and spiral nucleus were observed in individuals from all four genera. While spermatozoa of *Cephalobothrium* and *Adelobothrium* possessed a single crested body and ten parallel cortical microtubules medial to the restod body, *Flapoccephalus* appears to have two crested bodies, and *Tetragonoccephalum* possesses 20 parallel cortical microtubules peripheral to the crest body. In general, these characteristics are consistent with the minimal data available for species of closely related cestode orders, however the degree of variation was unexpected. The phylogenetic utility of spermatozoon ultrastructural characters can only fully be tested with a broader sampling of species within other cestode orders.
Manipulating central fatigue in mice bred for high voluntary wheel running using a serotonin agonist and antagonist

Central fatigue limits the performance of an organism to less than the level that might be predicted by classic models of physiological maxima, and numerous studies have shown that the concentration of serotonin (5-hydroxytryptamine; 5-HT) in the brain increases at the onset of fatigue. Central fatigue has been studied primarily in relation to forced exercise, and not voluntary exercise. We hypothesized that neurobiological differences related to central fatigue could explain evolutionary differences in both endurance capacity and levels of voluntary exercise. Mice from 4 lines that had been selectively bred for high voluntary wheel running (HR lines) for over 60 generations were previously shown to have higher endurance than those from 4 non-selected control (C) lines. We predicted that a 5-HT1A agonist (8-OH-DPAT) or antagonist (WAY 100 635) would alter endurance and the evolutionary advantage of HR lines during forced exercise. Male mice were endurance-tested three times using a forced treadmill protocol at 7–9 weeks of age under a randomized series of three pharmaceutical conditions, a vehicle injection, a low-dose of the designated drug (0.2 mg/kg body mass for 8-OH-DPAT and 35 µg/kg WAY 100 635) or a high dose (2 mg/kg body mass for 8-OH-DPAT and 350 µg/kg WAY 100 635). Time and distance to exhaustion were recorded. The same mice were then given wheel access for 14 days, until wheel running had reached an apparent plateau, and then subjected to a similar set of injections during the nightly peak of wheel running (1 injection/night) while wheel revolutions were recorded automatically. Supported by NSF Predoctoral Fellowship to GC and NSF grant IOS–1121273 to TG.

Fractal radiation; repeated patterns of diversification along an axis of body elongation in fishes

We explored patterns of body shape diversification in the mega-diverse spiny-rayed fishes. Geometric morphometric tools were used with landmark data collected from lateral-view photographs to characterize body shape for more than 2000 species of spiny-rayed fishes belonging to more than 40 families. Across the entire data set the first principal component of morphological variation reflects the extent of body elongation or shortening. When we conducted a separate PCA on each fish family we found the most common first PC reflects body elongation. Using available time calibrated species-level phylogenies for several individual families we worked up from the base to the tip of each tree, calculating PCAs at each node. At most nodes variation in body elongation characterized the first PC, even at very shallow phylogenetic scales. This fractal pattern, where elongation is the dominant axis of body shape evolution, whether the scale is across spiny-rayed fishes or within much smaller clades that are less than 10 million years old, indicates that fish body shape evolution has been characterized by repeated, similar changes in elongation. The repeated nature of the pattern raises the question of whether the morphology and developmental genetics underlying this axis of shape change is consistent, and highlights the importance of understanding the morphological and genetic underpinnings of this axis of body shape as well as its performance and ecological consequences.

Effects of morphological phenotypic plasticity on cichlid transcriptome expression

Trophic divergence in cichlid fish is linked to shifts in pharyngeal jaw morphology. However, it is unknown how much of this dramatic trophic specialization is due to the ability of these species to respond dynamically to their preferred diet type. Hypertrophy is observed in the major muscles of the lower pharyngeal jaw muscular sling in response to a diet shift in lab-reared *Vieja maculicauda* cichlids. We used next-gen whole transcriptome sequencing to identify genes that are up- and downregulated in these muscles in response to diet shifts.

Does Size Matter? The Interaction of Body Size, Temperature and Nutrition

Temperature is a major factor that influences an ectotherms growth and development. Importantly temperature impacts herbivorous higher thermal biology in multiple ways. Variation in temperature can lead to changes in an animals nutritional requirements as well as the efficiency that they can extract and convert nutrients to body mass. In addition, the ratio and amounts of nutrients an animal can obtain varies with both temperature and plant species. This interactive effect has led to Locusta migratoria (African Migratory Locust) both following and reversing the Temperature Size Rule, a form of phenotypic plasticity where ecotones typically grow larger but more slowly as temperatures decrease. Recently we have shown that a smaller locust, *Chortoicetes terminifera*, does not show any effect of temperature on final body size. Smaller locusts are more efficient at extracting nutrients; hence the initial size of an herbivorous insect may have profound effects on the degree with which temperature impacts nutritional outcomes. We will discuss results of the morphological and behavioural implications surrounding the interaction of temperature and nutrition, such as the importance of host plant selection, thermoregulation and microclimate use, and the potential impacts future climate change may have on body size.
Running on water: The impressive rushing behaviour of Western and Clark's Grebes

As foot–propelled diving birds, Western and Clark's grebes (Aechmophorus occidentalis and clarkii) spend almost their entire life in the water. They rely heavily on their powerful legs and unique lobate feet to hunt for fish, sometimes diving over 40 meters. But, grebes are best known for their elaborate pair bonding displays. The most spectacular display, rushing, is performed by these two species, which involves the birds lunging out of the water and running across the surface. Weighing up to 2000g (an order of magnitude larger than the Basilisk lizard), rushing grebes are the largest animals to run on the water surface without the aid of wing flapping. We present the first quantifiable high–speed footage of rushing (filmed at 325 fps). Previous estimates from sound recordings suggest that the birds use 16–20 steps per second as they run, traversing 5–20 meters. We find rates up to 22 steps per second and observe that birds with step rates less than 13 steps per second are unable to sustain rushing, ending early with a dive. Kinematic analyses of Basilisk lizards have shown that they must always keep one foot submerged, whereas some grebes exhibit an aerial phase. The movements of the birds show that Western and Clark's grebes exploit their unique hindlimb morphology during this display. The asymetrically lobed feet are fully splayed for maximal impulse during the water slap. The trajectory of the foot through the water makes use of the flattened tarsometatarsus. While the unusual grebe hind limb has been suggested to be important for underwater swimming, it is likely that it has also enabled rushing. Future work will quantify the hydrodynamic forces during rushing and analyze specific contributions of hindlimb elements.
Agile airframes II: closing the loop on abdominal actuation

Flying organisms achieve flight stability by employing a multitude of control surfaces, most notably the wings. However, airframe deformations, such as abdominal motions in the hawk moth Manduca sexta, have recently been shown to play a significant role in stabilizing flight. We sought to determine the control potential of abdominal deflections using a closed-loop flight arena. Tethered moths controlled the velocity of a projected black bar with their abdominal angle. Image velocity varied according to the difference between the abdominal angle and the set point (relative to the average abdominal angle). Poor performance (<50%) during low gain trials was characterized by steady state error, likely the average abdominal angle, scaled by a gain factor. Experimental trials were performed for a ten-fold range of gains at three different set points and consisted of 60s periods during which the moths attempted to stabilize the drifting bar. We measured performance as the percentage of trial time in which the animal stabilized image velocity below 5%. The moths were capable of stabilizing the image for all experimental conditions, with the highest average performance (50%) occurring at the medium gain and the set point corresponding to the average abdominal angle. Poor performance (<50%) during low gain trials was characterized by steady state error, likely the result of the relatively low image velocities. For high gain trials, the decreased performance (<35%) was characterized by large abdominal oscillations. These results support an active and plastic role for the abdomen in flight control, but also tested the limits of the abdominal control circuit. Adaptation to the range of gains indicates that the controller is robust to changes in body dynamics, while changes in set point demonstrate the behavior is learned and not reflexive.
Developmental and genetic basis of a morphological novelty in East African cichlids

The production of novel phenotypic variation provides new traits on which selection can act and is often associated with expanded ecological opportunity. For this reason the developmental and genetic origins of phenotypic novelty are key questions in evo-devo research. The massive adaptive radiation of East African (EA) cichlids is most commonly associated with convergence, but there are also several instances of novelty that have evolved in this group. Craniofacial variation is a major axis of divergence among EA cichlids, and a species at the far end of the phenotypic spectrum, *Labeotropheus fuelleborni* (LF), has an enhanced facial feature of unknown form and function. This novelty is a fleshy elongated snout (flap) that rests on the upper jaw, and is absent from any other cichlid, including a phenotypically similar ecological competitor, *Tropheops red cheek* (TRC). We analyzed flap development in both species and found that it begins to diverge relatively late in development when fry are about 1.4 cm in standard length, at which point the flap continues to grow isometrically in LF and plateaus in TRC. We also generated an F2 hybrid mapping population from a cross between LF and TRC, and a high-resolution linkage map in order to perform quantitative trait loci (QTL) mapping for flap size. We identified three significant QTL, which is consistent with our estimated number of loci (Castle–Wright estimator = 4–5 factors). Further, our QTL model is consistent with both a dominant and additive mode of inheritance, with little evidence for epistasis. Given these data and the tractability of this system, we are poised to identify the specific genetic loci and developmental mode of action involved in the evolution of this trait as well as a foundation for its ecological and biological significance.

Molecular and biochemical observations of *Mytilus californianus* under constant submergence

The mussel *Mytilus californianus* reside predominantly in the intertidal zone, a fluctuating environment at the interface of the terrestrial and marine biomes. However, cryptic populations have been found occupying subtidal regions offshore, which raise questions about what physiological mechanisms allow *M. californianus* to thrive in both environments. As a sessile species *M. californianus* encounters hourly, daily and seasonal fluctuations in oxygen, temperature, salinity and nutrient availability as a consequence of tidal and climate processes; whereas, these same physical and biological factors are comparatively more stable in subtidal environments. In order to investigate the link between intertidal and subtidal physiology, we performed transcript and metabolite screens of mussels held under constant submergence and compared the results to our previously published screens of mussels in a simulated intertidal environment. Specifically, submersed mussels were observed to exhibit either an open or closed valve state corresponding to periods of active cardiac activity and bradycardia respectively, and gill tissue was sampled from individuals exhibiting both states. Enrichment analysis of significantly expressed genes revealed that genes up-regulated in mussels exhibiting bradycardia and active activity were enriched for genes expressed during the simulated low and high tide respectively. A metabolomics screen revealed elevated levels of succinate, malate and alanine in mussels exhibiting bradycardia which suggested the activation of anaerobic pathways that are known to be induced during aerial exposure. Additionally, we observed higher levels of carnitine-conjugate intermediates of the fatty acid derivatives and branched-chain amino acid (BCKA) catabolism.

Evolution of thermal plasticity in changing environments.

Environmental fluctuations should favor genotypes that can perform across a broad range of conditions. When these fluctuations occur primarily among generations, developmental plasticity should evolve. Although genotypes from different populations frequently differ in their plasticity, no general support exists for the idea that more environmental variation leads to greater plasticity. We studied the evolution of developmental plasticity in populations of *Drosophila melanogaster* that had evolved for more than three years in one of four environments: two constant environments (16 and 25°C), a temporally variable environment (alternating between 16 and 25°C each generation), and a spatially variable environment (gene flow between sub-populations at 16 and 25°C). Flies that evolved in the temporally variable environment had greater plasticity of fecundity than those that evolved in constant or spatially variable environments. However, this greater plasticity of fecundity might have come at the cost of poor heat and cold tolerance; flies from the temporally variable lines had shorter survival during heat exposure and slower recovery from cold exposure than did flies from the other selection lines. These results suggest a tradeoff between plasticity and tolerance.

Is dewlap color an honest indicator of health in Anolis lizards? An analysis of population differences in body condition and parasite load.

Vibrantly colored ornaments often vary among members of the same species, and in some cases, such variability communicates information about the quality of an individual. However, which factors produce this variation is not well understood in many taxa. *Anolis* lizards possess dewlaps, brightly colored throat fans that are absent from any other species, and in some cases, such variability communicates information about the quality of an individual. However, which factors produce this variation is not well understood in many taxa. *Anolis* lizards possess dewlaps, brightly colored throat fans that are extended during behavioral interactions and vary in coloration both across the genus, and within the same species or even the same population. In this study, we investigated whether dewlap coloration serves as an indicator of two measures of male quality—body condition and parasite load. For each individual, we measured body length and mass, counted ectoparasitic mites, and quantified dewlap coloration using objective spectrometry. Measures of dewlap color were correlated with body condition and parasite load in each of the species when the analyses combined samples from all elevations; however, the relationships between color, body condition, and parasite load differed across the elevational sites. These results suggest that ecological factors at the different elevations, such as diet or temperature, may contribute more to dewlap color variation across populations than general animal health.
28.2 COOPER, LISA N*; SEARS, KAREN; SIMMONS, NANCY; NEOISED, Ohio, University of Illinois, Urbana-Champaign, American Museum of Natural History, New York; lnoelle.cooper@gmail.com

Regional alterations in bone thickness and density helped bats acquire active flight

The origin and diversification of bats are intimately linked with flight, therefore bats face a host of locomotor challenges not encountered by terrestrial mammals. For decades biologists have presented the need for elongated wing bones as one of the primary selective pressures shaping bat locomotor morphology and behavior. Only recently, biologists have reported that bat wing bones display decreased cross-sectional geometries and densities relative to terrestrial mammals. These architectural novelties likely increase bone compliance to accommodate the high bending strains that result from powered flight. This study investigates this fundamental issue of chiropteran bone function by testing hypotheses that relate evolutionary bone architecture with in vivo bone function. High resolution micro-CT scans of a taxonomically diverse sample of approximately thirty extant bats showed that, compared to terrestrial rodents, bats displayed thinner cortices forelimb and vertebral elements, and the mandible was only 80–85% as dense. Hindlimb elements showed a surprising range of thicknesses that were correlated mostly with locomotor patterns. Preliminary character state reconstructions, using mice as an outgroup, showed that the evolution of forelimb cortical bone thickness displayed little homoplasy, and the megabat Cynopterus displayed unusually thick cortices. Taken together, these data based on scans of the appendicular and axial skeletons of bats and mice showed that lightening of the chiropteran skeleton is localized to modify the wing bones and is therefore associated with the acquisition of active flight, rather than a systemic lightening of the entire skeleton.

103.4 COOPER, B.S.*; HAMMAD, L.A.; MONTOUTH, K.L.; Indiana University; brasscoop@indiana.edu

The evolution of cellular generalization and specialization in natural populations of Drosophila melanogaster

Changes in the environment can profoundly impact the fluidity of cell membranes. For small insects like Drosophila melanogaster, both changes in temperature and amounts of environmental ethanol perturb membrane fluidity. When environments vary greatly, alleles that enable cellular generalization should be favored by selection. Antagonistic pleiotropy and mutation accumulation, however, can create negative genetic correlations in fitness across environments leading to decreased performance of generalist relative to specialist genotypes. Our previous work has shown that an increased degree of cellular plasticity evolves in an experimentally variable environment, consistent with the selective advantage of an environmentally sensitive allele with associated costs in constant environments. This evolution of increased cellular plasticity enables specialization within generations in environments that vary among generations. Here, we extend this work to natural populations by evaluating the evolution of cellular generalization and specialization in populations of D. melanogaster from Vermont, Indiana, and North Carolina. We use two measures of the lipid composition of cell membranes as indices of physiological plasticity (a.k.a. acclimation) to evaluate the evolution of cellular generalization: (1) change in the ratio of phosphatidylethanolamine (PE) to phosphatidylcholine (PC) and (2) change in lipid saturation in cool (16ºC) relative to warm (26ºC) developmental conditions. We then evaluate the composition of cell membranes within each developmental environment to identify the evolution of cellular specialization in environments that differ in mean temperature. Our results shed light on the mechanisms underlying the evolution of generalization and specialization in environments that differ in mean and variance of temperature.
118.3 CORREA, S.*; ZOBEL−THROPP, P.; BINFORD, G.; SUTER, R.; GARB, J.E.; University of Massachusetts Lowell, Lewis and Clark College, Vassar College; scott098@ucre.edu
Exploring the silk and the silk−like venom from the spitting spider Scytodes thoracica.

Scytodids have evolved a unique way to capture prey from a distance. Scytodids spit an adhesive glue from their fangs onto prey. The ejected material contains long, fibrous strands with structural similarities to abdominal spider silk. We characterized venom and silk gland proteins from a spitting spider species, Scytodes thoracica, to determine its composition and possible evolutionary connections between the silk−like venom and their abdominal silk proteins (spidroins). We identified two novel spidroins: S. thoracica fibroin 1 and 2 showing the characteristics of all known spidroins, including repetitive sequences and conserved C−terminal domains. Amino acid composition analyses indicate that S. thoracica fibroin 1 is the major component of the major ampullate silk from this species. S. thoracica dragline silk was found to have high toughness, but was not as tough as previously described. Phylogenetic analyses suggest that proteins comprising spider dragline silk evolved independently, and is attributed to multiple gene duplication events. Forty percent of S. thoracica venom gland cDNAs encoded a family of glycine rich peptides, whereas another 17% of venom cDNAs encoded putative venom toxins. No venom cDNAs were homologous to spidroins, but the high expression of glycin−rich peptides suggest they constitute a major component of the Scytodes venom spit. Results indicate that scytodids evolved a unique way of synthesizing a fibrous silk−like material from their venom glands using novel proteins, supporting the proposed novel silk gene hypothesis.

85.1 COUGHLIN, DJ.*; WOYTANOWSKI, JR; Widener Univ.; djcoughlin@widener.edu
Thermal Acclimation in Rainbow Smell, Osmerus mordax, Leads to Faster Myotomal Muscle Contractile Properties and Improved swimming performance.

Rainbow smelt (Osmerus mordax) display an impressive ability to acclimate to very cold water temperatures. These fish express both anti−freeze proteins and glycerol in their plasma, liver, muscle and other tissues to avoid freezing at sub−zero temperatures. Maintenance of glycerol levels requires active feeding in very cold water. To understand how these fish can maintain activity at cold temperatures, we explored thermal acclimation by the myotome of smelt exposed to cold water. We hypothesized that cold−acclimated fish would show enhanced swimming ability due to shifts in muscle contractile properties. We also predicted that shifts in swimming performance would be associated with changes in the expression patterns of muscle proteins such as parvalbumin (PV) and myosin heavy chain (MyHC). Swimming studies show significantly faster swimming by smelt acclimated to 5°C compared to fish acclimated to 20°C. The cold−acclimated fish also had faster muscle contractile properties, such as a maximum shortening velocity (Vmax) almost double that of warm−acclimated fish. Cold−acclimation is associated with a modest increase in PV levels in the swimming muscle. More significantly, fluorescence microscopy using anti−MyHC antibodies indicates that MyHC expression in the myotomal muscle shifts in response to cold water. The complex set of physiological responses that comprise cold−acclimation in smelt includes modifications in muscle function to permit active locomotion in cold.
Proximate and ultimate mechanisms for intraspecific variation in male body size and sexual size dimorphism in the brown anole (Anolis sagrei)

Intraspecific variation can arise from genetic changes due to variation in selection and/or from phenotypic plasticity in response to local environmental conditions. These processes can differentially impact males and females, leading to intraspecific variation in sexual dimorphism. We combined studies of natural selection in the wild with common-garden studies in captivity to investigate the proximate and ultimate basis of intraspecific variation in male-biased sexual size dimorphism (SSD) in two island populations of the brown anole, Anolis sagrei. In the wild, SSD was significantly greater on Exuma than on Eleuthera. This difference arose primarily from intraspecific variation in the growth and body size of adult males, rather than females. However, patterns of viability selection on body size were highly congruent on both islands: females experienced stabilizing selection favoring intermediate size, whereas males experienced directional selection favoring larger size. Thus, sex-specific selection matched the overall pattern of male-biased SSD, but population differences in the magnitude of SSD were not associated with local differences in selection. Body condition was significantly lower on Eleuthera than on Exuma, suggesting that intraspecific variation in SSD reflects local variation in energy availability that disproportionately impact males on account of their greater absolute energy requirements. Nonetheless, our common-garden experiment indicated a strong genetic component to island differences in the growth and body size of adult males. We discuss these results in light of current research targeting the quantitative genetics of growth and sexual dimorphism.

Reconstructing Respiration and Olfaction in the Mammalian Nasal Cavity

The mammalian nasal cavity is a multi-purpose organ that houses a convoluted airway labyrinth responsible for respiratory air conditioning, filtering of environmental contaminants, and chemical sensing. Because of the complexity of the nasal cavity, the anatomy and function of these upper airways remain poorly understood in most mammals. However, recent advances in medical imaging, experimental and computational methods, and histological techniques are now permitting examination of interspecies differences in nasal anatomy and the resulting functional implications regarding respiration and olfaction. This presentation will highlight the research being carried out by our multidisciplinary team to better understand the form and function of the nose in different mammalian species that include terrestrial and semi-aquatic carnivorans (coyote, bobcat, sea otter), ungulates (white-tailed deer), and rodents (gray squirrel). Specifically, modern high-resolution medical imaging modalities are being combined with histological data to generate three-dimensional virtual reconstructions of the mammalian nose, which are used in computational fluid dynamics (CFD) simulations of nasal airflow, respiratory heat and moisture exchange, and odorant mass transport. State-of-the-art flow measurement experiments in transparent physical models are being used to validate the computational simulations. An overview of our approach, techniques, and results to date will be presented. Supported by NSF grants IOS-1120375 (to BAC and MHK), IOS-1113882 (to CJW), NSF IOS-0517748 (to BVV), and NSF IOS-1119768 (to BVV).
Integrating stress physiology with quantitative evolutionary models to predict population responses to environmental change: An amphibian perspective

The allostatic load and reactive scope conceptual models provide a rubric for integrating neuroendocrine stress axis activity with intrinsic and extrinsic factors within a life history; however the challenge ahead is to design studies that test specific ecological and evolutionary hypotheses with physiological data. Therefore, we need to take concepts generated by either allostatic load or reactive scope models one step further to determine how relationships between glucocorticoids and fitness (survival or reproduction) impact evolutionary and population dynamics with the use of demographic, epidemiological and quantitative genetic models. These models can also be used in a predictive way to assess which life history traits we should be focusing on when relating the impact of GCs on life history traits to project population−level effects (e.g., use of parameter elasticities within demographic models). Here, we describe three studies of amphibians that have used quantitative models that explicitly examine the influence of glucocorticoids (in response to environmental stress) in 1) the process of evolutionary adaptation, 2) projecting disease dynamics, and 3) predicting population dynamics. In all three contexts, these models provided a framework in which individual−level stress responses can be scaled up to population−level assessments of stress in order to address broader biological questions. Future collaborations among environmental endocrinologists and evolutionary and population biologists will facilitate the integration of stress physiology into the fields of population biology, evolutionary ecology, and conservation biology.

Does developmental stress modulate reproductive tactics in the zebra finch?

The long−term effects of developmental stress on phenotype and performance are well−known. In comparison, the effects of developmental stress on fitness remain largely unexplored. Developmental stress in known to decrease the quality of sexually selected traits (e.g. bird song) and, therefore, is assumed to decrease reproductive success. However, animals exposed to developmental stress may compensate for poor quality sexually selected traits by pursuing alternative reproductive tactics such as increased parental investment. Here, we explored the fitness consequences of developmental stress in male zebra finches (Taeniopygia guttata). Specifically, we investigated whether adult males exposed to stress during development sire fewer nestlings through extra−pair copulations, but invest more in parental behavior and, thus, rear nestlings in greater condition. These data will allow us to empirically evaluate how developmental stress affects reproductive success and draw inferences about the role of developmental stress in shaping alternative reproductive tactics.

Targets for hormone−mediated sex ratio adjustment in vertebrates

When considering sex ratios, we have to first define the nature of the question. Are we speaking of the gonads, secondary and accessory sex structures, physiology, brain, behavior, or all of the above elements. If these elements are not concordant, the exceptions can prove illustrative of underlying processes at both the proximate and ultimate levels. At each of these levels sex is the binary outcome resulting from the modulation of conserved networks of genes, proteins, cells, organs and, in the case of the brain, discrete nuclei. These networks operate at multiple, and sequential levels that usually are linear during the lifespan, but in some instances reversals are possible. For example, the gonads arise from a single anlage and, in most instances ovaries or testes result, although ovotestes are the norm in some species and gonadal reversal a property of other species. Other sexually dimorphic structures differentiate from multiple anlage by reciprocal and sex−specific atrophy/hypertrophy typically in an exaggerated manner, although the capacity to develop structures characteristic of the opposite gonadal sex remains inherent and intact. A perspective that integrates these different properties will be presented.

Deltoptychius: investigating the roots of the chimaeroid cranial condition

Chondrichthyes includes elasmobranchs and holoccephalans, but little is known about the early memberships of these groups. In the early 1980s the fossil collector S. P. Wood discovered exceptional specimens of Deltoptychius, a Lower Carboniferous holoccephalan, while excavating the fossil fish site at Bearsden, Scotland (Serpukhovian: ~326−318 Ma). Deltoptychius traditionally was diagnosed by features including a head shield and presence of mandibular spines. CT scanning of the Bearsden specimens revealed numerous characters that were not previously known, including details of the braincase concealed by the dermalcranium. Additional comparisons with recent chimaeras and early chondrichthians such as Chondrichthyes, inopercylans, and Pucapampella, allowed us to investigate character transformations that occurred during the evolutionary history of this group. Deltoptychius shares with modern holoccephalans the anterior location of the jaw articulation, similar size and position of the otic capsules, the presence of tooth plates, and the presence of a dorsum sellae. However, more primitive characteristics also are present. For the first time we see cranial characters approaching the general gnathostome condition within an otherwise undeniably holoccephalan taxon.
**83.6 CROCE, H.M.*; TURNER, R.L.; Florida Institute of Technology; hercoco@my.fit.edu**

**The Gomphoid Synarthrosis: a New Joint in Echinoderms**

Certain ossicles in crinoid, echinoid, asteroid, and ophiuroid echinoderms have long been thought to fuse. The development of these ossicle systems has not been well studied, often due to obstruction by other ossicles. Here, the development of vertebral ossicles in the ophiuroid Plectodermatia filograneus was examined. Arm tips, cleaned of soft tissue, were studied using electron microscopy. Vertebral ossicles originate under the ocular in halves. The two ambulacral ossicles grow towards each other; the stereom branches and eventually interdigititiae like a three−dimensional jigsaw puzzle. As vertebral grow, ambulacral ossicles interlock tightly, creating a suture line, which has been taken before as evidence of fusion. In mature vertebrae, the suture line was not always visible at articular surfaces, indicating fusion. This study suggests that interdigitization of ambulacrall ossicles forms an immobile joint, a gomphoid synarthrosis, joining vertebral ossicles in ophiuroids. We examined the gomphoid synarthrosis in vertebrae for the percentage by weight of magnesium making up the stereom. A higher magnesium content imparts greater strength to the ossicle; thus, this area is an excellent candidate for strengthening with magnesium. The gomphoid synarthrosis in Ophiuridae vertebrae is not, however, strengthened in this way. Other ossicle systems in echinoderms reported to fuse include compound plates and auricles of Aristotle’s lantern in echinoids, genital plates of irregular echinoids, the circumanal ring of brisingid asteroids, and infrabasal calyx plates and juncture of the stem and calyx in crinoids. These ossicle systems will also be examined for the presence of a gomphoid synarthrosis or fusion.

---

**61.1 CROFTS, S; Univ. of Washington, Seattle;crofts@uw.edu**

**The effects of tooth structure and loading on the distribution and magnitude of strain in durophagous teeth**

A broad range of taxa, both extant and extinct, have teeth that are specialized to break hard prey items, including several elasmobranch lineages, bony fishes, mammals and reptiles. These teeth have two competing functional demands to break the prey item and to avoid breakage themselves. While these teeth all serve the same general function, shape ranges from broad flat plates, to more rounded teeth with stress concentrators, and even cupped shapes. Furthermore there are presumably different constraints on teeth, dependent on the frequency that they are used and replaced, and the specific hard prey. To better understand the functional constraints on tooth morphology, I digitally constructed four series of models that graded from one morphological extreme to another, covering the range of tooth morphologies seen in nature. These models varied in the degree of convexity and concavity of the occlusal surface, and the morphology of a stress concentrating cusp. Using finite element analysis (FEA), I applied different loading regimes to the models, to mimic different potential prey items. I measured maximum principal strain to determine which model teeth would be most likely to fracture, and where that fracture would be most likely to occur. Both the magnitude of strains and the distribution through the models changed with the morphology and with different loading regimes. This suggests different optimal shapes, where strain is lowest in the tooth, possibly dependent on prey type. Laser scans of the slightly domed teeth of the extinct placoderm Placodus sp., were also analyzed and compared to the predicted optimal tooth shapes.

---

**55.2 CROCKETT, E.L.; Ohio University; crockett@ohiou.edu**

**Risky Fats and Antioxidant Arsenals in Cold− and Warm−Bodied Fishes**

Fishes living at cold body temperatures are rich in biological membranes that are fortified with polyunsaturated fatty acids (PUFA). PUFA are particularly susceptible to lipid peroxidation, a process initiated by reactive oxygen species (ROS) and propagated by oxidized lipids. Lipid peroxidation can damage the structure and integrity of biological membranes, and compromise the function of membrane−associated proteins. Although fishes at warmer temperatures do not contain as much lipid, or PUFA, they are confronted by higher rates of ROS production and lipid peroxidation. In our work with intracellular membranes from both temperate and Antarctic fishes, it is becoming apparent that phospholipid composition alone does not predict the inherent susceptibility of biological membranes to lipid peroxidation. Total antioxidant capacities, levels of low molecular weight antioxidants, and potential oxidants contribute to the protection against, or promotion of, oxidative injury. Activities of enzymatic antioxidants, including the family of glutathione peroxidases, are not altered with temperature acclimation. Levels of products of lipid peroxidation (e.g., phospholipid hydroperoxides) are a function of lipid quantity, more so than compositional quality. Taken together, our studies indicate that despite higher lipid contents, the risks of lipid peroxidation at low temperature are not greater than those faced by animals at warm temperatures. Fishes at cold and warm temperatures appear to require different arsenals to provide sufficient protection against lipid peroxidation. Supported by NSF IOS 0842624, ANT 0741301 and ANT 1043576.

---

**45.2 CROSSIN, GT*; PHILLIPS, RA; LATTIN, CR; ROMERO, LM; WILLIAMS, TD; Dalhousie University, British Antarctic Survey, Tufts University, Tufts University, Simon Fraser University; gt@dal.ca**

**Corticosterone mediated costs of reproduction facilitate a tradeoff between current and future reproduction.**

Lindström’s theory predicts costs of reproduction. One possible mediator of those costs involves the secretion of glucocorticoid hormones, which can be indexed by analyzing concentrations in feathers grown during breeding activity in birds. In the broadest sense, glucocorticoids mediate physiological responses to unpredictable environmental stressors, function as metabolic regulators during predictable events like reproduction, but can also have negative effects (e.g. molt, brood desertion). Here we show that corticosterone (Cort) in feathers grown during the reproductive season reflects breeding effort in two Antarctic seabird species (giant petrels, Macronectes spp.). In females of both species, but not males, feather Cort (fCort) was nearly 1.5 fold higher in successful breeders versus failed breeders (those that lost their chick), suggesting a cost of successful reproduction; high fCort levels in females reflect the elevated plasma Cort levels required to support high metabolic demands of successful chick−rearing. Increased fCort and successful breeding also led to delayed moult prior to winter migrations. By monitoring individuals in the following year, we then link fCort levels and pre−moult to subsequent breeding effort. A cost of reproduction, as indexed by high fCort and a delayed initiation of moult, were predictive of deferred breeding in the following year. Cort levels and the timing of moult thus provide a potential mechanism for the tradeoff between current and future reproduction.
105.2 CROSTON, R.*; HAUER, M.E.; CUNY Graduate Center, CUNY Hunter College, CUNY Graduate Center; RCrustom@cuny.edu

Spectral tuning and foreign egg rejection in American robins (Turdus migratorius)

By laying their eggs in the nests of other birds, avian brood parasites impose the cost of rearing their young upon the hosts. Recognition and rejection of foreign eggs are the primary and most effective host defenses against costly brood parasitism. Yet, hosts of parasitic brown-headed cowbirds (Molothrus ater) challenge co-evolutionary theory because most hosts accept parasitic eggs despite their drastically different appearance from the hosts own. American robins (Turdus migratorius) are one of few cowbird hosts to reject foreign eggs. Previous research yielded equivocal evidence whether egg rejection by robins evolved specifically in response to cowbird parasitism, or is based on recognition of own eggs and not specific to cowbird eggs. Our research employed avian visual perceptual modeling and behavioral experimentation to investigate mechanisms driving parasitic egg rejection in robins. We modeled effects of overall chromatic difference as JNDS (just noticeable differences) on rejection rates in response model eggs with artificial colors spanning the entire avian spectral sensitivity range. We then modeled effects of differences in quantum photoreceptor catches between natural and model eggs to determine which photoreceptor inputs best predict the rejection responses. The model best predicting rejection rates contained values from all photoreceptor types in the avian visual system, but JND values were not significant. Experimental eggs mimicking cowbird egg ground color were rejected in all experimental trials, but these differed little in JND value from both real and model robin mimetic eggs, which were typically accepted. We propose a nested rejection criterion where foreign egg rejection is driven primarily by differences across most regions of the avian visual spectrum, but beige eggs (as laid by parasitic cowbirds) are also always rejected.

12.4 CUFF, A.R.*; RAYFIELD, E.; University of Bristol, UK; Andrew.Cuff@bristol.ac.uk

Finite element validation of an avian skull using ex vivo measurements

Finite element models (FEMs) have potential to describe the detailed biomechanics of musculoskeletal systems. Validation studies assist in deducing how models reflect reality, yet in avians this is particularly difficult due to thin bone, the presence of a keratinous rhamphotheca and the kinetic nature of skulls. In order to validate a FEM of a large avian skull, a computed tomography (CT) scanned ostrich (Struthio camelus) skull was dissected and an artificial tendon (carbon fiber loops embedded in resin) attached at the M. psuedotemporalis superficialis muscle site. Using a specialised rig, the artificial tendon had loads applied that were within limits ascertained from PSCA during dissection. The strains on the skull were measured ex vivo using strain gauges applied to 14 sites. Using the CT scans, the cortical bone, cancellous bone, sutures and rhamphotheca were segmented using Avizo 6.3. The surface generated was transferred into Hypermesh 10 to produce a series of models with increasingly fine mesh size (convergence testing). Using the converged mesh size, the model was loaded with identical boundary conditions to the ex vivo skull. Material properties from both the literature and nano-indentation studies on another ostrich skull were used. Results show that there are broad similarities between ex vivo measurements and models run with homogenous properties from either the literature or nano-indentation. The presence of sutures affects strains differently across the entire skull, whilst a rhamphotheca lowers strains. Principal strain alignments are also closely matched. By validating the method on avian skulls it allows more accurate parameterisation for future studies.

14.2 CUI, R.*; SCHUMER, M.; KRUESI, K.; ANDOLFATTO, P.; ROSENTHAL, G.; Texas A&M University, Princeton University, Universidad Nacional Autónoma de México; melog@tamu.edu

Revealing extensive reticulate evolution in Xiphophorus fishes using high-throughput phylogenomics

Recent research has demonstrated that hybridization, a process once thought to be rare in fishes, is remarkably common. Although hybridization presents challenges in reconstructing phylogenies, it may play an important role in adaptation (and potentially speciation) in many species. In the present study we use next-generation sequencing techniques to examine phylogenetic relationships, historical gene flow and its implications in biogeographic patterns and trait evolution in a genus of freshwater fish (Xiphophorus). We found extensive ancient gene flow between and within clades. Two species were found to contain almost even-admixture of genomes from different ancestries, making them good candidates for hybrid speciation. Other species contained smaller proportions from the minor ancestry. Cyto-nuclear conflict of topology was found to an unreliable indicator of hybridization. Sexually selected traits can be better optimized on a reticulate phylogeny and the sword ornament may have spread through hybridization. The new phylogeny also shed light on palaeobiogeography of the genus. We identified multiple secondary invasions by platyfishes towards the north across the trans-Mexican volcanic belt, followed by hybridization with earlier settlers. Our study highlights the potential role of hybridization in these fishes. QTL mapping of ecologically or sexually important traits will allow us to investigate in more detail the role of introgression in adaptation and speciation.

76.1 CULLEN, J.A.*; MAIE, T.; SCHOFENFUX, H.L.; BLOB, R.W.; Clemson Univ., St. Cloud State Univ.; jccullen@clemson.edu

Can exuviation facilitate terrestrial invasion? Oral kinematics of climbing and feeding in a waterfall-climbing gobid fish

Species of the gobid fish genus Sicyopterus use a novel inching behavior to climb waterfalls, in which an oral sucker is cyclically protracted and attached to the climbing surface. This genus also has a distinctive feeding behavior in which the premaxilla is cyclically protracted to scrape diatoms from the substrate. With such generally similar motions, it is possible that one of these distinctive patterns was coopted from the other, representing an example of evolutionary exaptation. To evaluate this possibility, we used high-speed video to film climbing and feeding in S. stimpsoni from Hawaii, and measured oral kinematics for two comparisons: (1) Feeding kinematics of S. stimpsoni vs two suction feeding gobies (Aquaous guamensis and Lentipes concolor), to assess what novel jaw movements are required for algal grazing; (2) Oral kinematics in feeding vs climbing for S. stimpsoni, to quantify their similarity and evaluate the potential for either to represent an exaptation from the other. Premaxillary movements were most different between scraping and suction feeding taxa. Between climbing and feeding, S. stimpsoni showed significant differences in the maximum values of several kinematic variables, but overall profiles of motion through the cycle matched very closely for most variables, even with differences in maximum values. Current data cannot resolve whether oral kinematics for climbing was coopted from feeding, or feeding kinematics coopted from climbing, but similarities between feeding and climbing in S. stimpsoni are consistent with evidence of exaptation, with modifications, between these behaviors.
MUP expression is linked with sociality not competitive ability in male house mice

Although success in physical conflict is a major determinant of mammalian fitness, little is known about the relationship between chemical communication and an individuals competitive ability. Mice excrete large amounts of protein in their urine, most of which are Major Urinary Proteins (MUPs). MUPs are polymorphic and are involved in signaling individual identity, and their expression responds to changes in the social environment. However, it is not known how MUP expression relates to competitive ability. Here, we assessed the relationship between MUP expression, experience in a socially competitive environment, and competitive ability. Mixed sex groups were introduced into semi-natural enclosures and remained for multiple days to assess male competitive ability; urine samples were taken before and after each of two rounds of competition. MUP expression was strongly influenced by accumulating social experience; i.e., MUP expression increased after each social period. This supports the idea that MUPs function in social communication. Surprisingly, competitive ability lacked a strong association with MUP expression. However, a sires competitive ability was negatively associated with his sons MUP expression. This suggests that competitive ability might have a trans-generational influence on MUP expression. In conclusion, our results challenge the claim that MUP levels are not biologically meaningful.

Mechanisms of egg defense in Megapodes: avoiding infection in a compost heap

Interactions, over evolutionary time, between bacteria and vertebrate animals remain poorly understood. Infection is an important source of mortality for avian embryos but parental behaviors and eggs themselves can provide a network of antimicrobial defenses. Australian brush-turkeys (Alectura lathami) are unique among birds in that they produce heat for developing embryos not by sitting on eggs but by burying them in carefully tended mounds of soil and microbially decomposing vegetation. Despite the extremely high microbial abundance in these mounds, brush-turkey eggs are rarely infected, suggesting that they possess strong defensive mechanisms. To identify these mechanisms we first quantified antimicrobial albumen proteins and characterized eggshell structure, finding that albumen was not unusually antimicrobial, but that eggshells present a cuticle composed of nanometer-sized calcite spheres. Experimental tests revealed that these modified eggshells were significantly more hydrophobic and better at preventing penetration into the egg contents than control eggs. Our results show that the mutualistic cultivation of bacteria by megapodes has necessitated the evolution of novel defense mechanisms against parasitism.

Detection and characterization of an ontogenetic diet shift in the Naked Goby, Gobiosoma bosc

Ontogenetic shifts in diet allow organisms to maximize energy conservation, presumably by reducing the time spent foraging or increasing net energy intake. As many diet studies are descriptive and report only frequency or counts of prey items, the ability to precisely quantify and describe a diet shift can be challenging. The goals of this study were to report the diet composition of the Naked Goby, Gobiosoma bosc, and examine if there is a threshold body size at which the diet shifts from dominance of meiofauna to dominance of macrofauna. Gobiosoma bosc specimens were collected from oyster reefs in the Charleston Harbor estuary by examination of removable oyster shell and seine. To investigate diet composition, the digestive tract was removed from G. bosc individuals and prey types were identified to the lowest taxonomic level possible, measured, and enumerated. Stomach content analysis reveals G. bosc primarily consumes harpacticoid copepods from the meiofauna, and polychaetes and amphipods from the macrofauna. The consumption of macrofauna begins at a small predator size (11 mm standard length), and while the number of macrofaunal organisms ingested does not increase with predator size, the volume of macrofauna does.

Surprisingly, competitive ability lacked a strong association with MUP expression. However, a sires competitive ability was negatively associated with his sons MUP expression. This suggests that competitive ability might have a trans-generational influence on MUP expression. In conclusion, our results challenge the claim that MUP levels are not biologically meaningful.

Impact of nutritional status on ghrelin and growth hormone in phocid seal pups

Marine mammals have unique metabolic demands related to adipose accretion, yet previous studies show metabolic hormones involved in nutrient partitioning follow similar patterns to terrestrial mammals. Growth hormone (GH) and other components of the somatotropic axis promote growth, regulate nutrient partitioning, and are responsive to nutrient intake. In terrestrial mammals, GH increases with undernutrition, decreases with refeeding, and inhibits adipose accretion. Ghrelin responds similarly to GH with changes in nutrient intake, but has the opposite effect on adipose. Given this promotion of adiposity and the importance of adipose to marine mammals, we hypothesized that ghrelin may have a differential response to increased nutrient intake in marine mammals. This longitudinal study quantified ghrelin and GH from a fasted state through refeeding in harbor seal (n=10) and northern elephant seal (n=9) pups bi-weekly for 8 weeks. Body condition increased during refeeding (p < 0.005), reflecting lean tissue growth and adipose accretion. Surprisingly, ghrelin concentrations increased upon refeeding in both species (p < 0.05). However, in northern elephant seals ghrelin increased at week 2 (p < 0.001) while in harbor seals ghrelin increased at week 4 (p < 0.05). As expected, GH concentrations decreased throughout refeeding for both species (p < 0.01). While reduced GH concentrations favor adipose accretion, the atypical response of ghrelin may be a mechanism for promoting rapid compensatory deposition of lipids after fasting. Because significant adipose accretion is vital for survival in pinnipeds, this response to refeeding could be an adaptation to preferentially allocate nutrients to adipose when faced with nutritional challenges.
38.4 DALTON, B. E. *; CRONIN, T. W.; CARLETON, K. L.; University of Maryland, Baltimore County; briand7@gmail.com
Comparative Spectral Properties of axopodiflagellate photoreceptors: A Novel Mechanism of Photoresponse Tuning?
Detection of predators is a critical task that many animals accomplish visually. Because predators often appear as dark objects, their detection can be facilitated by making the background appear as bright as possible. According to the matching pigment hypothesis, this is accomplished by a receptor that is tuned to the background light spectrum. In nature, the color of the background differs with angle of view. Therefore, maximizing predator detection across the visual field requires multiple receptors tuned to heterogeneous backgrounds. Although cone cells sensitive to different wavelengths have been found in varying ratios across the retinas of diverse animals, the ecological function of this variation is largely unknown. Here, we tested whether opsins are expressed in retinal regions where they increase light absorbance of the corresponding backgrounds. Using in situ hybridization we found that cichlid fish coexpress spectrally distinct opsin genes in specific regions the retina. In these regions, coexpression increases light absorbance of the respective viewing backgrounds. Thus, opsin coexpression seems to tune the photoreceptors to their light environment. We confirmed the presence of cone cells containing opsin mixtures by microspectrophotometry. Interestingly, the frequency of coexpression varies among individuals, from a small number of widely distributed double cones in some fish, to regionally abundant coexpression in others. Visual modeling is being used to evaluate the effect of coexpression on detection distance of dark objects such as predators. Ongoing work also includes light habitat manipulation to examine phenotypic plasticity and in situ experiments to determine the opsin expression patterns of wild-caught individuals.

71.2 DAS, S.*; NAJAR, F.Z.; LAI, H.C.; WILEY, G.; GAFFNEY, P.M.; ROE, B.A.; DURICA, D.S.; Univ. of Oklahoma, OMRF; sunextra.das–1@ou.edu
NGS analyses of genes expressed during limb regeneration in the crab, Uca pugilator
Limb regeneration in fiddler crabs involves formation of a proliferative blastema, its differentiation into a segmented mini limb (basal phase) and hypertrophic growth of the mini limb via protein synthesis and water uptake (proecdysial phase). These phases are tightly coordinated with the molt cycle, i.e., accompanied by distinct fluctuations in circulating ecdysoyteroid titters, providing a useful model system to study changes in global gene expression. Among crustaceans, genomic and RNA–seq datasets are limited. We gave generated pilot transcriptome profiles to examine steady state changes in global gene expression during the limb regeneration process, including blastema, early and late proecdysial limb buds, using 454 and Illumina sequencing technology (NGS). Following sequencing, the reads were assembled de-novo by using the Newbler Assembler for 454 and the Trinity and SOAP Assemblers for Illumina sequence data. We have generated 103,700 and 704,395 sequences (all libraries combined) from the 454 and Illumina platforms, respectively. The average contig lengths from proecdysial libraries built by the three assemblers were: 511 bp (Newbler), 186 bp (Trinity) and 629 bp (SOAP). Analyses of the sequence data are available online at http://www.genome.ou.edu/crab.html, where the databases are both BLAST and keyword searchable. The database contains putative isoforms not detected through cDNA library cloning or anchored PCR. We have also obtained metabolic profiles of from early blastemal, and early and late proecdysial limb buds using the KEGG database. Further analysis of metabolic profiles, in association with experimental manipulation of ecdysoyteroid responsiveness, should provide information on gene pathways subject to ecdysoyteroid control.

100.1 DANOS, N*; AZIZI, E; Univ. of California, Irvine; ndanos@uci.edu
Muscle–collagen interactions at the fiber bundle level.
The passive force–length properties of muscle fibers are thought to be important determinants of a muscles operating length and force production. The extra–collagenic collagen surrounding muscle fibers (endomysium) and fascicles (perimysium) have long been considered the structures responsible for passive elasticity in muscle. However, few studies to date have developed a direct link between the mechanical properties of these intramuscular connective tissues and the passive elasticity of muscle fibers. In addition, it remains unclear how connective tissue structures within muscle impact contractile performance. We explore the role of collagen in the extracellular matrix of muscle fibers and bundles by first comparing collagen density and passive stiffness in the anconeus muscle of three species of anurans with divergent loading regimes: the bullfrog Rana catesbiana, the cane toad Bufo marinus and the African clawed frog Xenopus laevis. We then examine the in vitro passive and active properties of muscle fiber bundles before and after a collagenase treatment that partially digests extracellular collagen. We find that the fiber bundles begin to develop tension at longer lengths after collagenase treatment. Active tetanic contractions after collagenase treatment reach lower maximum forces and develop force more slowly compared with pre–collagenase contractions. The results indicate that endomysium and perimysium collagen contributes both to passive stiffness and to the profile of active force production in muscle.

140.3 DAVIES, S.*; DEVICHE, P; Arizona State University; scott.davies@asu.edu
The effect of food availability on the seasonal reproductive development of birds
Birds use food availability to synchronize seasonal reproductive activity with local environmental conditions, but the mechanism(s) by which this cue affects the hypothalamo-pituitary-gonadal (HPG) axis remain(s) poorly understood. We examined the effect of food availability on the HPG axis of adult male Abert's Towhees, Melozone aberti. We exposed captive birds to long days to stimulate reproductive development and assigned them to one of three groups: ad lib food, restricted food availability, in which they received 70% of ad lib consumption for four weeks, or two weeks of food restriction followed by two weeks of ad lib food. Two weeks of food restriction decreased body mass, fat, and pectoral muscle. Food availability had no effect on the number, area, or optical density of gonadotroin releasing hormone (GnRH) cells, the optical density of GnRH-I fibres in the median eminence (ME). Treatment also had no effect on the number of optical density of gonadotropin inhibitory hormone (GnIH) cells, or the optical density of ME GnIH fibers. However, the area of GnIH cell bodies was largest in ad lib birds and smallest in food restricted birds. Although paired testis masses and seminiferous tubule diameters were similar across groups, plasma testosterone (T) levels were higher in ad lib birds than in food restricted or reinstated ad lib birds, and there was no difference between food restricted and reinstated ad lib birds. The width of the cloacal protuberance (CP) and the width of the cloacal protuberance (CP) and the angle of view. Therefore, maximizing predator detection across the visual field requires multiple receptors tuned to heterogeneous backgrounds. Although cone cells sensitive to different wavelengths have been found in varying ratios across the retinas of diverse animals, the ecological function of this variation is largely unknown. Here, we tested whether opsins are expressed in retinal regions where they increase light absorbance of the corresponding backgrounds. Using in situ hybridization we found that cichlid fish coexpress spectrally distinct opsin genes in specific regions the retina. In these regions, coexpression increases light absorbance of the respective viewing backgrounds. Thus, opsin coexpression seems to tune the photoreceptors to their light environment. We confirmed the presence of cone cells containing opsin mixtures by microspectrophotometry. Interestingly, the frequency of coexpression varies among individuals, from a small number of widely distributed double cones in some fish, to regionally abundant coexpression in others. Visual modeling is being used to evaluate the effect of coexpression on detection distance of dark objects such as predators. Ongoing work also includes light habitat manipulation to examine phenotypic plasticity and in situ experiments to determine the opsin expression patterns of wild-caught individuals.
Understanding Connectivity of Acropora Corals Across Remote Islands Using Genetics and Biophysical Modeling

Many Indo-Pacific Acropora corals have species ranges that exceed thousands of kilometers. These ranges seem to preclude the growth consensus that dispersal distances of many marine species are less than previously assumed. Understanding larval dispersal is imperative to predicting population level responses to climate change. Few studies have looked into the connectivity among isolated reefs across large geographical scales. Knowledge of source-sink dynamics between remote reefs is important as they occur as discrete stepping-stones across large expanses, and extinctions of individual populations may have far-reaching demographic effects. Here we employ a spatially explicit biophysical model to predict larval dispersal between Micronesian islands. These predictions were then evaluated against genetic data and coalescent models of gene flow in two Acropora species. We analyzed twelve SSR loci across nearly 2000 individuals to determine connectivity patterns and the distribution of genetic diversity in Acropora hyacinthus and A. digitifera in Micronesia at different spatial scales, with samples from 22 reef sites across 9 island groups. Due to westerly equatorial Pacific Ocean currents, we hypothesized that genotypic diversity would decrease from west to east across Palau, the Caroline Islands and into the Marshall Islands, and that migration would predominantly be west to east. We observed strong genetic structure across Micronesia for both species with highly significant FST and isolation by distance signatures. However, dispersal routes modeled by the coalescent approach and the biophysical model are more complex than the simple isolation by distance model, which might help explain the extensive ranges of Acropora.

Evolutionary consequences of nongenetic inheritance

There has been widespread interest in recent years in inheritance mechanisms that exist alongside genetic inheritance, and the role that these might play in evolution. I will present some work that develops a unified theoretical framework for modeling evolution under the combined effects of genetic and nongenetic inheritance. Despite the considerable diversity of proximate mechanisms of nongenetic inheritance, I will show how they can all be integrated within a relatively simple theory. The approach will be illustrated with some examples that show how nongenetic inheritance can lead to novel predictions and patterns of evolution that would otherwise be unexpected.

Wave Energetics in Fiddler Crabs: Variability in Signaling Investment

Fiddler crabs are a group of small, intertidal crustaceans that exhibit a high degree of sexual dimorphism. Male fiddler crabs are characterized by strong body asymmetry, as the large major claw can constitute more than half of the organism’s body mass. Males within this genus both wave the major claw to attract a mate during courtship, and also fight with the major claw for control of mating burrows. Both of these functions are essential for male mating success. Fiddler crab species are highly variable in claw morphology and in the kinematics of waving. Here, we quantify energetic investment in waving across 14 species of fiddler crabs. Using field observations and video analysis of courtship, we calculated waving rates (waves/second), waving time budgets (percent time spent waving), and the energetic cost of a wave (Joules/wave). Additionally, morphological and mechanical measurements were made for each of these species. Wave energetics are highly variable across species. Work (J) per wave varies by two orders of magnitude. Wave rates ranged from 0.29 to 1.1 waves/second. All species studied waved frequently during courtship periods, with 28% to 77% of time spent waving. Combining these data sets, we estimate each species’ energetic commitment to waving. We then use these data to test hypotheses about the relationship between waving investment and morphology (e.g. body size, claw force), and reproductive behavior.
Body condition modulates responses to capture stress and exogenous corticosterone in female red-sided garter snakes.

Many studies have examined the role of corticosterone (CORT) in male reproduction, but relatively little is known about how CORT affects female mating behavior. We treated female red-sided garter snakes (Thamnophis sirtalis parietalis) with capture stress during the spring mating season in Manitoba, Canada. Blood samples were collected before (0h), during (2h) and after (4h) capture stress treatment. Stress-treated and control females were then placed individually in an arena containing 20 males and latency to copulate was recorded. Body condition was determined as the residual from a regression of body mass on snout-vent-length. Capture stress significantly increased plasma CORT (p=0.025). However, only females with negative body condition exhibited increased CORT after 2 hours of capture stress (p=0.043). Importantly, baseline CORT did not differ between females with negative or positive body conditions, suggesting that differences in hormonal stress responses were related to differences in hypothalamus-pituitary-adrenal axis sensitivity. Similar to previous results in male red-sided garter snakes, capture stress did not influence mating behavior (p=0.090). These results suggest that females may also be behaviorally resistant to capture stress during the mating season. However, in a second experiment, exogenous CORT (15 or 60 μg) significantly increased latency to copulate (p=0.010). Interestingly, only females with negative body condition responded to the lower CORT dose, suggesting that glucocorticoid receptor sensitivity and/or density varies with body condition. Collectively, our results indicate that female body condition modulates hormonal and behavioral responses to elevated CORT during their short mating season.
41.3 DELEPINE, M.B.*; BARANNYK, O.L.; SHADWICK, R.E.;
Univ. of British Columbia, Vancouver, Univ. of Victoria, BC;
delepine@zoology.ubc.ca
Performance of Thunniform Propulsion: A High Bio–fidelity
Experimental Study
Tunas, lamnid sharks and whales are some of the fastest sustained
swimming animals. These animals are part of the thunniform
propulsion (TP) group, characterized by streamlined bodies with
broad hind fins that generate lift-based thrust. This unique adaptation
is due to the fluid mechanics of the body and the surrounding flow.
These animals are immune to fatigue failure. We hypothesize that
propulsive efficiency and thrust coefficients were calculated from
the forces and torque measurement for each motion regime. Vortex
shedding was visualized by means of digital particle image
velocimetry. In conclusion, the TP of other animals and propellers
were compared with our results, and major parameters responsible
for this enhanced performance were identified.

80.1 DENNY, MW*; MARTONE, PT; Stanford University,
University of British Columbia; mwden@stanford.edu
Indefatigable: Erect Coralline Alga Is Immune To Fatigue
Intertidal organisms are subjected to intense hydrodynamic forces as
waves break on shore. These repeated insults can cause an
organisms structural materials to fatigue and fail even though no
single force would be sufficient to break the plant or animal. Indeed,
Mach et al. (2011) found that mortality in the intertidal red alga
Mazzaella flaccida was caused by fatigue rather than by the
one–time imposition of extreme force. When pushed to 50% of
one–time breaking stress, Mazzaella breaks after a few thousand
cycles. One might suppose that erect coralline algae—composed of
rigid calcified segments separated by genicula: small, flexible
joints—would be even more susceptible to fatigue: strain is
concentrated in the genicula. We tested this supposition by
repeatedly loading fronds of Calliathron chelisporioides, a
coralline alga common on wave washed shores in California. Loaded
to 50% of its one–time breaking stress Calliathron commonly
survives more than a million cycles, with a record of 52 million. The
maximum lifetime of Calliathron is six years, during which it
experiences only a small fraction of this number of stressful events.
Thus, Calliathron is immune to fatigue failure. We hypothesize that
Calliathrons fatigue resistance is due to the microscale structure of
its genicula. Each geniculum is a single layer of cells that are
attached at their ends to the calcified segments but have minimal
adherence to each other. This lack of adherence allows each cell to act
as a crack stopper, inhibiting the growth of fatigue cracks.
Reference: Mach, KJ, Tepler SK, Staaf AV, Bohnhoff JC, and Denny

107.6 DEMES, KW*; PRUITT, JN; HARLEY, CDG;
CARRINGTON, E; University of British Columbia, University of
Pittsburgh, University of Washington, Friday Harbor Labs;
demes@zoology.ubc.ca
Survival of the weakest: Decreased frond mechanical strength
increases survival in a wave−swept kept via self−pruning
Organisms ability to withstand the physical forces of their
environment is a key determinant of their success. Mechanical
performance of organisms is often dictated by the properties of the
materials which compose them. In mechanically stressful habitats,
mechanical variation in tissue properties may result in differential
fitness and enable natural selection to act on material performance.
We tested the hypothesis that tissue mechanical properties influence
survivorship (a fitness component) of the perennial kelp, Egregia
menziesii, in a mechanically stressful, wave−swept intertidal habitat.
We measured intraspecific variation in frond strength and flexibility
in 38 E. menziesii and tracked their survivorship in the field over the
winter storm season to determine if variation in mechanical
properties led to differential survivorship. Significant
inter−individual variation was found in most mechanical properties,
including strength and flexibility. Individuals with increased
flexibility and decreased strength were more likely to survive the
duration of our study, although this effect was more pronounced in
individuals with smaller holdfasts. Increased frond strength was also
associated with a reduction in self−pruning, potentially explaining
the observed increase in whole plant mortality with increasing frond
strength. Results from this study demonstrate that variation in tissue
mechanical properties among conspecifics can influence survivorship
and this has important evolutionary implications.

17.7 DEORA, T.*; SINGH, A.K.; SANE, S.P.; National Centre for
Biological Sciences, TIFR, Bangalore; tanvid@ncbs.res.in
A general mechanical model of the Dipteran thorax
The evolutionary miniaturization of body size in diverse insects
meant that their wing beat frequencies had to substantially increase to
meet the aerodynamic requirements of flight. In many cases, wing
beat frequencies far exceed 100 Hz to rates that challenge the ability
of the nervous system to directly control every wing stroke.
However, because subtle alterations of wing strokes can result in
significant aerial maneuvers, these insects still need to ensure that
their wing motion is accurate. How do insects handle the dual
challenge of being both fast and accurate? The evolution of indirect
and asynchronous flight muscles partially addresses the challenge of
enhancing wing beat frequency, but it is relatively unknown how
insects coordinate their wing motion with respect to other flight
related sensory organs. Using the black soldier fly, Hermetia
illucens, we show that the answer lies in the physical architecture of
the thorax, which includes a system of multiple, distributed
mechanical linkages that connect the wings and halteres. These allow
the wings to oscillate in phase with each other, but the halteres
oscillate anti−phase to the wings. Moreover, this coordination
between the wings and halteres is essential for flight and its
disruption causes flight defects. Based on the principles investigated
during the course of the study, we propose a general mechanical
model of the Dipteran thorax that explains how insects manage to
maintain the mutual phase relationships between their wings and
halteres.

January 3−7, 2013, San Francisco, CA
DEPEW, M. J.*; COMPAGNUCCI, C.; FISH, J.; DEBIAIS, M.; COOLON, M.; BERTOCCINI, F.; CASANE, D.; MAZAN, S.; UCLF, CNRS, Université de Cadière, Université de Perpignan, Diderot, Station biologique de Roscoff; michael.j.depew@gmail.com

**Pattern and Polarity in the Development and Evolution of the Gnathostome Jaw: Both Conservation and Heterotopy in the Branchial Arches of the Shark, Scyliorhinus canicula.**

The acquisition of jaws constitutes a landmark event in vertebrate evolution. Jaw development involves an intricate spatiotemporal series of reciprocal inductive and responsive interactions between the cephalic epithelia and mesenchyme. The coordinated regulation of these interactions is critical for both the ontogenetic registration of the jaws and the evolutionary elaboration of jaw morphology. A Hinge and Caps model has been proposed that addresses the mechanisms of jaw development by placing the articulation, and subsequently the polarity, of the upper and lower jaws in the context of neural crest competence to respond to positionally located epithelial signals. This model has been built on evidence gathered mostly in amniotes and augmented by a much smaller data set on the zebrafish and Xenopus, as well as by work focused on the jawless lamprey. Chondrichthians are the most basal extant gnathostomes, and comprise the crucial clad uniting amniotes and agnathans; yet despite their critical phylogenetic position, evidence of the molecular and cellular underpinnings of jaw development in chondrichthians is still lacking. Recent advances in genome and molecular developmental biology of the lesser spotted dogfish shark, Scyliorhinus canicula, make it ideal for the molecular study of chondrichthyan jaw development. Here, we have further examined the empirical foundation for the Hinge and Caps model by investigating evidence of heterotopic (relative changes in position) and heterochronic (relative changes in timing) shifts in gene expression, relative to animotes such as mice, in the jaw primordia of S. canicula.

---

DETRICH, H.W.*; YAN, Y.L.; TITUS, T.; ALLARD, C.; Notothenia coriiceps

The role of chemicals in interactions between inking molluscs and their predators.

Inking is a striking behavior of marine molluscs such as sea hares, octopus, squid, and cuttlefish. Inking can function as an antipredatory defense by acting as a visual smoke screen or visual decoy, especially in fast-moving cephalopods. But molluscs also use ink as a chemical defense. Ink of the slow-moving sea hares acts on the chemosensory systems of would-be predators such as crustaceans (spiny lobsters, blue crabs), fish (sharks, sea catfish, wrasses), and sea anemones through an impressive array of mechanisms. These include sensory inactivation (using chemicals in ink to disrupt the reception of appetitive chemicals naturally released by the would-be prey), deterrence (using aversive or unpalatable chemicals in the ink to deter the attack), and phagomimicry (using appetitive chemicals in ink to attract the predator to the ink and away from the releaser). Ink also functions as a chemical defense through alarm cues: sea hares show escape behavior when they detect ink from conspecifics. The chemical deterrents and alarm cues are diverse in molecular structure, numerous, and include both diet-derived and de novo synthesized molecules. Some alarm chemicals are multifunctional molecules, having been co-opted from other functions including as sunscreens and antimicrobials. Fast-moving molluscs, such as squid, may also use ink as a chemical defense, since their ink contains chemicals that are unpalatable to predatory fish. Thus, using ink in both the chemical and visual realms may be a common defensive mechanism for inking animals. These modes of chemical defense contribute together with other defenses to protect inking animals from predators. Supported by NSF IOS-1036742
109.3 DEVRIES, MS*; WINTERS, CP; HOLBROOK, AL; JAWOR, JM; University of Southern Mississippi; margaret.devries@eagles.usm.edu

Its Complicated: Testosterone Production, Aggression, and Parental Care in Male Northern Cardinals

Interrelationships of testosterone (T), male aggression, and paternal care have received much investigative attention. Many studies have focused on examining such relationships with avian species characterized by relatively brief periods of territoriality and breeding. Few have investigated links between circulating T and reproductive behavior with birds that are year-round territorial residents and have lengthy breeding seasons, such as the Northern Cardinal (Cardinalis cardinalis). Here, we report findings from a 4-year project with the male cardinal examining aspects of T production and potential interconnections with circulating T, aggression, and paternal care. Our work suggests that male cardinals have the physiological capacity to significantly increase T levels during non-reproductive periods in response to standardized gonadotropin-releasing hormone (GnRH) injections. Male cardinals maintained the ability to significantly elevate T following GnRH injections across the pre-breeding and breeding seasons; yet, circulating T levels were not significantly higher following simulated aggressive encounters and no relationship existed between T concentrations and the degree of paternal care provided by individuals. This lack of relationship between relative circulating levels of T and behavioral performance suggests a complex association between T and reproductive behavior among males of this species. Whether this complicated relationship of circulating T and male behavior is unique to the cardinal or characteristic of other temperate resident species exhibiting a similar behavioral ecology is unknown and deserves greater attention.

133.5 DIAL, KP*; MARTIN, TE; Univ. of Montana, Missoula; kdial@mso.umt.edu

Predation correlates of locomotor ontogeny among altricial bird species in Arizona and Borneo: Relative development at fledging

Locomotor ontogeny among species is incredibly diverse and could be under strong selection from environmental pressures like predation risk. Laboratory studies on precocial species have demonstrated that dramatic differences exist in the rate of development between the forelimbs and hindlimbs, with correspondingly different capacities of locomotor performance. Does such variation in locomotor ontogeny change with level of predation in the natural environment? In this study, we explore variation in locomotor ontogeny among altricial songbirds that show a wide range in fledging time (8–18 days) and in their risk of nest predation associated with different nest types (e.g., ground, off-ground, and cavity). We find that in two very different environments, northern temperate (northern Arizona) and tropical (Borneo, Malaysia), species with relatively high predation risk develop their locomotor appendages fast but fledge early when locomotor appendages are relatively small. In contrast, species that have relatively low risk of predation develop slower but prolong their stay in the nest and fledge with much more fully developed wings and legs. Such differences lead to variation in wing loading and performance and provide novel insight into the developmental tradeoffs that influence the evolution of avian diversity.
Phenotypic Changes in Lung Function After Acclimation to High Altitude in Deer Mice

Small mammals living at high altitude face low O2 partial pressures, cold ambient temperatures necessitating an increase in energy expenditure. Deer mice (Peromyscus maniculatus) inhabit a broad altitudinal range (0 to 4000 m) in the US and are used as a model species to demonstrate genetic adaptations in hemoglobin O2 affinity. It appears from recent research, however, that the hemoglobin/genetic adaptations are insufficient to explain the highly successful active life history of deer mice. Previously, we have reported that deer mice also display phenotypic changes in organ size (heart, lung, gut, and blood volume) that vary along the altitudinal gradient, are linked to the improved aerobic performance necessary for high levels of activity. We have also reported moderate changes in pulmonary surfactant composition that may lead to changes in surface tension to support aerobic activity in the low O2 availability at high altitude. Here we report results showing that although mice living at high altitude produce the same total amount of surfactant lipid as those living at low altitude, 85% of high altitude individuals (n=13) include lipids that were not detected in low altitude mice (n=11). Conversely, 65% of low altitude individuals have lipid species that were not detected in high altitude individuals. Also while there is a nearly double amount of surfactant protein B (responsible for spreading lipids) in mice at high altitude there is enough variability in the levels of this protein so that this difference is not statistically significant. From these results, we predict that subtle changes in surfactant composition are important at high altitude but they must be accompanied by changes in lung architecture (and lung mass).

Endocannabinoid regulation of glucocorticoids for the birds

Endocrine regulation of corticosterone (CORT) release during the stress response is well described in wild birds. Neural mechanisms impinging upon this endocrine system and regulating it seasonally are less well defined. Typically, the CORT response is down-regulated during molt in seasonally--breeding birds, yet underlying mechanisms of this phenomenon are unclear. The endocannabinoid (eCB) system, a lipid–signaling pathway, may act as a central influence upon baseline and stress--induced CORT release in a seasonal manner. Here, we demonstrate a role for the eCB system in regulating the changing CORT response between breeding and molting conditions. First, using two groups of male European starlings, we targeted action at the eCB neural receptor (CB1) by injecting a CB1 specific antagonist, AM251, and measured subsequent CORT concentrations. CORT significantly increased with injection of the antagonist regardless of observed seasonal changes in CORT concentrations. These data suggest that blockade of the eCB signal releases the CORT response. Notably, the antagonist resulted in greater CORT increases in breeding males. Thus, the eCB system likely acts to inhibit the CORT response, an effect which may be stronger in breeding versus molting birds. Using in situ hybridization, we confirmed the presence of CB1 receptor expression in the paraventricular nucleus (PVN) of the hypothalamus, hippocampus (HP) and nucleus taeniae amygdala (TuA), sites known for their role in eCB–mediated CORT regulation in mammals. qPCR data suggest that the highest degree of CB1 expression in these nuclei occurs in the TuA followed by the HP and then PVN. Overall, these findings indicate a previously unidentified role for the endocannabinoid system in the regulation of the avian stress response.
S11–1.2 DIGGLE, P.K.; University of Colorado, Boulder; pamela.diggle@colorado.edu

Metameric modules, phenotypic plasticity, and the evolution of diverse sexual systems in plants

Plant development is metameric: apical meristems produce a sequence of repeated units over space and time. These metamers, in turn, may be modular with the potential for independent adjustment of component traits. As a result, plastic developmental responses can occur at multiple levels of the phenotype. For example, flowers within inflorescences are metamers, and within individual flowers the development of the androecium (male reproductive structures) and gynoecium (female reproductive strictures) may (or may not) be relatively independent and modular. Changes in allocation to male vs. female reproduction potentially can occur via modification of intra–floral development and via the number and timing of metamere production. Both types of response, however, occur with in the context of whole plant properties such as architecture. I will discuss the relationship between phenotypically plastic responses at multiple levels of organization to the evolution of the diverse sexual systems observed among plants.

34.3 DOLCEMASCOLO, P*; DILEO, K; Montclair State University, NJ Division of Fish and Wildlife; dolcemascolo1@gmail.com

The Genomics of Colonization: Evidence for a Recent Range Expansion in Hyla cinerea

Green tree frogs, Hyla cinerea, are ubiquitous across their geographic range, from Delaware south along the Atlantic Coastal Plain to Florida, westward along the Gulf Coastal Plain to eastern Texas, and north into the Mississippi River Valley to southern Illinois. In June 2011, a large population of H. cinerea was discovered in southwestern New Jersey along the Delaware River. This was the first recorded occurrence of H. cinerea in Delaware. Subsequent reports of this species have been confirmed along the Delaware Bayshore. Northeastward range expansions by this species have been documented in Illinois and recently metamorphosed H. cinerea have been found 0.5 km from the nearest breeding habitat, demonstrating dispersal capacity. To determine whether the NJ population was established via colonization by Delaware tree frogs, genetic analyses were undertaken. Toe clips were collected from both populations and partial sequences of the mitochondrial ND1 gene were used to generate a statistical parsimony network. Four haplotypes were distinguished, with all NJ haplotypes being identical to the most prevalent Delaware haplotype and the Delaware haplotypes differing by at most one base pair. A sequence from a Louisiana green tree frog obtained from GenBank could not be joined in the network with 95% confidence. These results indicate a recent movement of Delaware frogs into NJ. Museum specimens collected throughout the species range are being analyzed in order to place the new NJ population in the context of species–wide diversity. Although movement may have been human–mediated, rising temperatures are possibly favoring the persistence and establishment of these frogs in new areas.

80.3 DOLINAJEC, T.H.*; KOEHL, M.A.R.; Univ. of California, Berkeley; dolinajec@berkeley.edu

Hydrodynamic forces and moments on microscopic aquatic animals

Many aquatic animals are microscopic and interact with the water around them at a range of velocities in which both viscous and inertial forces are important. In spite of the biological importance, hydrodynamic forces on bodies in this size and velocity range are poorly understood. We studied how the morphology and orientation of a variety of ecologically–important microscopic marine animals (copepod, veliger larva, barnacle nauplius and cyprid larvae) affect the forces they experience while swimming in the water column, and on surfaces (e.g. predator tentacles, benthic substrate). Our focus was on a range of velocities that these animals would encounter while swimming or while on surfaces in wave–swept habitats. We measured hydrodynamic forces on dynamically–scaled physical models because they offer a better signal–to–noise ratio and enable manipulations of orientation and posture that are not possible for real microscopic organisms. We measured drag, lift, and side forces as well as moments about three axes for each model in different orientations relative to the flow and substratum. These forces and moments can reorient swimming animals, or push, lift, peel, or shear animals off surfaces. We found that body shape, orientation, and proximity to a surface had significant effects on the magnitudes of the forces and moments on the animals. Drag was the dominant force and lift was negligible in all cases. In contrast, orientation determined whether shearing or peeling moments were greatest on attached animals. These results indicate that the forces and moments that can tumble or dislodge organisms in this little–studied size range depend on body shape, and can vary drastically with changes in posture and orientation.
The escape response is a common anti-predator behaviour observed in most animal species. Fish escape responses have long been considered all-or-none, stereotypic responses. However, recent work has shown that the kinematics and timing of fish escape responses are quite diverse, both within and across species. The kinematics, spatial and temporal characteristics of fish escape responses may be affected by a number of factors. Among these, stimulus characteristics (direction, intensity, distance), schooling, and environmental factors (i.e. hypoxia, temperature) can play an important role in modulating escape responses. Here, I argue that the variability found in kinematics and timing of escape responses in fish and other animals does not necessarily form a continuum, but rather reveals multimodal patterns of distributions in many case studies. Escape latencies are not always minimized, possibly as a result of a graded system through which sub-maximal responses may be used when the threat is not maximal, or in extreme environmental conditions. Similarly, specific patterns of escape directions were found. While maximizing unpredictability would correspond to random directions of escape, work on various species shows that escape trajectories are not random, although they can be multimodal as found in many species. Theoretical work suggests that optimal trajectories for escape should span 90–180 degrees from the predators’ attack, depending on the ratio between the speeds of predators and prey. Experimental results are in line with this prediction. Temporal, directional and kinematic patterns of escape response will be discussed in terms of their potential physiological and functional bases and their evolutionary significance.

110.1 DOMYAN, ET; KRONENBERG, Z; VICKrey, AI; YANDELL, M; SHAPIRO, MD*, Univ. of Utah; shapiro@biology.utah.edu
Genomic and developmental basis of diversity in the domestic pigeon
Domestic pigeons are spectacularly diverse and exhibit variation in more traits than any other bird species. Despite intense historical interest in pigeon genetics, little is known about the molecular basis of their vast diversity. We used genome-wide scans of allele frequency differentiation and a probabilistic gene finder to identify regions of the pigeon genome associated with derived traits. Strikingly, one such scan revealed a shared haplotype in all pigeons with derived crest phenotypes, suggesting that a causative mutation occurred just once and spread to multiple breeds by ancient introgression. A single shared variant is perfectly associated with the crest phenotype across 79 diverse breeds of domestic pigeon, and is therefore a convincing candidate for the crest (cr) locus of classical pigeon genetics. This locus appears to act as a developmental switch for the trait, but the tremendous variation in crest phenotypes suggests that other loci must contribute as well.

7.1 DOO, SS*; FAN, TY; FUJITA, K; MAYFIELD, AB; CHEN, HK; NGUYEN, HD; BYRNE, M; National Museum of Marine Biology and Aquarium, University of the Ryukyus, University of Sydney; stevedoo@gmail.com
Developing molecular techniques to assess resilience in large benthic foraminiferan communities
Large benthic foraminifera (LBF) compose a significant portion of calcareous sediments in coral reef ecosystems, buffering against dieback changes in seawater chemistry and contributing to maintenance of coral sand cays. The vast majority of recent studies on biological responses of large benthic Foraminifera (LBF) to changing climates have indicated deleterious effects on these crucial organisms. In this study, we present new techniques developed to monitor effects of changing climates to the foraminiferal holobiont. Western blotting technique was used to determine protein expression of RuBiSCO, a highly conserved rate-limiting photosystem II enzyme, in Baculovipora sphaerulata collected from intertidal algal flats of the coral island Xiao Liu Chiu, Taiwan. Data indicated reduced protein expression (~50% decrease) of RuBiSCO in response to an acute heat stress (5hr) at +8°C. In a separate project, the potential for recovery in two common LBFs, Calcarina gaudichaudii (diatom-bearing) and Amphisorus hemprichii (dinoflagellate-bearing) was assessed by subjecting specimens to 24 h heat stress (amb, +4°C, +8°C), then returning foraminifera to ambient conditions for an additional 24h. Maximum dark adapted yield (Fv/Fm) measurements of C. gaudichaudii indicate increased Fv/Fm values in mild heating (+4°C) treatments, while no significant effects were observed after return to ambient temperatures. The response of A. hemprichii indicated no significant effects of heat stress up to +8°C to Fv/Fm values after 24h heating, but deleterious effects were observed in our +8°C treatment after 24h of return to ambient temperatures.
Human are also mammals: using the human melanocortin–2 receptor as a model for analyzing the evolution of MC2Rs. Studies on the human melanocortin–2 receptor indicate that: a) this MC2R can only be activated by ACTH, but not by any of the MSH–sized melanocortins; b) human MC2R requires interaction with the accessory protein MRAP1 for functional activation; 3) spontaneous mutations in the human gene can result in either loss of function mutations or trafficking impaired mutants. This information can be used as a reference point for evaluating the evolution of MC2R orthologs in non–anamniote tetrapods, teleosts, and cartilaginous fishes. From these comparisons it is possible to re–construct the functional evolution of the melanocortin–2 receptor, a critical component in the HPA/HPI of teleosts and tetrapods.

Small–scale spatial and temporal variation in metabolic and antioxidant enzyme capacities within a population of rocky intertidal mussels (Mytilus californianus)

Denizens of wave–exposed, rocky intertidal shores inhabit a spatially complex and dynamic environment, characterized by rhythmic and/or stochastic exposures to both environmental (e.g., emersion, desiccation, temperature extremes) and biological challenges (e.g., predation, competition, food availability). Much effort has been devoted to studying physiological and/or genetic variation within and between such species, along latitudinal, vertical, seasonal or other relatively large scales. More recently, attention has been focused on small–scale, intra–population variation in physiology and the factors that might regulate it. For example, other work has documented temporal variation in gene expression in the intertidal mussel Mytilus californianus over the course of tidal cycles. In the present study, we approached this issue of intra–population variation from a functional perspective. We quantified temporal changes (over a 5–d period) in biochemical capacities for ATP generation (citrate synthase and malate dehydrogenase) and antioxidant defense (catalase and superoxide dismutase) in mussels from four different micro–sites separated in space by short distances. The patterns of temporal variation varied among micro–sites, but overall metabolic and antioxidant capacities were strongly correlated. We then examined candidate environmental factors that might contribute to spatial and temporal variation in physiology, including variation in emersion time, thermal history, or food abundance. Our results implicate a complex suite of interacting factors that influence the biochemical state of intertidal mussels.
Rainbow smelt is a small (H10cm) fish that feeds under the sea ice during winter. Freeze resistance is achieved in part by the accumulation of high levels of glycerol (200-400 mM). Glycerol is produced primarily in the liver and builds up in all tissues via delivery through the circulatory system. Initial glycerol production is fueled by liver glycogen but thereafter animals must continue to feed to survive as glycerol is continuously lost across the gills and skin at a rate of H10% per day. Dietary protein serves as a major source of glycerol. Regardless of the source of glycerol, the final metabolic steps involve the conversion of DHAP to G3P to glycerol. The glycerol cycle is controlled at the level of G3DPH, PEPCK, PDH, and enzymes of amino acid trafficking. Cellular uptake mechanisms remain to be addressed. Tissue glycerol equilibrates with glycerol in the plasma. At least in heart, glycerol appears to enter cells by passive diffusion down the concentration gradient with a linear relationship between extracellular glycerol and rate of uptake. Red blood cells (RBCs) present a different dynamic. In RBCs glycerol uptake shows two linear relationships with a transition point around 50 mM extracellular glycerol. The slope of the second phase is much steeper and is eliminated by phloretin, a blocker of facilitated transport. I propose RBCs have a low affinity aquaglyceroporin (AQGP) that facilitates glycerol entry at relatively high levels of extracellular glycerol. I further speculate that the presence of such an AQGP relates to the unique loading/unloading demand placed upon RBCs and no other tissues. Theoretically, RBCs show loose glycerol upon transiting the gill. Upon passage through the liver circulation the RBCs should reload at high extracellular glycerol levels.

Effects of PAHs on Respiration and Gene Expression in Primary Hepatocytes isolated from Natural Populations of Fundulus heteroclitus

We are investigating the effect of polycyclic aromatic hydrocarbons (PAHs) on metabolic function and gene expression using primary hepatocytes from two populations of the salt marsh teleost Fundulus heteroclitus: one population inhabiting a Superfund site highly contaminated with PAHs and a nearby reference population. Individuals from the population inhabiting the Superfund site are resistant to the PAHs in their environment, but the mechanism of this resistance is not yet well understood. Because PAHs are known to affect metabolism, mitochondrial respiration will be measured in primary hepatocytes using high resolution respirometry. The activities of specific complexes in the electron transport chain will be quantified by exposing hepatocytes to the corresponding substrates and blockers and then correlated with changes in gene expression. Differences between the polluted and reference populations will provide insights into PAH resistance and help us to better understand the evolution and adaptation of natural populations in response to anthropogenic pollution.
Adaptations of Elephant Skin for Non−Evaporative and Evaporative Heat Loss

Despite lacking sweat glands, elephants have among the highest rates of cutaneous water loss (CWL) of a variety of arid dwelling herbivores. Though the unique morphology of elephant skin has been recognized, neither its thermal nor water barrier properties have been investigated. We measured thermal conductivity (W m\(^{-2}\)°C\(^{-1}\)) and conductance (W m\(^{-2}\)°C\(^{-1}\)) as well as cutaneous water loss (CWL, mg cm\(^{-2}\) hr\(^{-1}\)) and resistance (s cm\(^{-1}\)) of integument from Asian (n = 4) and African (n = 2) elephants and correlated these values with morphological and compositional analysis of the skin. Manatee (n=5) and pig (n=5) integument were also included for comparison. We found significant inter and intra−species variation in morphology and composition of the integument which corresponded to differences in both the thermal and water barrier properties. The thermal conductivity of Asian (0.19 ± 0.01 W m\(^{-1}\)°C\(^{-1}\)) and African elephant (0.23 ± 0.13 W m\(^{-1}\)°C\(^{-1}\)) integument approached the upper limit of previously measured values as a result of high water and low lipid content. CWL was significantly greater (p<0.0001, F = 54.21) and resistance significantly lower (p<0.0001, F = 35.11) in both the elephant and manatee integument relative to that of the pig at all measured temperatures. All four species demonstrated a significant increase in resistance at the highest temperature treatment (39.7°C) but this was most pronounced in elephants and manatees and may correlate with the transition temperature of stratum corneum lipids. Our results indicate that elephant integument conducts heat up to 11 times better than mammals with arctic or sub−arctic pelage and loses water at rates that are comparable to some amphibians, allowing elephants to maximize both non−evaporative and evaporative heat loss.
Energetic constraints and parental care: is corticosterone an important mediator of incubation behavior in a precocial bird? 

Suppression of the adrenocortical response (e.g., corticosterone release) to an acute stressor is a physiological adjustment thought to decrease the likelihood of avian parents abandoning their nests. However, some periods of parental care, like incubation, are energetically costly, thus corticosterone could increase during these stages to allow incubating parents to utilize energy reserves. Wood ducks (*Aix sponsa*) have ~30 day incubation periods and only the female incubates the eggs. We hypothesized that corticosterone would be important in regulating energy availability during incubation in this species. Because resources invested in reproduction increase with clutch size, we also hypothesized that clutch size would influence plasma corticosterone during incubation. We measured baseline and stress--induced corticosterone in incubating females during early and late stages of incubation. At both stages of incubation all hens had low baseline corticosterone levels. However, we found that stress--induced corticosterone was 105% greater late in incubation than early in incubation. We also detected a significant negative correlation between female body mass and stress--induced corticosterone late in incubation, but not during the early stages of incubation. Furthermore, we found a significant positive relationship between stress--induced corticosterone and clutch size. These lines of evidence support the hypothesis that incubation in wood ducks is energetically costly and corticosterone is important in catalyzing energy stores needed to support the energetic demands of incubating hens. Our findings suggest that corticosterones role in supporting parental care behaviors are dynamic and are influenced by several factors and that there is a greater physiological cost associated with incubating larger clutches.

Bite performance of the extant coelacanth Latimeria chalumnae 

The coelacanth *Latimeria* is the only extant genus of a group of lobe--finned vertebrates (sarcopterygian) originating in the Devonian times. Since its discovery in 1938, this genus has been of considerable interest due to its striking similarity with fossil coelancaths and the presence of anatomical features that are only known in fossil sarcopterygian fishes. Notably, it is the only extant genus showing a skull divided into an anterior (i.e. ethmosphenoid) and a posterior (i.e. otocipital) part, which articulate by means of an intracranial joint. This complex articulation is thought to allow an elevation of the snout by 10° to 20°, which would enhance mouth opening distance and velocity allowing a powerful suction. Although the cranial anatomy of *Latimeria* is well known, the function of its kinetic joint during feeding remains poorly understood. Indeed, the lack of information on some key anatomical structures as well as on the actual movements of the cranial elements during feeding has led to the proposition of a number of hypotheses on the role of the intracranial joint and other structural elements of the head during jaw movement. Based on morphological data acquired from the recent dissection of a coelacanth specimen from the MNHN collections, we re--describe the jaw closer muscles, and estimate bite forces using a static equilibrium model. Implications in the skull kinesis and feeding behaviour of *Latimeria* will be discussed, and future directions of this study will be presented.

Examining factors influencing body size change for insular rodents 

When organisms colonize an island, they often undergo dramatic shifts in size. This phenomenon has been observed in birds, reptiles, amphibians and even plants, but it is especially evident among mammals, where insular shifts towards larger body sizes in small species and smaller body sizes in large species have come to be known as the island rule. Despite early assertions that mammals followed this rule with law--like regularity, it is now clear that the island rule is an oversimplification of a complex process where exceptions abound. Multiple processes have been hypothesized to influence these size shifts, but no single variable has proven to be capable of explaining a significant portion of the size variance observed on islands. The order Rodentia has presented particular challenges to the island rule because among rodents on islands exist cases of both size increase and decrease with little apparent relation to original body size. To address this issue, we previously assembled a data set of insular rodent populations and made use of classification tree methods to identify which hypothesized processes were most useful in predicting the direction of size change for insular rodents. We found the most important factor predicting direction of change to be mainland body mass and while other variables had some predictive power, their roles in determining direction of size change were more context--dependent. Here, we expand our data set and confirm some previous findings, we use more traditional linear methods to focus on how these predictor variables influence the degree of size change, and we explore to what extent different degrees of size change reflect a significant difference between island and mainland rodent populations.

Agile airframes I: maneuverability from abdominal actuation 

Flying animals face trade--offs between maintaining stability versus the ability to accomplish quick maneuvers. Unlike terrestrial or aquatic locomotion, flight requires the active and continuous generation of lift forces and control along multiple degrees of freedom. For insects, maintenance of flight stability is particularly difficult about the pitch axis, which is further destabilized by oscillations generated by the periodic forcing of the wing beats. This instability requires sensory feedback to actively coordinate motor responses to pitch stimuli in order to stabilize flight. Here we investigate the extent to which pitch instability can be controlled, not by the wings, but through the deformation of the animals airframe via abdominal flexion. To accomplish this, we developed analytic methods for determining how control of abdominal angle in the hawkmoth *Manduca sexta* contributes to stability. By combining measured sensory gains and delays with a model of a flexing flying animal we found that moths operate on the very edge of stability, within 1% of the dynamic range. Thus, small changes in control surfaces can move the animal to unstable (and maneuverable) dynamics. In this way, the animal may take advantage of multiple motor outputs, such that small changes in single outputs can quickly shift the animal to an agile regime, while the other outputs are available to quickly stabilize the animal.
Fluid–solid coupled model of flapping flexing insect wings reveals multiple maxima for flight forces

Many insect wings deform significantly during flight. This deformation is due to musculoskeletal forcing of the wing base, which results in passive emergent bending, along with aerodynamic loading of the surrounding fluid. Since deformation can change the amount of lift and thrust that the wing develops, the mechanical structure of the wing can influence flight performance. We explored two key issues associated with the design of compliant wings: over a range of driving frequencies, how does wing stiffness influence (1) the lift and thrust generated and (2) the relative importance of fluid loading. Since the parameter space is expansive, experimental methods and robotic realizations are not feasible. Thus, we developed a computational model that uses vortex methods and a spring−mass−damper model to couple the fluid loading to the structural dynamics. Actuation frequencies and flexural stiffnesses for the model were based on a range of values that encompass those measured for a number of insect taxa (4−80 Hz; 10−4−10−3 N m−2). Over the entire range of parameters, we show that fluid loading never contributes more than 10% to the average flight forces. We also show a non−monotonic relationship for lift and thrust, which exhibits more than five local maxima over the same range of parameters. This non−monotonic relationship follows from several interacting periodic phenomena: elastic vibrations, oscillatory boundary conditions, and vortex shedding. As a result, for insect wings of any given stiffness or driving frequency, there exist multiple local maxima for lift and thrust.

Evidence that high pCO2 affects coral recruits through perturbed protein metabolism

The recruitment of larvae to benthic surfaces is critical for scleractinian corals, for the outcome determines where adults will live for decades and the extent to which populations grow. In the coming century, rising pCO2 poses new challenges to coral recruits, and while there is evidence of negative effects, little is known of the proximal mechanisms involved. We have developed techniques to grow coral recruits under ecologically relevant conditions and test their response to environmental conditions in the first few days of benthic existence. Initial experiments using this technique reveal that recruitment in Seriatopora caliendrum involves a 70% increase in metabolic rate within 3 d of settling, and that 86 Pa pCO2 depresses metabolic rate 12% within 5 d of benthic existence. The reduction in respiration at high pCO2 suggests that metabolic depression may be used as a short−term response to hypercapnea. We indirectly explored the role of protein synthesis in mediating these changes by measuring the respiration of S. caliendrum recruits with and without the protein inhibitor emetine following 1−4 d at 45 (ambient) versus 77 Pa pCO2 at 25.3°C. Two days after settlement, respiration was affected by the interaction of emetine and pCO2, with respiration reduced 63% at 45 Pa pCO2, but 26% at 77 Pa pCO2; this interaction disappeared in 5−day old corals, in which respiration was reduced 28% by emetine. These results suggest that high pCO2 affects protein metabolism in coral recruits, potentially by impairing protein synthesis but incurring new costs through other pathways. Further investigations of the effects of high pCO2 on protein metabolism in corals may be productive.

Ciliogenesis, neurogenesis, and the intersection of aneural and neural larval swimming behaviors in the genome−enabled marine snail Lottia gigantea

Larval swimming often begins prior to gastrulation in marine invertebrates. Thus, larval swimming may span both aneural and neural behavioral controls in taxa having a nervous system. To test this idea, we characterized larval swimming, ciliogenesis, and neurogenesis in Lottia gigantea. Swimming behavior was characterized by observation and video analysis. Cilia functioned by six hours post−fertilization, and swimming movements become increasingly complex. Ciliogenesis was characterized by electron microscopy, immunohistochemistry, and in situ hybridization. Although prototroch cilia functioned early, a stereotypic shifting of cells and the formation of ciliary plates still needed to occur, and may influence swimming behavior and ability. Surprisingly, cilia−related transcription factors were expressed within distinct domains of the prototroch. Also surprising, structural proteins functioning in ciliary motility were expressed in both motile and non−motile ciliated cells. Neurogenesis was characterized by neurotransmitter immunohistochemistry. Diverse spatiotemporal patterns of expression were observed, with the earliest onset occurring between fifteen and eighteen hours, long after establishment of complex swimming behaviors. Our results suggest that the prototroch is under both aneural and neural control in Lottia, with later neural control potentially modulating an aneural system. Understanding aneural versus neural control in marine invertebrate larvae may provide new insights into the early evolution of animal behavior and nervous systems, and new perspectives on neuronal function in human health and disease.
Estrogenicity in soybeans varies among plant organs, and changes across the season as plants mature, and respond to seasonal environmental change. Estrogenicity of plant tissues comes from phytoestrogens – lignans, coumestans, and especially flavonoids. These plant molecules serve myriad physiological and ecological roles in plants, including UV protection, auxin transport regulation, attraction of pollinators and symbionts, and modulation of herbivore endocrine function. The effects on herbivores are due to cross-reactivity of phytoestrogens with animal estrogen receptors. We have also shown that exogenous estradiol (an animal estrogen), genistein (a phytoestrogen), and bisphenol A (an estrogenic component of plastics) alter development, growth, and reproduction in green beans. Our data show that plants are sensitive to environmental estrogens as are animals. These observations suggest a larger ecological and evolutionary role for estrogens as cross-taxon signaling agents, a hypothesis that is supported by recent findings of flavonoids in basal groups red, green, and brown algae, and mixtures of cyanobacteria and diatoms.

Phylogeny and biogeography of the shell-eyed chitons

Over their half a billion-year history, chitons have had numerous aesthetic sensory organs in their shells, with shadow detection as one of their proposed functions. Much more recently, a clade of chitons have diversified that have not only aesthetes but also much larger ocelli, and these are image forming and each has an aragonitic lens, retina, and other hallmarks of animal visual systems. Shell-eyed chitons are not known as fossils older than the Miocene yet since then have become some of the most common reef-dwelling chitons in tropical and southern hemisphere localities worldwide. Despite their ecological importance and their status as the animals with the most recently evolved eyes, their phylogenetic relationships have not been well resolved. They have been classified as either Toniciciniae or Acanthopleurinae within Chitonidae based on whether the girdle is nude or is covered with calcareous armor (spines or scales), respectively. We tested this subdivision with DNA sequence comparisons. Our results strongly corroborate the shell-eyed clade but not its internal subdivision into conventional groupings. Instead, our results support separate New World and Old World radiations, with loss of girdle elements corresponding to polyphyletic lineages nested within the shell-eyed clade. There is also intriguing evidence of regional patterns of speciation or phylogeographic divergence. For example, Acanthopleura gemmata from northeastern Australia have closer affinities with western Pacific populations from New Caledonia than they do with A. gemmata from Western Australia, and the latter have closer affinities with Indian Ocean populations as far west as Africa. In between, populations north of Australia are different again with likely unrecognized species diversity. Improved phylogenetic and biogeographic resolution will allow us to relate variation in ocelli to the pattern of evolutionary diversification.
We examined potential vasomotor control mechanisms in Antarctic fishes, compared with teleosts of different phylogenetic relatedness from both cold and temperate environments. In general, vascular constrictor activity showed a modest α and β adrenergic tonus, but with greater potency for cholinergic and serotoninergic vasoconstriction, in Antarctic notothenioids and both related and phylogenetic sister group species from warmer waters around New Zealand. This unusual pattern of control appears to be primarily a consequence of evolutionary lineage rather than low environmental temperature, but may be modified according to functional demand e.g. a pelagic species showed a dominance of vasodilatation over vasoconstriction. Prostanoid vasodilators were effective in reducing vascular tone, but a variety of potential nitro-dilators all failed to elicit a response (though they were active in trout vessels). Polar and temperate northern hemisphere species, phylogenetically distant from each other and the notothenioids, showed both similarities and differences making simple inferences about phenotype vs. genotype difficult. In light of a reduced importance for the classical adrenergic and nitro-ergic vascular control, maintenance of adequate cardiovascular control at extremely low temperatures likely involves compensation by a variety of other vasoactive substances. In addition, each species possessed a unique pattern of vascular innervation that partially differentiated between notothenioids and non-notothenioids, while functional consequences for oxygen delivery to locomotory muscle also involve changes in microvascular structure. We conclude there is little evidence for cold adaptation of branchial airway contractility, and mechanisms of vascular control likely reflect phylogeny rather than thermal history.

The shape of the mammalian nasal passages plays a key role in the principal functions of the nose: respiration, olfaction, and in some bat species, echolocation. However, we still have only a rudimentary understanding of how differences in the shape of the nasal passages relate to differences in functional abilities between species. Our approach to tackling this problem has been to examine patterns of airflow among closely related species of phyllostomid bats. These species differ substantially in the relative length of the rostrum, with corresponding differences in internal airflow morphology. In this study we hypothesize that these morphological differences impact the patterns of airflow to and within the olfactory region of the nose. We predict that air arrives to the olfactory region more quickly in short-faced species because of the shorter distance air travels to reach this region. We also predict that the extensive development of the olfactory recess in some species allows odorant-laden air to remain entrained for longer periods of time, potentially improving olfactory performance in these species. We used CFD to study airflow and histological preparations to examine the distribution of olfactory epithelia in three phyllostomid species. As in rodents and dogs, we found that the majority of airflow is directed ventrally through the airway, never contacting the olfactory region. Short-faced species have more extensively developed olfactory recesses, which experienced slower airflow. These short-faced species are also dedicated frugivores, so more extensive olfactory recesses may relate to these species reliance on olfaction in foraging. This association between the morphology of the olfactory recess and airflow is consistent with previous suggestions that the olfactory recess plays a key role in olfactory function.

**Biohydrodynamics of branchial artery tone in Antarctic fish**

**Neuromuscular Facilitation in the Motor Networks of Cubomedusae**

The first modern physiological analysis of cnidarian nerve nets was performed by Pantin, in which he provided the first detailed investigation of the staircase effect. He later coined the term facilitation to describe the process in which a train of sufficient stimuli affects the response to subsequent stimuli in the direction of augmentation. In the case of jellyfish, a succession of stimuli elicits a graded increase in the force of muscle contraction. This process is frequency dependent in that decreasing interpulse interval produces stronger contractions. Jellyfish swim via rhythmic contractions of the bell musculature and rely on frequency dependent neuromuscular facilitation (FDNF) as a mechanism to produce strong, periodic contractions and efficient swimming. Cubomedusae further rely on FDNF for the existence of a biphasic modulatory potential within the swim system where jellyfish swim at approximately 80% of maximum. These data were taken from the subumbrella of *C. marsumialis*, but recently it has been shown in this and another species (*T. cystophora*) that the subumbrellar network is sparsely innervated and relatively disorganized as is stereotypical of a nerve net. The velarium and frenulum exhibit significantly higher network densities, and neurons of the latter align with radial muscle fibers. Similar networks in the retractor muscles of some anemones exhibit rapid conduction velocities and faster times to maximal facilitation. Here we investigated the facilitation properties of the subumbrella, velarium and frenulum in two box jellyfish species (*C. quadranus*) and *T. haponema* seasonally local to North Carolina. Differences in facilitation properties were found between muscle sheets as well as between different sizes of the same species. These results may offer clues to the functioning of different muscle sheets in executing complex swimming behaviors.

**The effect of thermal stress and hypoxia on the hyperiid amphipod Phronima**

Hyperiid amphipods in the Eastern Tropical Pacific migrate across a temperature gradient of 10 degrees or more and spend daytime at oxygen levels less than 0.1 mL/L. To determine if these current conditions are physiologically demanding, oxygen consumption, lactate accumulation and HSP 70 expression were measured in the hyperiid amphipod *Phronima*. Thermal stress experiments were conducted at 23°C, the approximate maximum surface temperature in the region, with recovery at 10–20°C or further thermal stress up to 29°C. Separate respiration experiments were performed under conditions equivalent to day and nighttime exposure, 10°C hypoxia (1% O₂), and 20°C normoxia (21% O₂). Oxygen consumption decreased from 2.82 μM O₂/g/h in normoxia to 1.82 μM O₂/g/h in hypoxia. The Q10 (a measure of temperature dependence of metabolism) is approximately 2 between 10 and 20°C. L-lactate, an index of anaerobic ATP production, was significantly higher, in hypoxia (8.92 ± 1.33 mmol/L Lactate), compared to normoxic, (3.47 ± .47 mmol/L lactate) specimens. In hypoxic conditions lactate accumulation increased at higher temperatures, and was elevated after 24hrs at 23°C even in oxygen saturated conditions. These data indicate that amphipods are near maximum thermal levels and approaching critical oxygen levels during their current migration. Climate change is predicted to cause an increase in oceanic temperatures and decrease in oceanic oxygen levels. Ecological implications of these changes will be discussed.
Effects of supplemental food and corticosterone treatment on begging and feeding behavior in Florida Scrub–Jays (Aphelocoma coerulescens)

Begging is believed to communicate an honest signal of a nestling's nutritional needs. When a nestling requires more food, it will beg to elicit feeding from its parents. The rate and duration of this behavior and the parental response may be influenced by a number of factors. In this study we investigated the roles of two such factors: 1) food availability through supplemental feeding and 2) an individual's corticosterone (CORT) levels, a hormone known to influence begging and parental behavior. We studied the role of food availability by indirectly supplementing all nesting Florida Scrub–Jays (Aphelocoma coerulescens) within a brood by providing ad libitum supplemental food (meal worms) to their parents during the nesting period. The role of CORT was examined by feeding one nestling per assigned CORT treated nest a CORT–injected wax worm twice–daily for 4 days (Days 8–11 post–hatch) and a second nestling in the same nest a vehicle–injected wax worm. We quantified nestling and adult behaviors using high definition videos recorded with a camera set atop a pole (3–6 meters tall) on Days 5, 8, 11, and 13 post–hatch. We found that the rate and duration of begging of all nestlings in the CORT treated nests was greater than that of nestlings in food supplemented and control nests. In addition, the adults with CORT treated nestlings in their nest visited a greater number of times per hour and fed nestlings more frequently than did controls. Individual nestling behavior and data on nestling baseline and stress–induced CORT levels (collected on Day 11) will also be discussed.

Regional comparisons of the effects of summer and winter low tide conditions on photosynthetic recovery in a high intertidal alga

Because the timing of low tides varies among locations along the US west coast, populations of a species can experience different abiotic conditions in different regions. We studied populations of the high intertidal alga Endocladia maricata in Washington and southern California to determine how individuals responded to regional ambient low tide conditions. We collected individuals from the high and low edges of the algal tidal distribution in winter and summer and determined their ability to recover from one hour and four hour exposures to low tide conditions. Low tide treatments were fully factorial with two hydration levels and three temperatures (winter=10°C, 20°C, 30°C; summer=20°C, 30°C, 40°C). We compared post–emersion photosynthetic rates to pre–emersion rates to evaluate recovery. Completeness and rate of recovery differed between individuals collected at different tidal heights and was affected by low tide temperature, desiccation state, and the length of the low tide exposure. Individuals from the high edge of Endocladia tidal distribution recovered from low tide conditions more completely than low edge individuals. In both regions and seasons, recovery was slowed following four hour low tide exposure compared to one hour low tide exposure. Individuals in high temperature treatments frequently showed reduced recovery relative to individuals in low temperature treatments, although the interaction between hydration status and temperature varied among seasons and regions. Understanding geographic variation in the factors that affect individual photosynthetic recovery following low tide exposure may help us make predictions about the persistence of populations in the face of climate change.

Effects of supplemental food and corticosterone treatment on begging and feeding behavior in Florida Scrub–Jays (Aphelocoma coerulescens)

The colors of birds are diverse but limited relative to what they can perceive. This mismatch may be partially caused by the properties of their color–producing mechanisms. Aside from pigments, several classes of highly ordered nanostructures (e.g., thin films, multilayers, photonic crystals) can produce a range of colors. However, the variability of any single nanostructural class has rarely been explored. Dabbling ducks are a speciose clade with substantial interspecific variation in the iridescent coloration of their wing patches (specula). We used electron microscopy, spectrophotometry, refractive index–matching experiments, optical modeling and phylogenetic comparative methods to investigate the mechanism and evolution of these colors. We show that color is produced by a complex nanostructure consisting of a thin film of keratin and hexagonally arranged melanin rods (melanosomes) within feather barbules. Although the range of potential variation of this nanostructure is theoretically broad, only relatively close–packed, energetically stable variants producing more saturated colors were observed, suggesting that ducks are either physically constrained to these configurations or are under selection for the colors that they produce. Thus, we further tested how functionally independent components of this nanostructure evolve within this limited region of morphospace and found that melanosome diameter and spacing evolve at different rates, but species explore available morphospace uniformly. Taken together, these results reveal a previously undescribed color–producing nanostructure and suggest that both physical variability and constraints within single nanostructural classes may help explain the broader patterns of color across Aves.
82.2 ENG, CM*; PANCHERI, FQ; LIEBERMAN, DE; BIEWENER, AA; DORFMANN, A; Harvard University, Tufts University; cmeng@fas.harvard.edu

Pulling in two directions: biaxial material properties of fascia lata
We tested the biaxial material properties of goat fascia lata (FL), a highly organized collagenous tissue that is in intimate connection with the thigh muscles. Previous studies show that lower limb fascia plays a key role in limb stability and force transmission across segments, and recent work measuring muscle and fascia strain in vivo provides evidence that the FL may store and recover limb kinetic energy in locomoting goats. Further investigation is critical in determining how fascia stiffness and hysteresis influence its potential to serve a variety of functions during locomotion. Because FL has a sheet-like structure and attaches to muscles and bones at multiple sites, it must be strained biaxially, and its functional potential cannot be assessed using uniaxial tests. Furthermore, in situ experiments suggest that biaxial strains modulate longitudinal stiffness in aponeuroses, fascia-like structures found at muscle-tendon junctions. We used planar biaxial testing with strain control to investigate the hypothesis that, like aponeuroses, fascia stiffness can be modulated by different biaxial strain conditions. Because the two layers of collagen fibers in the FL are oriented approximately perpendicular to each other, we performed biaxial tests on longitudinal and transversely oriented samples in each goat. Samples were cycled to multiple strain levels while the non-cycling direction was held constant at 0% and 3% strain. Results show that FL stiffness and hysteresis are higher in the longitudinal vs. transverse direction and stiffness does not increase with perpendicular strain in either direction. Differences in material response in the longitudinal vs. transverse direction and in aponeuroses vs. fascia are likely related to collagen fiber content and orientation.

51.6 EPEL, D.; Stanford University; depel@stanford.edu

Epigenetics as a stress response and its differing roles in the embryo and in the adult
I explore the view that the adult and the embryo handle environmental change in radically different ways. The adult handles change through reversible and temporary changes referred to as the adaptive stress response. The response can ensue from environmental changes in temperature, xenobiotic, oxygen, nutrients and osmolality etc., The embryo might utilize similar reversible stress responses during the development period, but the most important response to environmental change are embryo-unique adaptive epigenetic mechanisms. The outcome is an irreversible change in phenotype resulting from the deployment of alternative developmental pathways in response to specific environmental signals. The signals that the embryo responds to could come from sensing nutrients, predators, photoperiod, maternal behavior, chemicals and probably a plethora of unappreciated environmental signals. Irreversible epigenetic changes also occur in the adult but these appear to be maladaptive. I end with a discussion of how this reframing of adult vs embryo stress responses provides a new view of epigenetics and its changing role during the life history of the organism.

143.4 EME, J.; Univ. of North Texas; dane.crossley@unt.edu
Ontogeny of Cardiovascular Physiology In Embryonic Reptiles: Capacity for and susceptible periods of Environmentally-induced Phenotypic Plasticity.
In response to chronic developmental stress, embryonic reptiles exhibit phenotypic plasticity resulting in multiple morphological and physiological modifications. Utilizing the developmental stressor, chronic hypoxic, we have investigated the plasticity of cardiovascular regulatory maturation in two species, the American alligator and the common snapping turtle. These species exhibit both common and unique responses to developmental challenges. Both species exhibit phenotypic plasticity in relative heart mass and intrinsic heart rate, with a common increase in heart mass and depression in heart rate in response to hypoxic stress. However, they differ in their capacity to modify the timing of cardio-regulatory ability and the strength of each regulatory mechanism during development. These include the activation of vagal tone on the heart and a cardiovascular chemoreflex. To investigate the developmental periods during which the cardiovascular system is amenable to environmentally induced phenotypic change, we focused on the American alligator. Relocation of hypoxic (10% O₂) incubated embryos to normoxia (H to N) at 70% of incubation returned heart mass to control values measured at 90% of development. The opposite manipulation (N to H) did not result in an increase in relative heart mass compared with hypoxic-incubated (control) animals measured at 90%. Physiological phenotype was also altered by this manipulation resulting in an intrinsic heart rate that was reduced by the N to H shift compared to the H to N change. Collectively these data indicate that the degree cardiovascular developmental phenotypic plasticity is species dependent and may require exposure during finite windows of development to produce a given response. NSF CAREER IBN IOS-0845741 to DAC

142.5 ERICKSON, GM*; KRICK, BA; NORELL, MA; SAWYER, WG; Florida State Univ., Tallahassee, Univ. of Florida, Gainesville, American Museum of Natural History, New York; gerickson@bio.fsu.edu

Complex Dental Structure and Wear Biomechanics in Hadrosaurid Dinosaurs
Mammalian grinding dentitions are composed of four major tissues that differentially wear, creating coarse surfaces for pulverizing tough plants and liberating nutrients. Although such dentition evolved repeatedly in mammals (e.g. horses, bison, elephants), a similar innovation occurred much earlier (~85 ma) within the duck-billed dinosaur group Hadrosauridae, fueling their 35 million year occupation of Laurasian mega-herbivorous niches. How this complexity was achieved is unknown, as reptilian teeth are generally two-tissue structures presumably lacking biomechanical attributes for grinding. Here we show that hadrosaurids broke from the primitive reptilian archetype and evolved a six-tissue dental composition that is among the most sophisticated known. Three-dimensional wear models incorporating fossilized wear properties reveal how these tissues interacted for grinding and ecological specialization.

142.2 ENG, CM*; PANCHERI, FQ; LIEBERMAN, DE; BIEWENER, AA; DORFMANN, A; Harvard University, Tufts University; cmeng@fasc.harvard.edu

Pulling in two directions: biaxial material properties of fascia lata
We tested the biaxial material properties of goat fascia lata (FL), a highly organized collagenous tissue that is in intimate connection with the thigh muscles. Previous studies show that lower limb fascia plays a key role in limb stability and force transmission across segments, and recent work measuring muscle and fascia strain in vivo provides evidence that the FL may store and recover limb kinetic energy in locomoting goats. Further investigation is critical in determining how fascia stiffness and hysteresis influence its potential to serve a variety of functions during locomotion. Because FL has a sheet-like structure and attaches to muscles and bones at multiple sites, it must be strained biaxially, and its functional potential cannot be assessed using uniaxial tests. Furthermore, in situ experiments suggest that biaxial strains modulate longitudinal stiffness in aponeuroses, fascia-like structures found at muscle-tendon junctions. We used planar biaxial testing with strain control to investigate the hypothesis that, like aponeuroses, fascia stiffness can be modulated by different biaxial strain conditions. Because the two layers of collagen fibers in the FL are oriented approximately perpendicular to each other, we performed biaxial tests on longitudinal and transversely oriented samples in each goat. Samples were cycled to multiple strain levels while the non-cycling direction was held constant at 0% and 3% strain. Results show that FL stiffness and hysteresis are higher in the longitudinal vs. transverse direction and stiffness does not increase with perpendicular strain in either direction. Differences in material response in the longitudinal vs. transverse direction and in aponeuroses vs. fascia are likely related to collagen fiber content and orientation.

51.6 EPEL, D.; Stanford University; depel@stanford.edu

Epigenetics as a stress response and its differing roles in the embryo and in the adult
I explore the view that the adult and the embryo handle environmental change in radically different ways. The adult handles change through reversible and temporary changes referred to as the adaptive stress response. The response can ensue from environmental changes in temperature, xenobiotic, oxygen, nutrients and osmolality etc., The embryo might utilize similar reversible stress responses during the development period, but the most important response to environmental change are embryo-unique adaptive epigenetic mechanisms. The outcome is an irreversible change in phenotype resulting from the deployment of alternative developmental pathways in response to specific environmental signals. The signals that the embryo responds to could come from sensing nutrients, predators, photoperiod, maternal behavior, chemicals and probably a plethora of unappreciated environmental signals. Irreversible epigenetic changes also occur in the adult but these appear to be maladaptive. I end with a discussion of how this reframing of adult vs embryo stress responses provides a new view of epigenetics and its changing role during the life history of the organism.
29.3 ESSOCK–BURNS, T.*; TARRELL, A.; MATHAI, P.; GOHAD, N.V.; MOUNT, A.S.; MAKI, J.S.; RITTSCHOF, D.; Duke University, Marquette University, Clemson University; te18@duke.edu

Interactions between biofilm bacteria and barnacles Balanus amphitrite

Biofilms are associated with macrofouling organisms. We are interested in the interactions between bacterial communities and barnacles. Here, we report results bacteria–barnacle associations of larval stages, colonization of primary attachment of glue by bacteria, what happens to bacterial communities under juvenile barnacles as they grow, and experimental studies of bacterial communities associated with adult barnacles attached to dialysis membranes. Finally, direct contact tests using glue and bacteria isolated from surfaces. Barnacle nauplii and cyprids collected from the plankton no evidence of bacteria using epifluorescent microscopy and bacterial staining techniques. The same technique showed bacteria on the surface barnacle cyprid primary attachment glue. Barnacles are found under the base of 6–day old juvenile barnacles. By 14 days there are no bacteria present under the barnacles. Late juvenile barnacles were reattached to sheets of cellulose dialysis membrane and grown for 1–2 months. Denaturing Gradient Gel electrophoresis data show different bacterial composition of biofilms under barnacles than exposed biofilms on the membranes. Based on these results, we explored the interaction between bacteria isolated from surfaces and fresh barnacle glue in direct contact tests. Two major findings from the direct contact test are: 1) growth was stimulated by glue in bacteria grown in low and high nutrients and 2) bacterial growth in high nutrient conditions was unexpected and suggests hormesis. Our results suggest, the symbiosis between barnacles and bacterial communities is complex and may involve active management by barnacles.

47.2 EVANS, T.G.*; HOFMANN, G.E.; California State University East Bay, University of California Santa Barbara; tylergevans@gmail.com

Ocean acidification in the Northeast Pacific: a genomics perspective

Ocean acidification (OA), the decline in seawater pH caused by the absorption of atmospheric CO₂, has emerged as a global-consequence of anthropogenic activity. However, coastal zones of the Northeast Pacific Ocean already experience declines in pH as a result of oceanic upwelling, which exposes contemporary marine populations to seawater conditions not expected to occur in other parts of the ocean until 2100. To explore the impacts of OA in the Northeast Pacific, we capitalized on the availability of genomic resources for a keystone calcifier in the region, the purple sea urchin Strongylocentrotus purpuratus and monitored gene expression in larvae raised in laboratory mesocosms that simulate future ocean scenarios. We addressed three important questions surrounding the biological effects of OA in the Northeast Pacific: 1.) What are the molecular mechanisms that allow species to sustain function in a low pH ocean? 2.) Do responses to OA differ across species ranges? 3.) How will future ocean warming combine with OA to influence organismal function? Genome-wide transcriptomics provided considerable insight into all three questions. Firstly, modifying the transport and bioavailability of calcium, the primary cation used in organismal function? Genome-based analysis revealed striking differences between OA and warming conditions, highlighting the need for integrative approaches that consider the impact of multiple stressors on biogeographic range and species distributions. Additionally, our results suggest that the molecular responses to OA may vary across species ranges, with some species more resilient to OA and others more susceptible. Finally, we discuss the implications of our findings for the conservation of vulnerable species in the face of ongoing climate change.
Physiological and behavioral responses to multiple environmental stressors in San Francisco Bay–Delta fishes: linking mechanism to management

An important goal of aquatic conservation biology is to understand how environmental factors, both natural and anthropogenic, influence physiological performance, and further whether or not these physiological effects contribute to changes in the distribution, abundance, survival, and overall health of conservation–relevant species. In the San Francisco Bay–Delta (SFBD), many native fishes are in rapid decline and multiple stressors such as entrainment (i.e. fish drawn through intakes) at water pumping stations, loss of critical associated watersheds. Adults and young−of−the−year encounter objects often involves complex rotations of the lower forelimb we predict that species capable of manipulation show strong differences in the shape of the radius and ulna. Here we examine for a data set comprising eight species of procyonoids, one ailurid and eight mustelids whether species with good manipulative skills differ from others in the shape of the forelimb elements. To do so we used a surface sliding semi−landmark approach capable of characterizing the articulations between bones in their full 3D complexity. The results analysed in a phylogenetic context show that carnivorans with high manipulative skills differ markedly from others in the shape of the forelimb bones. Both the proximal and distal articulation areas of ulna (axis 1) and radius (axes 1 and 2) discriminated between species with and without manipulative skills. The humerus also showed significant differences between manipulators and non−manipulators, but only on the second shape axis. Thus, our results confirm our prediction and illustrate that the functional signal of manipulation ability is stronger for the lower forelimb bones, which are most strongly implicated in the movement. Moreover, our results demonstrate the importance of using surface methods to capture non−discrete aspects of morphology related to complex movements.

Ultraconserved elements are abundant, universal markers for population genetic and behavioral studies

Ultraconserved elements (UCEs) are numerous, orthologous loci shared among large groups of taxa (e.g., amniotes, teleosts, etc.), and we have demonstrated that UCEs are universal markers useful for addressing phylogenetic hypotheses across these groups. However, the utility of UCEs at shallow levels of divergence is poorly understood. In silico work with human genome data and ongoing analyses of avian and reptilian genome sequence data strongly suggest that UCE loci are sufficiently variable to test hypotheses at the species, population, and individual levels. To test the assumption that UCE loci are useful at the population−and individual−level, we used target enrichment techniques and massively parallel sequencing to collect data from 5,000 UCE loci across all members of known−families representing three species of birds (Sula nebouxii, Sialia sialis, Sialia mexicana). After sequencing, we enriched an average of 4,160 (95 CI = 95) UCE loci from each individual having an average length of 622 bp (95 CI = 29) and totaling an average of 2.6 Mbp (95 CI = 17.2 Kbp) per individual. We will discuss the utility of these UCE data in behavioral (parentage/relatedness) and population genetic (diversity/structure) contexts, in addition to discussing these data in relation to ongoing projects using UCEs at the species level. We will also address the utility of UCEs as universal genetic markers allowing apples−to−apples comparisons at the species, population, and individual level across large taxonomic groups (e.g. tetrapods).
50.4 Farmer, CG*; Schachner, ER; Sarrazin, JC; Feilich, K. L.*; Lauder, G. V.; Harvard University, Amphimedon (Petrosia ficiformis) shows the greatest number of Corticium candelabrum lacks, Procambarus is unusual among sponges in either Amphimedon FAulkes, Z.; The University of Texas−Pan American; Amphimedon, was discovered by European pet owners in the Marmorkrebs populations in natural North American habitats, but the Marmorkrebs are in the North American pet trade. Non−native crayfish have caused substantial ecological and economic damage, and several states and provinces have passed laws prohibiting the import or ownership of crayfish. Much of the pet trade is a grey market, however, and documenting the sale of animals, particularly invertebrates, is challenging. An online survey and monitoring of Internet websites shows that Marmorkrebs have been available in North America since at least 2003 (the year Marmorkrebs first appeared in a scientific publication). Marmorkrebs are kept as pets in at least 38 American states and five Canadian provinces, and this is probably an underestimate of their distribution. It seems likely that almost every state and province in North America either has, or soon will have, someone keeping Marmorkrebs as pets. Of eight states and provinces with laws that would prohibit owning Marmorkrebs, six had Marmorkrebs owners, who were apparently breaking local laws by keeping these crayfish. There are no confirmed cases of Marmorkrebs populations in natural North American habitats, but the pet trade creates a significant risk that this crayfish will be introduced.

Fifty states of grey market: Assessing the pet trade for parthenogenetic marbled crayfish, Marmorkrebs, in North America

Faulkes, Z.; The University of Texas−Pan American; zfaulkes@utpa.edu

Why do fish have different shapes? A test using simple physical models

Feilich, K. L.*; Lauder, G. V.; Harvard University, Cambridge, MA; kfeilich@fas.harvard.edu

Post−synaptic Density (PSD) and Axon Guidance Genes in the Transcriptomes of 8 Sponges

Farrar, N*; Riesgo, A; Leys, S; University of Alberta, Farmar@ualberta.ca
Pulmonary bypass shunt reduces oxidative damage in the American alligator

Various hypotheses have been proposed to explain the evolutionary persistence of cardiac shunting among the vertebrates. We hypothesised that the right-to-left (R–L) shunt acts to reduce oxidative stress in tissues, and offers protection during periods of atmospheric hyperoxia. In order to test this hypothesis, we eliminated R–L shunting ability by surgical ligation of the left aorta (Lao) in juveniles of the American alligator (Alligator mississippiensis), effectively converting their circulatory system from in-series to in-parallel. Experimental animals (no R–L shunt; n=8) and sham-operated controls (shunt intact; n=8) were exposed for 25 days to normoxia (21%O2) and hyperoxia (35%O2) at 30°C. Plasma samples collected after each exposure were assayed for lipid peroxidation and antioxidant activity. We found significantly higher (+13%) malondialdehyde concentrations in response to hyperoxia in experimental animals, and no differences in catalase concentration between treatment groups. This suggests alligators without shunting ability suffered increased oxidative damage, but were unable to mount sufficient antioxidant defences to protect against reactive oxygen species. We suspect the pulmonary bypass shunt, by admixture of deoxygenated and oxygenated blood, reduces blood oxygen tension and limits oxidative damage to systemic tissues. Palaeoatmospheric oxygen fluctuations would have had limited effect on contemporary vertebrate taxa with in-series circulation. Evolution of in-series circulation in ancestors of mammals and birds must have necessitated upregulation of antioxidant expression.

Funded by NSF grants IOB 0445680 and IOS 922756 to JWH.

143.6 FELBINGER, K*; OWERKOWICZ, T; EME, J; SCHRINER, S/E; HICKS, JW; California State University, San Bernardino, University of North Texas, Denton, University of California, Irvine; kfelbing@hotmail.com

Molecular and Morphological Description of Stomatopod Larvae

The stomatopod larval phase is adapted for survival in the pelagic environment. Larvae have thus evolved an overall morphology that is separate from the adult, making them difficult to identify since they lack the adult characters used to classify species. The traditional methods of larval species identification have been to either hatch larvae from a known mother or rear larvae through adulthood. The limits of these techniques have resulted in a small and patchy description of larval morphology and species diversity in the stomatopod literature. With the advances and accessibility of molecular techniques, DNA barcoding of the cytochrome oxidase I (COI) mitochondrial gene has emerged as an adequate solution to the problems associated with larval species identification. We designed degenerative primers based on known stomatopod sequences to amplify an 864 base pair fragment of the COI gene. Larval sequences were then aligned with 138 adult reference sequences to construct a maximum-likelihood tree. Larval sequences that were reciprocally monophyletic or had a genetic distance of less than 3% from a reference sequence were regarded as a species. Using these methods, we have positively identified 14 species of stomatopod larvae from collections on the reef platform of Lizard Island Research Station (LIRS, Queensland, Australia). This represents approximately half of the adult species that have been sampled for DNA barcoding at LIRS. We have also sampled 8 species of stomatopod larvae with unknown species identities, suggesting a greater diversity of stomatopod species at LIRS than previously sampled. Based on these data, we have begun morphological descriptions of the last stage larval forms of commonly captured species at this site, including Alima pacifica and Alima orientalis. Continuing research will use barcode data to investigate genetic diversity within and among species.
Flow patterns associated with swimming motions of benthic and pelagic batoids as visualized with DPIV. Batoïd fishes display undulatory and oscillatory swimming kinematics of the enlarged pectoral fins that are associated with either benthic or pelagic habits, respectively. Each swimming mode is related to distinct flow patterns that are linked to the propulsion efficiency of the fin motion. Digital particle image velocimetry (DPIV) was used for quantitative flow visualization. Batoids were tested in a long still water tank, where the ray could dictate its own swimming speed, or in a flow tank at 0.25 m/s. The wake structures were visualized for the undulatory Atlantic stingray (Dasyatis sabina) and freshwater ray (Potamotrygon motoro) and the oscillatory cownose ray (Rhinoptera bonasus). The wake of the ray was characterized by vortices shed from the trailing edge of the pectoral fin with a posteriorly oriented momentum jet flow. For undulating rays swimming along the bottom of the tank, the momentum jet was horizontally directed, whereas when swimming in the water column, the jet was directed at a downward angle to the horizontal. The cownose ray produced a wake with a thrust-type vortex street of two staggered rows of alternating vortices that were generated from the distal end of the pectoral fin. The cambered profile of the rigid central body induced water movement in the wake with a downward directed component. The fluid motion and vorticity in the wake of swimming batoids show distinct differences in pattern that are associated with thrust production for each swimming mode, buoyancy control and with proximity to the bottom.

Batrachochoytrium dendrobatidis, an emergent pathogen linked to amphibian declines, produces factors that inhibit adaptive immunity in both amphibians and mammals. Batrachochoytrium dendrobatidis (Bd) is a pathogenic chytrid fungus that infects the keratinized epithelium of amphibian skin to cause the lethal disease chytridiomycosis, which is linked to global amphibian declines. While adaptive immune defenses appear to be involved in resistance, a robust response is often lacking; and the mechanisms by which Bd avoids immune surveillance are not well understood. One hypothesis to explain the ineffective immune responses is that this fungus produces virulence factors that inhibit lymphocyte functions. To address this hypothesis, we studied the effects of Bd cells or supernatants on in vitro proliferation of Xenopus laevis splenic lymphocytes induced by PHA or other activators. Proliferation was inhibited by Bd cells or cell–free factors released by Bd. A closely related non–pathogenic chytrid, Homolaphyllex polyrhiza, was poorly able to inhibit lymphocyte functions suggesting that Bd has unique virulence factors. These factors induced splenocyte apoptosis, activating both caspase 8 and caspase 9 pathways. Bd factors also inhibited activation and induced apoptosis in murine and human lymphocytes. Ongoing studies of the molecular nature of the fungal virulence factors suggest that they are soluble, non–protein components of the Bd cell wall. These results suggest that Bd has evolved a mechanism to impair adaptive immunity in host amphibians in order to colonize the skin. The inhibitory factors appear to target a pathway shared between amphibians and mammals. Research Support: NSF grants 0843207 and 1121758 to LR—S
FLAMMANG, B.E.*; LAUDER, G.V.; Harvard University; lifiamang@post.harvard.edu

**Quest for Muscle Specific Genes in Pleurobrachia bachei: Had mesoderm independently evolved in Ctenophores?**

Teleost fish, like the bluegill sunfish, have multiple flexible fins that are used as modifiable control surfaces. This helps to make fish highly maneuverable, permitting behaviors like reversing direction of motion and swimming backwards without having to rotate body position. To answer the question of how fish swim backwards we used highspeed videography and electromyography to determine the kinematics and muscle activity necessary to produce reverse direction propulsion in four bluegill sunfish. Comparison of backwards swimming to forwards swimming determined that the two swimming modes are not reciprocal actions. To swim forwards at low speeds, sunfish primarily used their pectoral fins only without appearing to use any other fins. Conversely, backwards swimming is a multifin effort, utilizing the pectoral, dorsal, anal, and caudal fins. The pectorals alternate direction synchronously, broadly flared on the outstroke and feathered on the instroke. The dorsal fin and dorsal portion of the caudal fin act out of phase as do the anal fin and ventral portion of the caudal fin. Electromyography of all muscles in the pectoral, dorsal, anal, and caudal fins demonstrated bilateral activation when the fin changed direction, suggesting that the fin is stiffened at this point. Because teleost fish are statically unstable, locomotion at slow speeds requires precise fin control to adequately balance the torques that are produced about the center of mass. Therefore, we expect that bluegill sunfish require a coordinated multifin motion pattern in order to swim backwards in a controlled manner.

MOORE, I. T.; Virginia Tech, Radford University; fliesand@msu.edu

**Immune defenses of captive and wild spotted hyenas (Crocuta crocuta): a comparative analysis**

Evolutionary processes have shaped the vertebrate immune system over time, but proximate mechanisms control activation, duration, and intensity of an immune response. Ecological and demographic factors such as sex and pathogen pressure can influence immune function. Conventional immunology relies primarily on laboratory-reared animals, which introduces the possibility of altered developmental trajectories of the immune system as compared to animals in their natural habitat. Here we assessed differences in immune function between wild spotted hyenas that inhabit a pathogen-rich environment and captive hyenas that inhabit a more hygienic environment. We used the immune defense component model framework to characterize immune defenses along two continuums: constitutive to induced and non-specific to specific. Our results show that wild hyenas have significantly greater concentrations of total IgG, total IgM, natural anti-KLH IgG, and a trend for increased natural anti-KLH IgM. We observed no difference in bacterial killing ability between the wild and captive populations. This has important implications for serological monitoring of disease in wildlife. Furthermore, there is little evidence of disease-induced mortality in the wild hyena population, indicating that immune defenses are robust in this population. This leaves open the possibility that pathogen exposure is important for proper development and maintenance of the immune system, as suggested by the hygiene hypothesis.
9.2 FOO, SA*; BYRNE, M; Univ. of Sydney, Australia; shayna@anatomy.usyd.edu.au
Effects of ocean warming and ocean acidification on the sea urchin Heliocidaris tuberculata
The concurrent effects of ocean warming and ocean acidification will have deleterious effects on many marine invertebrates however certain species may show potential for adaptation. Adaptation to stressful climate conditions depends on heritable genetic variance for stress tolerance present in populations. We studied the interactive effects of warming (+4°C) and acidification (~0.3–0.5 pH units) on development of the sea urchin Heliocidaris tuberculata, near future (2100) ocean conditions projected for the southeast Australian global change hot spot. There were significant effects of pH and temperature on early development with significant interaction between stressors. Decreased pH and increased temperature had negative effects on larval development with smaller larvae in near future levels of these stressors. However there was no significant interaction between warming and acidification on larval development. Multiple dam–sire crosses were used to quantify the effects of climate change on development to assess adaptive capacity.

9.4 FOSTER, K.L.*; HIGHAM, T.E.; Univ. of California, Riverside; kfoott01@ucc.edu
Neuromuscular control of arboreal locomotion: how green anoles (Anolis carolinensis) deal with changes in incline and perch diameter
Arboreal habitats comprise a diverse array of inclines, substrate diameters, and obstacles that pose considerable functional challenges for locomotion. Arboreal lizards often alter limb kinematics as they execute the complex maneuvers necessary in this habitat. However, there is virtually no information regarding how limb muscles control and propel arboreal lizards. We assessed activity patterns of the biceps dorsalis, puboischiobiaulis, ambiens pars dorsalis, caudofemoralis, and peroneus brevis and longus using synchronized electromyography (EMG) and three dimensional high speed video of 9 adult male green anoles (Anolis carolinensis) running on flat (9cm wide) and small, round (1.3cm diameter) perches inclined at 0°, 45°, and 90°. The majority of muscles exhibited two bursts per stride, the first of which occurred during stance and had a greater amplitude and longer duration than the second. The activity patterns of all muscles were consistent with the propulsive functions hypothesized based on anatomy, although several appeared to have secondary antagonistic functions during the swing phase. Although EMG amplitude generally correlated positively with angular excursion of the corresponding joint, activity levels in the biceps, caudofemoralis, and peroneus were disproportionately greater at 90°, especially on the narrow perch, suggesting steep, small diameter perches may be suboptimal from a physiological perspective. However, the reverse was true on the small diameter inclined at 45° for the ambiens, which exhibited decreased recruitment despite greater knee extension than the other treatments. We show that these muscles respond differently to the challenges of perch diameter and incline and suggest that their relative contribution to propulsion may shift.
Deep transcriptome insights into cave beetle eyes

The small carrion beetle genus Ptomaphagus diversified into more than 50 species, which range from ancestral surface dwellers to facultative and obligatory cave inhabitants in the Southeast of the United States. One of the best-studied representatives is the troglobite Ptomaphagus hirtus, which is endemic to the cave system of Mammoth Cave National Park. P. hirtus adults are characterized by complete reduction of the hind wings and near complete reduction of the compound eye to a small lens patch. In his survey of North American cave animals, Packard (1888) was unable to detect photoreceptors or optic neuropils in sections of the adult head of P. hirtus, which led him to conclude that P. hirtus lacks visual senses. This assessment, however, is in conflict with the induction of lens cell specification in the developing insect compound eye. The recent deep sequencing of the transcriptome of the adult P. hirtus head recovered orthologs of a large number of sensory, structural and regulatory vision-related genes. I will discuss how these data inform us about the organization of the visual system in P. hirtus and other microphthalmic cave arthropods.

Sexual conflict occurs when the evolutionary interests of females and males are divergent. Sex-differences in optimal copulation duration can be a source of conflict. Males may evolve mechanisms to prevent females from remating to ensure their reproductive success, while females may otherwise benefit from mating again with a different male. Increased copulation duration may be advantageous for males as it delays female remating. Males of many species actively guard females to prevent them from remating, and in some cases males produce copulatory plugs to prevent remating. This conflict may be especially onerous to a female if precopulatory choice is limited at the time of her first mating. Male red-sided garter snakes (Thamnophis sirtalis parietalis) produce a gelatinous copulatory plug during mating that occludes the opening of the female reproductive tract for approximately two days. The size of the plug is influenced by the copulation duration. We experimentally tested the contribution of male and female control over copulation duration. We ablated the largest basal spine on the males hemipene and found a reduction in copulation duration and an increase in the variation of plug mass. Further we anesthetized the females cloaca and found copulation duration increased in this treatment group as well. This suggests that males benefit from increased copulation duration while females actively try to reduce copulation duration. Therefore, sexual conflict is manifest in divergent copulation duration optima for males and females.
42.3 FUQUA, R.D.*; MONROY, J.A.; NISHIKAWA, K.C.; FURIMSKY, M. M.; Westminster College − PA; had distinct elongated and narrow in growth inhibition assays has Sternoptyx diaphana Brom GAGNON, YL*; JOHNSEN, S; Duke University; GAMMILL, WM; ROLLINS−SMITH, LA*; Vanderbilt mutants suggest that this mechanism growth, and the individual pure synthetic R. sphenocephala (and louise.rollins−smith@vanderbilt.edu Pterotrachea coronata Batrachochytrium muscles were not affected. Data from wildtype and heterozygous silhouettes against the downwelling light at mesopelagic depths. maximum (FWHM) of all the examined species. This matches well had the highest angular resolution and smallest full PSF width at half Hatchefishes, Argyropelecus aculeatus and Sternoptyx diaphana, the highest angular resolution and smallest full PSF width at half maximum (FWHM) of all the examined species. This matches well the predictions that these fish need high resolution for viewing silhouettes against the downwelling light at mesopelagic depths.

108.3 GAGNON, YL*; JOHNSEN, S; Duke University; 12.yakir@gmail.com Visual acuity in deep−sea fish and mollusks The ocean can be a challenging environment for visually active animals. Downwelling light is absorbed by the water and decreases exponentially with depth. At epipelagic depths (0−200 m), targets reflect ambient light and create expanded scenes. The most suitable lenses at these depths maintain high image contrast at the viewer's resolution (the highest spatial frequency that can still be registered by the viewer's retina). At mesopelagic (200−1000 m) and bathypelagic depths (>1000 m), bioluminescence is more common and the ambient light is many orders of magnitude dimmer than at shallower depths. The visual scene becomes dominated by point source targets requiring a different type of lens. Scenes become more binary (with less gray levels) and low contrast at the cutoff resolution does not necessarily affect the image quality. We looked at the optical characteristics of the lenses of 24 different species of deep−sea fish and pelagic mollusks. The lenses' radii, focal lengths, and focal capabilities were measured. Collimated light (550 nm) was focused on a camera CCD by adjusting the paraxial distance of the lens (suspended in buffer). We imaged the lens' point spread function (PSF) (quantifying the amount of blur introduced by the lens). The PSF was used to calculate image contrast of targets with varying spatial frequencies. These results were compared to known cutoff frequencies of the investigated species, their depth, and biology. The heteropod, Pterotrachea coronata, had distinct elongated and narrow PSFs matching the linear array of photoreceptors in its retina. The Hatchefishes, Argyropelecus aculeatus and Sternoptyx diaphana, had the highest angular resolution and smallest full PSF width at half maximum (FWHM) of all the examined species. This matches well the predictions that these fish need high resolution for viewing silhouettes against the downwelling light at mesopelagic depths.

42.1 FURIMSKY, M. M.; Westminster College − PA; furimsky@westminster.edu Taking time to teach scientific methodology and communication in a first year biology course In addition to learning new information in the classroom, first year biology students are also developing important skills and competencies to carry forward into their upper level courses and beyond. Recent assessment of student learning has inspired revisions to existing curricula for the purpose of preparing the new generation of students for success in a competitive academic environment. The three hour per week lab component of our first year biology courses include one week skills workshops (e.g. solutions, microscopy, genetics), as well as three week lab modules. The lab module approach has permitted the careful stepwise use of the scientific method under the guidance of biology faculty, including gathering appropriate scientific literature, experimental design, data analysis and scientific writing. Details of the changes to our undergraduate curriculum will be discussed, with the primary focus being the experiential learning component of our first year biology courses.
Fresh Insights from RNA-Seq Analysis into Black Widow Spider Venom Composition and Evolution

Venoms are chemically complex secretions that have independently evolved in several animal lineages for the purposes of predation and defense. Venoms have attracted enormous interest because of their pharmacological applications, and because of their dynamic evolutionary histories, which can be directly linked to organismal ecology. Despite the biological importance of venoms, their molecular composition and evolution is poorly understood in many medically significant and ecologically interesting species. A case in point are the black widow spiders, representing several species in the genus Latrodectus, which have a potent neurotoxic venom that immobilizes both vertebrate and invertebrate prey. We assembled venom gland gene transcripts from the Western black widow spider (Latrodectus hesperus) using Illumina RNA-Seq libraries as well as traditional cDNA libraries. We compared these venom transcripts to Illumina-derived transcripts from L. hesperus silk gland and cephalothorax tissues. Our analyses identified large numbers of transcripts that are exclusively or primarily expressed in venom glands, including many novel toxin sequences. Our results show that black widow venom has far greater molecular complexity than previously realized, which is in part explained by dramatic expansion of toxin gene families. We are expanding this transcriptomic work across related species to further understand how changes in molecular composition and gene expression have led to the extreme toxicity of black widow venom.

Sensory switching in sharks: the role of multimodal stimuli in prey tracking and capture

Hunting involves a sequence of steps with increasing sensory input as the distance between predator and prey decreases. Little is known about multimodal aspects of hunting underwater, where prey can be visible, emit hydrodynamic disturbances, odors, sounds and/or electric fields. We investigated three shark species from different ecological niches: nurse sharks, bonnetheads, and blacktip sharks. We blocked olfaction, vision, the lateral line, and electroreception, alone and in combination, to elucidate their complementary and alternative roles in feeding. Interspecific similarities and differences exist among sharks in terms of which senses they focus on for particular phases of feeding behavior. In most cases, multiple senses can be used for the same behavioral task, allowing sharks to switch to alternative sensory modalities to successfully capture prey. Under our experimental conditions, nurse sharks rely on olfaction for detection and track using olfaction combined with vision, the lateral line, or touch. They orient to prey using the lateral line, vision, or electroreception, but will not strike without olfaction. Capture requires electroreception or touch. Bonnetheads normally use olfaction to detect prey, olfaction combined with vision or the lateral line to track, vision to line up a strike, and electroreception for capture. They can detect, orient, and strike visually in the absence of olfactory cues. Blacktip sharks also detect prey using olfaction or vision, and track using olfaction combined with vision or the lateral line. Long-distance orientation and striking is visually mediated but in the absence of vision, close-range orientation and striking can be lateral line-mediated. Capture requires electroreception or touch. Collectively, these results reveal species-specific sensory hierarchies for shark feeding behavior.
Developing markets for a new product: Aquacultured Red Claw in Mexico

The number of farms, production and demand of Cherax quadricarinatus or Redclaw has had major shifts in the last fifteen years in Mexico. These shifts also have been caused by the marketing strategies for the organism and their source (aquaculture/fisheries). In 1996 there were around 20 active farms of redclaw in the States of Tamaulipas alone; by the end of 2001 there were just four. A major transformation in production practices and marketing occurred since then. There was the need to make the redclaw more accessible to the people and to expand the markets. More markets attracted more investors and the redclaw industry started to grow, more farms started operations in ten more states and redclaw looked like a booming aquaculture activity. The number of farms was over 40 again by 2007. Nobody thought there would be anything that could stop the booming of this industry. Unfortunately, illegal stocking in man–made dams and reservoirs occurred in Tamaulipas and suddenly the market was flooded with redclaw of all sizes at $50 M/X and sometimes $50 MXN so competition between farmers and fisherman started in 2007. Since then there has been a balance and producers that have been able to market their product through quality and consistency have succeeded and the ones that have not are struggling or have failed and closed operations. Farms by 2010 are reported to be 15 nationwide. Redclaw is in Mexico to stay, and it will depend on expanding the current markets that a new round of expansion occurs for the aquaculture farms or that innovative production systems can reduce the current production cost and make the farms competitive again.
Plastic selection, and the potential for adaptation in newly established populations

Novel environments often impose directional selection for a new phenotypic optimum. However, new environments can also be a source of phenotypic variation by inducing plasticity and changing the distribution of phenotypes exposed to selection. Plasticity can either be cогradient, where the plastic response is in the same direction favored by selection, or countergradient, where the response deviates from the direction of selection. Cогradient plasticity is thought to be adaptive, as it provides a better pairing between the phenotype and local ecological conditions, but results in weaker directional selection. In contrast, countergradient plasticity is thought to be non-адaptive, as there is a greater mismatch between the expressed phenotype and the optimum favored by selection, resulting in strong directional selection. Thus, understanding how phenotypic plasticity and selection in new environments jointly shape suites of morphological, physiological, and behavioral traits is critical to predicting evolutionary responses and population differentiation. Here we review plastic responses in a diversity of traits for Trinidadian guppy populations adapted to high and low predation environments. Specifically, we examined plasticity in response to the presence or absence of predator cues during development and suggest that the type of plasticity a trait exhibits can be used to predict how it will respond to selection.

Testing the melanism-desiccation hypothesis using experimental evolution

Several Sophophora species on the Indian subcontinent show clinal patterns in pigmentation, with darker populations occurring in northern, drier locations. We used experimental evolution to test the melanism-desiccation hypothesis, which proposes that dark cuticle in Sophophora is an adaptation for increased desiccation tolerance. We selected for dark and light body pigmentation in replicated populations of S. melanogaster and assayed traits related to water balance. We also scored pigmentation and desiccation tolerance in populations selected for desiccation survival. Populations in both selection regimes showed large differences in the traits directly under selection. However, after over 50 generations of pigmentation selection, dark-selected populations were only slightly more desiccation tolerant than light-selected and control populations. Our results do not support an important role for melanization in Sophophora water balance. Supported by NSF award EnGen-0725930.
**Reproductive State Influence on Female Bottlenose Dolphin Ranging Patterns**

Variation in mammalian home range patterns is often linked to energetic requirements, which likely differ depending on reproductive status. Yet, few studies have tested whether bottlenose dolphins (*Tursiops truncatus*) adjust their ranging patterns with respect to reproductive status. Using data from Indian River Lagoon, Florida (1997–2007), we compared the ranging patterns of nursing and non-nursing adult females with both longitudinal and cross-sectional analyses. The size of females home ranges (HR) and core areas (CA) were not significantly different between reproductive states (P>0.05), presumably due to a lack of directional pattern among females. HR size varied greatly among individual females, 9.490.8km² nursing versus 20.9±8.6km² non-nursing, CA size ranged from 0.46.7km² nursing and 0.4e7.7km² non-nursing. Overlap between nursing and non-nursing ranges also varied greatly among individuals (HR: 12.995.0%, CA: 89.0%). Nursing females continued to utilize 82.0±1.5% of their non-nursing HR but only 19.1±5.45% of their non-nursing CA. In our cross-sectional analysis, a large portion (77.75±4.1%) of the non-nursing 95% utilization distribution was also used by nursing females across all seasons. However, overlap between nursing and non-nursing 50% utilization distributions was low (<35%) in all seasons except summer. These findings suggest that variation in ranging patterns among individual females was greater than by reproductive state. Females continued to use a large proportion of their overall range, but concentrated in different areas depending on their reproductive status.

**Methodological Refinements to Using Lugol’s Iodine as a Contrast Agent in X−ray Micro−CT Imaging**

Visualization methods vastly enhance our ability to appreciate and harness complex anatomical relationships for understanding the nature of morphological change. Most notably, the widespread use of non-destructive X-ray computed tomography (CT) and micro-CT (µCT) has greatly augmented our ability to comprehensively detail and quantify the internal hard–tissue anatomy of vertebrates. However, the utility of X-ray imaging for gaining similar paradigm–altering insights into vertebrate soft tissues has yet to be fully realized due to the naturally low X-ray absorption of non-mineralized tissues. In this study we detail how the soft–tissue anatomy of the head and neck including differences between white and grey matter of the brain, individual fascicles of the cranial musculature, dural venous sinuses, glands, fat deposits, and the overall cranial nerves in all cases yielding promising results. However, anatomical visualizations among the larger, post-embryonic specimens have remained incomplete. Our research builds on these previous studies by systematically testing for optimal staining using differences in contrast levels of resulting µCT images from intact archosaur heads prepared under differing treatments of Lugols iodine. We further demonstrate the utility of this method using computer rendering software to describe and quantify the 3-D anatomy of the brain, cranial musculature, and cranial nerves in *A. mississippiensis* and *D. novaehollandiae*.

**Gecko toe and lamella adhesion on macroscopically rough surfaces**

The role in adhesion of the lamellae and toes – intermediate sized structures – found on the gecko foot remains unclear. Insight into the functional role of these structures can lead to a more general understanding of the hierarchical nature of the gecko adhesive system, but in particular how environmental topology may relate to gecko foot morphology. We sought to discern the mechanics of the lamella and toes by examining gecko adhesion on controlled macroscopically rough surfaces. Live Tokay geckos, *Gekko gecko*, were used to observe the maximum shear force a gecko foot can attain on an engineered substrate with sinusoidal patterns of varying amplitudes and wavelengths in sizes similar to the dimensions of the lamella and toe structures (0.5–6mm). We found shear adhesion was significantly lower on surfaces that had amplitudes and wavelengths approaching the lamella length and inter-lamella spacing, losing 95% of adhesion over the range tested. We also found that the toes are capable of adhering to surfaces with amplitudes much larger than their dimensions even without engaging claws, maintaining 60% of adhesion on surfaces with amplitudes of 3mm. Results suggest that gecko adhesion may be predicted by the ratio of the lamella dimensions to surface feature dimensions, and that macroscopic–scale features are necessary to maintain contact, and consequently, generate adhesion on macroscopically rough surfaces. Findings on the larger scale structures on gecko feet could provide the biological inspiration to drive the design of more effective and versatile synthetic fibrillar adhesives.
Physiological Constraints on the Genome Size of Species

Biologists have long sought to explain the over 3000-fold variation in genome size among animals. Cell size is perhaps the only phenotypic trait that has been shown to be correlated with genome size across diverse taxa, but it remains unclear whether cell size constrains genome size or vice versa. Here I present a model that aims to predict genome size based on how physical chemistry constrains cell size, and cell size in turn constrains genome size. Data compiled from a broad range of species from diverse environments are presented in support of the model. Results suggest that much of the heterogeneity in genome size can be explained based on differences in organismal physiology.

The function of DNA methylation in insects

Many organisms are capable of developing distinct phenotypes in response to ecological variation. This developmental plasticity is particularly prevalent in insects, which can produce alternate adaptive forms under different environmental conditions. Developmental plasticity often relies on epigenetic information, which affects gene function and is transmitted through cell divisions. One of the most important epigenetic marks, DNA methylation is found in many insect taxa, yet its function remains unclear. We have investigated the prevalence and patterns of DNA methylation in insect genomes. We have found that DNA methylation is preferentially targeted to genes showing active and uniform expression among insect phenotypes. Genes displaying DNA methylation also tend to be involved in particular biological functions and are conserved phylogenetically. Finally, we provide novel insight into the nature of DNA methylation in insects by contextualizing its role in the multi-layered epigenome.

Bathymetric Patterns of Genetic Variation: Implications for Evolution in the Deep Atlantic

The deep-sea is a vast and complex ecosystem with a rich and highly endemic fauna. Modern research has focused on the ecological mechanisms that allow such high alpha diversity. Few studies have considered how populations diverge or new species form to create this remarkable diversity. Recent work suggests that population divergence decreases with depth in response to reductions in biotic and abiotic heterogeneity below the continental shelf. Consistent with this hypothesis (referred to as the depth-differentiation hypothesis), species diversity, morphological divergence, and genetic differentiation all peak at bathyal depths, decreasing towards the abyss. Potential causes of this pattern include greater isolation of populations at bathyal depths due to topography, environmental heterogeneity, and depth-related variation in evolutionary rates. We test the depth-differentiation hypothesis in the western North Atlantic by comparing patterns of genetic variation between congeneric protobranch bivalve species pairs that have primarily bathyal (500–3000m) or abyssal (> 3000m) depth ranges. Comparing congeners controls for any taxonomic differences in evolutionary rates, ecology or life-history characteristics between more distantly related taxa. Multilocus analyses of both mitochondrial and nuclear loci are used to partition individuals into putative populations, estimate migration rates and test for divergence among these populations. Observed bathymetric patterns of genetic variation have important implications for evolution in the deep North Atlantic.
Neuroendocrine regulation of sexual plasticity in fishes
The study of sex differences has produced major insights into the organization of animal phenotypes and the regulatory mechanisms generating behavioral variation from similar genetic templates. Coral reef fishes display an extraordinary diversity of sexual expression including simultaneous hermaphroditism and functional, socially-controlled sex change. These systems provide powerful models for understanding gonadal and non-gonadal influences on behavioral and physiological variation. The Caribbean bluehead wrasse, Thalassoma bifasciatum, shows a fully male sexual behavior phenotype can develop even in the absence of gonads, key influences of the neuropeptide arginine vasotocin on sexual and aggressive behavior, and a controlling role for estrogen biosynthesis in regulating female-to-male sex change. Transduction of social cues into reproductive responses by a sex-changing female wrasse is not understood, but patterns in mammals and some neuroanatomical findings in fishes suggest the potential for direct vasotocinergic and estrogrenic influences on sexual function and sex change mediated through kisspeptin effects on GnRH neurons. Advances in next generation sequencing and bioinformatics are also creating opportunities to extend genomic approaches to non-model species. We are using these methods to examine global gene expression patterns in brain and gonads and contrast these patterns between the sexes, between alternate male reproductive phenotypes, and over the course of sex change in the bluehead wrasse. We are also extending these studies to other sex changing wrasse species to determine whether there is an evolutionarily-conserved core set of transcriptional changes associated with sex change.

Jumping without slipping: spiders need sticky feet for take–off
Many insects and spiders can perform rapid jumps from smooth plant surfaces. If jumping arthropods relied only on classic friction, they should slip on smooth surfaces except for very steep take-offs. They can overcome this biomechanical problem by using surface adhesion while accelerating. Most adhesive structures only grip when pulled toward the body, but jumping with hind legs requires pushing, against the usual direction-dependence. We studied how jumping spiders (Pseudoscurphus lanigera and Sitticus pubescens) leap from smooth surfaces. Both species accelerated with their 3rd and 4th leg pairs. In P. lanigera the jump was mainly powered by the 3rd legs, and 4th legs touched the surface only at the start of the jump. In contrast, S. pubescens mainly used the 4th legs while the shorter 3rd legs detached early. The different position of the leg pairs in both spiders resulted in a different orientation of the tarsus during take-off. While 4th-leg tips pointed backward in both species and pushed, 3rd-leg foot tips in P. lanigera were oriented forward and pulled. This opposite tarsus orientation led to the use of different attachment structures. High-speed video microscopy recordings of tarsi during take-off revealed that “pushing” 3rd legs in P. lanigera made brief (~9 ms) adhesive contact with their claw tuft setae. In contrast, the distal claw tuft setae of “pushing” 4th legs were lifted off the ground, and contact was only made by some setae of the proximal pretarsus. In S. pubescens the 3rd legs were oriented laterally and adhesive contact was only rarely visible, while “pushing” 4th legs made clear adhesive contact with proximal claw tuft setae. Experimental ablation of adhesive structures caused accelerating spiders to slip, confirming that adhesion is essential for jumps from smooth substrates.
68.5 GONZALEZ–GOMEZ, PL*; MERRILL, L; VENEGAS, C; PANTOJA, J; VASQUEZ, RA; WINGFIELD, JC; Univ. of California Davis, Oklahoma State University, Universidad de Chile, Universidad de de Chile; plgonzalezgomez@ucdavis.edu
Seasonal modulation of testosterone and stress response in a highly stable environment
Birds inhabiting seasonal environments typically have well defined breeding seasons, adjusting the production of sex hormones such as testosterone accordingly. Glucocorticoid hormones, meanwhile, mediate physiological and behavioral responses to changing environmental conditions, allowing animals to respond by improving the chances to survive. We examined the relationship of these hormones to breeding and molting condition in a wild bird in a highly stable environment with no environmental cues limiting the breeding or molting seasons. We collected baseline testosterone (T) and baseline and stress–induced corticosterone (CORT) in blood samples from Zonotrichia capensis during one year in the Atacama Desert, Chile. We expected low levels of T and CORT year–round. We did not find seasonality in breeding stages, and consequently T levels were affected by breeding condition, but not season. Molt did not follow any pattern or seasonality and it was negatively correlated with stress–induced levels of CORT. Molt and breeding stages overlapped at population and individual levels. Our results suggest that in absence of environmental challenges and cues, the adrenocortical stress response is regulated by physiological constraints such as feather production. Further research is needed to assess the role of social cues on T in breeding stage.

57.6 GRACCEVA, G*; HERDE, A; KOOLHAAS, JM; PALME, R; ECCARD, JA; GROOTHUIS, TGG; Institute of Behavioural Neurosciences, University of Groningen, University of Potsdam, University of Groningen, University of Veterinary Medicine, Vienna, University of Groningen; g.gracceva@rug.nl
Turning shy on winters day: effects of season on personality and stress response in Microtus arvalis
Many animals of temperate environments have evolved physiological and behavioural adaptations to cope with the cyclic seasonal changes. This may result in changes in personality: suites of behavioural and physiological traits that vary consistently amongst individuals. Winter, typically the adverse season challenging survival, may require individuals to have shy/cautious personality whether during summer, energetically favorable to reproduction and survival, individuals may benefit from a bold/risk taking personality. In order to test the effects of seasonal changes in early life and in adulthood on behaviour, body mass and stress response, we have manipulated the photoperiod and quality of food in two experiments to simulate the conditions of winter and summer. We used Microtus arvalis as they have been shown to display personality based on behavioural consistency over time and context. In both experiments we tested the voles for activity, exploration and risk–taking behaviours. Summer–born voles allocated to winter conditions at weaning had lower body mass, a higher corticosterone elevation after stress and a less active, more cautious behavioural phenotype in adulthood compared to voles born in and allocated to summer conditions. Behavioural consistency over time and context was unaffected. By contrast, adult females only showed plasticity in corticosterone–induced stress levels, which were higher in the animals placed in the winter condition than to those staying in summer conditions. These results suggest a sensitive period for season related plasticity of personality in which juveniles shift over the bold–shy axis as expected.

117.3 GRACE, J.K.*; ANDERSON, D.J.; Wake Forest Univ.; gracjk7@wfu.edu
Personality, stress, and fitness in a long–lived seabird
The relationship between the stress response and personality has recently become controversial. General rules of personality developed in laboratories appear to be less applicable in the wild or across species. Here, we test the hypothesis that shy individuals mount a greater corticosterone (CORT) stress response than bold individuals in free–living Nazca boobies. Incubating adults were tested in the field for personality, and CORT stress response. We compared structural equation models of personality and stress response using corrected Akaike Information Criterion values. Nazca boobies have a domain–specific personality syndrome (aggression, agitation, and anxiety), including reaction to a novel object, human intruder, and simulated conspecific (mirror), which is repeatable across years. Plasticity between tests was not correlated with any personality domain. Maximum CORT and the area under the CORT curve during a capture–restraint test were repeatable across years, but not baseline CORT. Personality had slight predictive power on the CORT stress response, but no trait was highly correlated with CORT concentration. This supports current research suggesting that links between personality and stress are more complicated in field than lab settings. In many cases, personality can affect mate choice and fitness. In Nazcas, aggressiveness of males and females were generally correlated within pair. However, assortative and disassortative mating had no impact on fledgling production, within a year. The only personality trait associated with fledgling production was male aggression toward an intimidating novel object. Because this trait was repeatable across years (r = 0.31), this relationship is probably not due to changing behavior based on chick viability, but rather is a fitness consequence of a personality trait.
Population genetics of the symbiotic sea anemone *Aiptasia* sp.

Sea anemones (Cnidaria; Anthozoa; Actiniaria) belonging to the genus *Aiptasia* have been used as a model organism in an increasing number of studies detailing mutualism of dinoflagellate–cnidarian symbiosis, bleaching mechanisms, and invertebrate reproduction. Despite its use in several disciplines of biology, many basic evolutionary and ecological aspects of the genus are still unknown. The latest taxonomic revision revealed 16 valid species distributed on tropical and subtropical shallow marine environments worldwide. However, current descriptions of most species are incomplete by modern standards and phylogenetic analyses are nonexistent. Preliminary studies including morphological analysis and molecular phylogenetics have revealed that this model organism is actually a single cosmopolitan, presumably invasive species. The genetic structure of the species was explored using 16 polymorphic microsatellite loci specifically developed for this project from a pyrosequencing EST library. More than 400 individuals within the genus *Aiptasia* have been collected through an extensive sampling effort that encompasses the entire distribution of the 16 currently described species. Specifically we aimed to discriminate distinct population across the globe, and to test different hypothesis that help explain its extreme widespread distribution.

The organization of "wars" by pavement ants

The pavement ant (*Tetramorium caespitum*) is a tramp species commonly associated with human habitation in northern temperate regions. The species is well known for its ant wars* in which thousands of workers from two colonies fight in a large group. Fighting appears to be ritualized; ants engage in fights by grabbing another ant mandibles with its own and pairs undergo what can be described as a push–of–war while other ants recruit more workers. Few ants die during the battle. What are the rules that influence organization of these wars? I report that workers discriminate nestmates and non–nestmates by detecting cues coded in the mixture of cuticular hydrocarbons on the cuticle of ants they antennate. Nestmate recognition cues are coded in the relative abundance of methyl–alkane and alkene hydrocarbons. However, detection of cues on the cuticle of non–nestmate ants is not sufficient to stimulate fighting. Patterns of recent interactions with nestmate ants and the size of the group of ants fighting influence an ants decision to fight. Workers respond to interactions with heterospecific ants using a different set of rules that do not depend on group size.

Stabilizing falls in confined environments

Many organisms live and move in underground environments which they have excavated. Such environments may present challenges for locomotion, in part because organisms move within confined and crowded tunnels and chambers. We hypothesize that the ability to engineer underground habitats provides opportunities to facilitate movement. We studied subterranean locomotion of fire ants (*Solenopsis invicta*, body length BL = 0.35 ± 0.05), which build networks of underground tunnels. In a laboratory experiment we challenged fire ants to climb through 8 cm long glass tunnels (D = 0.1 ± 0.9 cm) that separated a nest from an open arena with food and water. During ascending and descending climbs we induced falls by a rapid, short, translation of the tunnels downward. We monitored induced falls over 24 hours in groups from five separate colonies. The confinement ratio (BLD = ±) significantly influenced the ability of ants to rapidly recover from perturbations. The probability to arrest a fall (p arrest) within the observed tunnel length fit a logistic equation with p arrest = 0 for small ±, p arrest = 0.5 at ± = 0.73, comparable to natural tunnel diameter. The distance fallen prior to arrest (dmax) decreased with increasing ±. At small ±, ants fell large distances and rarely arrested. At large ±, falls were arrested through the use of rapid jamming of limbs, body and antennae against the tunnel walls, arresting in as low 30 ms. We measured the upper bounds of dmax and found that the maximum arrest distance was consistent with scaling predicted from a model of falling in tunnels. Our data indicates that fire ants moving through natural tunnels can employ antennae, limbs, and body to rapidly stabilize falls.

Abdominal pumping in caterpillars has only been documented during molting. Using synchrotron x–ray imaging and high–speed flow–through respirometry, we show that *Manduca sexta* caterpillars also contract their bodies in response to hypoxia, which results in significant compression of the tracheal system. Tracheal compression induced by abdominal contraction appears to be the driving force for external gas exchange, as evidenced by the high correlation between CO2 emission peaks and external body movements. Abdominal pumping was only observed in larger, older caterpillars (> 0.2 g body mass), suggesting that the hypoxia response varies with ontogeny. In caterpillars that exhibited abdominal pumping, neither the frequency of compression nor the percent change in tracheal diameter varied with body mass, suggesting that there is a threshold for this behavior. As insects increased in size, the fraction of tracheal system structures in the head increased, but not as much as would be predicted based on geometric scaling. The fraction of the body occupied by tracheae in the prothorax and last abdominal segment remain constant throughout ontogeny. Furthermore, the diameters of the major tracheae either did not vary with body mass or did not increase as much as expected, suggesting that trade–offs between non–respiratory structures result in smaller tracheae than would be expected based on geometric scaling.
How the hawkmoth Manduca sexta moves left and right

Understanding flight control strategies in insects is essential for drawing a complete picture of the evolutionary and biomechanical underpinnings of flapping flight. Many flying animals can produce lateral sideslip maneuvers, which we investigate here in the moth Manduca sexta. We elicit maneuvers using phototaxis, whereby moths follow an oscillating low-intensity light source in a dark flight chamber. We measure angular and translational kinematics of the moth body and wings in flight with high-speed 3D videography. Our data show that sideslipping moths roll to redirect their body–weight lift vector, a reorientation which is sufficient to produce the lateral accelerations we observe. Using wingtip position, rather than body position, to calculate roll angle produces the strongest relationship between roll and lateral acceleration. Thus moths can, to some extent, actuate their wings independently of body roll. Still, larger lateral accelerations require weak–body roll in addition to wing stroke changes. Among the many possible ways to create roll acceleration, moths produce left–right wing asymmetries in both sweep amplitude and long–axis rotation angle. Conceptually, asymmetries in both quantities create yaw and roll torques. Preliminary data support a scenario in which a moth producing a roll to the right during upstroke alters its long–axis rotation angle so as to reduce the angle of attack of its left wing relative to that of its right. This angle of attack asymmetry also creates a yaw–left torque. The moth counters this yaw torque by increasing the relative sweep amplitude of its left wing during that upstroke and/or decreasing the relative sweep amplitude of its left wing during the subsequent downstroke.

The role of maternal hormones in avian sex ratio manipulation

Avian species can manipulate the sex ratio of their offspring before these offspring hatch. In birds, mothers can not only affect the secondary sex ratio, but also the primary sex ratio of their offspring as the mother is the heterogametic sex. Avian sex ratios vary in relation to environmental or maternal condition. The production of maternal steroid hormones is sensitive to those conditions, and the hormones are also involved in reproduction and deposited in the egg before meiosis. Therefore, we explored what extend and how maternal steroid hormones may be involved in affecting clutch primary or secondary sex ratio. We showed in the rock pigeon, as well as in a related wild pigeon species, the wood pigeon, both producing clutches of two eggs, a clear case of seasonal change in sex ratio in first eggs. In the homing pigeon, domesticated from the rock pigeon, testosterone treatment induced a clear male bias in first eggs, and corticosterone a female bias and we argue that this is in line with sex allocation theory. We next analysed treatment effects on follicle formation, yolk mass and yolk hormones, the latter both pre- and post–ovulatory, in order to test a diversity of potential mechanisms related to both primary and secondary sex ratio manipulation. In addition, we review the existing avian literature on correlative and experimental evidence for effects of maternal steroids on the primary and secondary sex ratio. We conclude that hormone levels in the mother may affect several pre–ovulatory mechanisms affecting offspring sex ratio, whereas egg hormones are probably involved in secondary sex ratio manipulation only.
55.4 GROVE, T.J.*; WHITTINGTON, A.C.; NIENOW, T.E.; WHITTINGTON, C.L.; FORT, T.J.; Valdosta State University, Florida State University, University of South Florida; tjgrove@valdosta.edu

From Muscle to Molecule: Function and Structure of the Calcium–Binding Protein Calsequestrin from a Eurythermal Teleost

Calsequestrins (CSQ) are Ca\(^{2+}\)–binding proteins in the sarcoplasmic reticulum (SR) of striated muscles that sequester calcium during muscle relaxation. CSQ undergoes conformational changes from a random coil at low levels of Ca\(^{2+}\) to highly ordered crystalline aggregates at high Ca\(^{2+}\) levels, but the underlying mechanism by which this structurally dynamic protein remains functional in eurythermal organisms is not known. The intertidal mummichog, Fundulus heteroclitus, provides an interesting study system for investigating thermal adaptation. Recorded twitch times of glycolytic skeletal muscle from F. heteroclitus decrease, while force increases, with increasing temperature (5–25°C). Preliminary data indicate that force production decreases in the presence of the CSQ inhibitor, trifluoperazine, and this effect is more pronounced at higher temperatures. Recombinant CSQ from F. heteroclitus glycolytic muscle (FCSQ) is relatively insensitive to temperature changes in the physiological range (10–25°C). At 35°C, Ca\(^{2+}\)–binding ability of FCSQ decreases, correlating with a decrease in force production at this higher experimental temperature. Structural modeling of FCSQ reveals a highly conserved salt–bridge network critical for high-capacity Ca\(^{2+}\)–binding. The benefits of this work are two-fold: (1) we will be able to deliberately alter the physicochemical properties of FCSQ and measure the functional response to environmental perturbation, and (2) we will correlate the resulting in vitro functional changes with muscle function and whole organism performance. Supported by National Science Foundation grant IOS-0817805.

26.4 GUNDERSON, A.R.; Duke University; arg12@duke.edu

Testing common models of temperature–dependent activity: implications for predicting responses to climate change.

Understanding behavioral responses to thermal variation is crucial for our attempts to predict the biological impacts of climate change. Several models have been proposed to explain the temperature–dependence of activity, usually with reference to the preferred temperature range (i.e., the temperatures organisms assume in a thermal gradient). I evaluated the agreement between observed activity of the Puerto Rican lizard Anolis cristatellus under natural conditions and three models of temperature–dependent activity with varying levels of thermal constraint. Activity rates and body temperatures of 299 A. cristatellus were measured in two habitat types: wet and dry forest. The data were then transformed according to the assumptions of the following behavioral models: Model 1–organisms are only active when body temperatures are within the preferred temperature range. Model 2–organisms are only active if body temperatures are below the upper bound of the preferred temperature range, and Model 3–body temperature does not affect activity within the activity window (i.e., if you are active, body temperature does not matter). I found that Model 1 provided a poor representation of A. cristatellus activity. However, the agreement between Models 2 & 3 and A. cristatellus activity depended on habitat type. Both models provided good representations of activity patterns in the wet forest but not in the dry forest. Thus, even among populations of a single species occupying the relatively small island of Puerto Rico, models did not perform equally well. These results illustrate the need for more fine–scale studies to inform the development of models that accurately reflect behavioral patterns seen in nature. More generally, our knowledge of the behavioral consequences of thermal variation is extremely limited, a problem that must be tackled in order to better understand the consequences of rising global temperatures.

6.3 GUTMANN, A.K.*; LEE, D.V.; MCCOWAN, C.P.; University of Idaho, University of Nevada, Las Vegas; agutmann@uidaho.edu

Collision dynamics of bipedal hopping

Kangaroos and wallabies are able to maintain a nearly constant metabolic rate across a wide range of speeds when hopping bipedally. The anatomy of large, bipedal hoppers undoubtedly effects locomotion energetics 30–70% of the mechanical energy required to hop is stored and returned by the long, compliant tendons of the ankle extensors. However, we wanted to determine the effects of collision dynamics. We compared the collision dynamics of two bipedal hoppers, tammar wallabies and desert kangaroo rats, and two quadrupedal trotters, domestic dogs and goats, across a range of speeds. We calculated collision angle (the angle between the ground reaction force vector and C.o.M. velocity vector) and collision fraction (the actual collision angle/maximum collision angle possible for a particular set of ground reaction force and velocity vectors) for all animals. Collision angle was substantially larger for wallabies than kangaroo rats (6°) and dogs or goats (9°) across all speeds. A large collision angle may allow wallabies to take advantage of the potential for elastic strain energy storage and return in their ankle extensor tendons and, thus, allow them to bounce more economically than other species. Kangaroo rats may not use as large a collision angle as wallabies because their shorter, stiffer tendons are less suitable for elastic energy storage and return. Collision fraction was close to one (0.97) and remained constant for bipedal hoppers across all speeds but decreased with increasing speed for quadrupedal trotters. This suggests that bipedal hoppers are able to adjust collision geometry such that they can store and return elastic strain energy in a nearly ideal manner across a broad range of speeds, whereas quadrupedal trotters cannot store and return elastic strain energy as effectively at higher speeds.

January 3–7, 2013, San Francisco, CA
Towards an Evolutionary Classification of Mycalina and Latrunculina (Poecilosclerida)

A cladistic assessment of familial relationships on the basis of morphological characters obtained low support for the monophyly of Mycalina, with Isodictiidae and Desmacellidae included (Bayesian Analysis – BA), or left out of it (Maximum Parsimony MP, and Neighbor Joining – NJ). BA retrieved no clades within the suborder, while MP and NJ shared only slight congruence in assigning Hamacanthidae and Merliidae to the same clade, a trichotomy with Podospangiidae in NJ. No morphological cladistic study of Latrunculina affinities has been carried this far. Mycalina and Latrunculina are rather poorly represented in molecular studies. Recent highlights are the non–Mycaline affinity of the polyphyletic Desmacellidae (28S) and Podospangiidae (Diacarnus, 28S & COI), as well as the confirmation of Abyssoscleridae assignment to Cladorhizidae (28S & COI). The PorToL project 18S tree confirms the non–Mycaline affinity of both former families, and suggests that Esperiopsidae (Amphilectus) may be a sister of Isodictiidae (Isodictya), both being sister of Podospangiidae (Diacarnus, Negombata, Neopodospongia). This project also suggests that Desmacella lampra may actually belong in Mycalae, that Mycalidae (Mycale) and Guitarridae (Guitarra) may be sister groups, and that Latrunculina (Latrunculia, Tisitisanna) may be monophyletic and belong in the Poecilosclerida. Important taxa of Mycalina and Latrunculina still missing in molecular trees are Hamacanthidae and Merliidae, further genera of Esperiopsidae, Guitarridae and Latrunculidae, and additional subgenera of Mycale. It is also important to add Cladorhizidae into more comprehensive trees.

Fish fins function as dual sensory and motor neuromechanical systems. The roles of fin movement in behaviors have been studied widely across the broad diversity of jawed fishes, both living and extinct. Fish sense diverse behavioral functions. They propel and brake, maneuver and stabilize, clasp, threaten and defend. In tetrapods, such behaviors require considerable feedback from mechanosensors in the limbs that provide proprioceptive information on limb position and movement. Without such input limb movements and the behaviors that include them are greatly impaired. We have found that fish fins used extensively in locomotion and for stability receive proprioceptive feedback from several types of sensory nerve fibers. Afferents run distally along the fin rays and into the fin membranes. With physiology on the pectoral fins of bluegill sunfish, a species that uses its pectoral fins extensively during swimming, we determined that these nerve fibers respond both to bending and to static position of the rays. Surveying several taxonomically distant species suggests that a proprioceptive response to fin ray bending is common. Transaction of the pectoral fin ray nerves of bluegills alters fin use in locomotor behaviors, indicating that the sensory feedback these nerves provide is important for motor function. Together these data demonstrate that pectoral fins with significant roles in locomotion and other behaviors also need to be examined as potential sensory structures. Considering pectoral fins used in locomotion as dual sensory and motor systems has implications for studies of their morphology and movement, as changes in fin shape, size, stiffness and movement pattern could impact the sensory input received. We suggest that other fins likely use similar feedback and that mechanosensory function and sensorimotor integration should be considered in studies of fin functional morphology and evolution.

To Pause or Not to Pause: Effects of Pauses and Grouping on Fluid Flow around the Bell of the Upside−Down Jellyfish, Cassiopea spp.

The sessile nature of the upside−down jellyfish Cassiopea spp. makes it an ideal organism for gathering large sets of data on the kinematics of bell pulsations. Previous experiments and simulations have demonstrated the important role secondary structures play in directing flow around the bell. Here we present numerical simulations examining the effects of pulse timing and of spacing between organisms. We develop a discrete time Markov chain model based on pulse patterns of laboratory specimens to drive the bell kinematics. Effects of observed grouping of similar size and of different size specimens are explored in conjunction with the Markov chain model. Immersed boundary methods are used to solve the resulting coupled fluid−structure interaction problem. Our preliminary results show that variability of pauses between muscle contractions result in very different bulk flow patterns around the bell with implications for particle capture and exchange efficiency. Simulations of paired jellyfish indicate grouping has the potential to enhance opportunity for particle sampling, particularly for smaller specimens.
44.2 HANAUER, RE*; KETTERSON, ED; Indiana University; rhanauer@indiana.edu

Does corticosterone deposited in feathers in autumn predict circulating corticosterone during breeding?

The adrenal steroid hormone corticosterone (CORT) is involved in the regulation of energy balance, behavior, and stress responses. Individuals differ in the degree to which they elevate CORT in response to acute stress, and in some species this has been shown to be a stable trait over the individuals lifetime. In birds, CORT is generally measured by taking blood samples immediately after capture and again 30 minutes later. Interest has grown in measuring CORT extracted from feathers because it is not affected by the process of capture, and it provides a longer-term measurement integrated over the time it took the feather to grow. Feather CORT has been found to correlate with an individuals elevated circulating CORT in response to an acute stressor. However, previous work reported circulating CORT during feather growth. It is unknown if this relationship holds in birds whose feathers grow months earlier. I compared hormone levels from feathers and blood samples to determine whether feather CORT might be a reliable predictor of circulating CORT during the breeding season. Wild male dark-eyed juncos (n=80) were captured during the breeding season at two sites in southern California. Blood samples were collected at 0 and 30 minutes after capture. One tail feather, which had grown the previous autumn during molt, was collected, along with measures of endo- and ecto-parasites. Results will reveal whether circulating CORT correlates with feather CORT deposited several months earlier in a wild passerine and which measure of CORT is a better predictor of the prevalence of parasites. This study will be useful to researchers interested in less-invasive methods, and will inform future research in the fields of animal personalities, eco-endo-immunology, and conservation.

5.2 HANLON, S/M*; PARRIS, MJ; University of Memphis; hanlon2107@gmail.com

Taking the good with the bad: Varying effects Roundup® on amphibian health.

Organisms are exposed to a variety of perturbations in natural communities. In aquatic systems, pesticides are a common anthropogenic pressure that can negatively affect non-target organisms such as amphibians and larval anuran behavior, morphology, or life histories. Glyphosate, especially the commercial formulation Roundup®, is the most widely applied herbicide worldwide and is known to reduce amphibian performance and survival; however, the mechanism of such reductions is currently unknown. We conducted three separate studies on two anuran species to test how: 1) Roundup affects tadpole foraging behavior, 2) application timing alters the effect of Roundup on life history traits, and 3) Roundup affects tadpole mouthpart damage (a potential mechanism for reductions in life history traits). In experiment 1, Roundup significantly altered tadpole foraging behavior. In experiment 2, tadpoles exposed to Roundup later in development experienced increased growth and accelerated development compared to subjects in non-Roundup treatments. In experiment 3, tadpoles exposed to Roundup experienced significantly increased tadpole mouthpart damage (specifically to jaw sheath structures) in a dose-dependent manner. Additionally Roundup at higher concentrations significantly slowed development. Our results suggest that factors such as concentration and application timing may play an important role in understanding how anthropogenic disturbances (e.g. pesticides) affect non-target organisms.

11.5 HANNA, B.SK*; CHANG, PK; MEDINA, MM; University of California, Merced; bkameil@ucmerced.edu

Tissue specific gene expression in the fresh water snail Biomphalaria glabrata: implications for biomineralization and shell formation

The lack of good manipulatable models to study biomineralization in molluscs led us to investigate the potential use of the fresh water snail Biomphalaria glabrata. Using comparative bioinformatics on several molluscan mantle transcriptomes from previous studies, we were able to detect conserved transcripts responsible for biomineralization. We conducted RT-PCR based experiments for a subset of the genes (n=70) in order to explore specific expression patterns in four different B. glabrata tissues: Mantle edge, foot, hepatopancreas and ovotestis. Six out of the 70 novel transcripts showed exclusive expression in the mantle edge. While 19 genes showed significant over expression in the mantle edge over the other tissues. Using a combination of in-situ hybridization and RNAi we are currently trying to understand the functional role of these novel biomineralization-related genes.
HARDEN, L.A.*; WILLIARD, A.S.; Univ. of North Carolina, Wilmington; lah492@uncw.edu
Seasonal variation in osmotic and metabolic status of diamondback terrapins
Estuarine ectothermic vertebrates are faced with highly variable, tidally–influenced conditions, and many aspects of their biology reflect their ability to withstand and respond to the challenges posed by this environment. Diamondback terrapins Malaclemys terrapin experience broad fluctuations in temperature and water availability during the summer, and sub–zero temperatures and low oxygen availability while buried in the mud during the winter. The physiological adjustments necessary to maintain water and salt balance and the metabolic adjustments that accompany seasonal changes in activity and behavior have not been well–characterized for terrapins under field conditions. To investigate seasonal changes in terrapin osmotic and metabolic physiology, we obtained repeat blood samples from 10 radio–tagged female terrapins maintained in a semi–natural open–air salt marsh enclosure that encompassed their typical habitat and allowed them to experience natural shifts in temperature, salinity, and photoperiod. From September 2011 to May 2012 we measured monthly plasma concentrations of inorganic and organic osmolyte concentrations (Na+, K+, Cl–, uric acid, urea, glucose, total Ca2+, Mg2+), osmolality, and lactate. Monthly changes in blood parameters were analyzed using repeated measures ANOVA and Tukeys post–hoc analysis with sample collection date, terrapin size, and environmental variables (e.g. rainfall, salinity, behavior, tide, and mud, water, and air temperatures) included as model covariates. This study will provide unprecedented insight into the physiological strategies of terrapins exposed to natural environmental fluctuations throughout the year and provide baseline blood composition data for diamondback terrapins.

HARVEY, TA*; PRUM, RO; Yale University;
and evolution within populations, between sexes, and among species.

Hyperspectral Patterns
3D Imaging Spectroscopy for Measuring Organismal
Hyperspectral Patterns

The color phenotype of an organism consists of a complete description of the variation in spectral reflectance over the entire organismal surface. Scientific description of the color phenotype requires detailed documentation of both the spectral variation and spatial variation of the surface of the organism. Because many organisms use color in communication and crypsis, the color phenotype should be described over the visible spectrum of the organisms themselves, their predators, or ecological interactors. From flowers and fishes to birds and butterflies, organisms have evolved integuments of astounding beauty and diversity, including brilliant color and dramatic pattern. Research into the evolution of color, size, shape, and distribution of reflectance is limited by current technology. Therefore, we developed novel methods to capture simultaneously a 3D virtual model of organismal surface geometry and the NUV–Vis–NIR spectral reflectance over the organism’s surface. Example data sets demonstrate how we integrate 3D laser scanning, hyperspectral imaging, range image/hyperspectral image registration, and surface mesh–texture integration to capture the color phenotypes of a diversity of bird plumages. Using physiological models of tetrachromatic avian color vision, we then calculate avian color channels for each pixel on the surface of the 3D virtual model of the bird and project these color channels back on to the 3D virtual model. We anticipate that an entirely new standard in visual ecology, behavioral ecology, and evolutionary biology will be established as new methods exploit the advantages of 3D, whole organism, and hyperspectral data sets to test hypotheses about coloration, function, and evolution within populations, between sexes, and among species.

HATTON, R. L.; DING, Y.; CHOSET, H.; GOLDMAN, D. I.; Oregon State University, Georgia Institute of Technology, Carnegie Mellon University; Ross.Hatton@oregonstate.edu
Influence of Deformation Geometry on Sand–swimming Performance

Many animals move within granular media such as desert sand. Studies of an undulatory sand–swimmer, the sandfish lizard, showed that the grains around the organism form a frictional fluid in which inertial effects are small and kinematics dominate. To examine the kinematics of swimming in granular media (GM) we have adapted, from our work in robotics, a geometric model for swimming in viscous fluids. This model relates the net displacement induced by a stroke to an area integral in the stroke parameters. It also gives rise to a visualization that allows us to better understand the performance of the system, whether it be an animal or a robot. For each component direction – forward, lateral, and rotational – this visualization can be viewed as a graph of a function or a “terrain map.” A closed loop in this space represents a cyclic motion, i.e. a stroke. If a stroke encompasses a large positive “mountain” or deep negative “valley,” then it accrues positive or negative displacement, respectively, in its component direction. If the stroke encloses as much positive as negative area, then it produces no displacement; it has enclosed a self–canceling region.

Previously, we demonstrated the principles of the geometric approach on a reduced system, the three–link swimmer. Here, we extend them to continuous systems that can still be modeled by two internal degrees of freedom. In particular, we look at traveling waves of body curvature. The resulting visualizations highlight both the fundamental similarities between various modes of swimming and the differences in their effectiveness.
Havird, J. C.*; Henry, R. P.; Santos, S. R.; Auburn University; jhavird@auburn.edu

Using RNA-Seq and gene-specific methods to examine salinity–induced gene expression changes in an anchialine shrimp

Understanding how organisms respond to environmental variation is critical in order to comprehend how they function in their niches. Taxa from the coastal anchialine ecosystem represent good candidates for studying responses to environmental variation since their habitats undergo wide oscillations in physical and chemical properties, like temperature and salinity. Currently, little is known on how anchialine organisms cope with the environmental variation experienced in these habitats. To address this, we investigated how the Hawaiian anchialine shrimp Holocaridina rubra responds to changing salinity via analyses of gene expression. Illumina technology was first used to sequence transcriptomes from two H. rubra genetic lineages (from East Hawaii and Windward Oahu) previously identified based on divergence in their mitochondrial COI. Six known crustacean osmoregulatory genes were identified from this transcriptomic data and targeted for expression analyses using qPCR. The expression levels of these genes remained relatively constant, or decreased, when shrimp were transferred from iso-osmotic conditions (320) to either hyper-regulatory (150 and 20) or hypo-regulatory (450) conditions. This is in contrast to previously studied crustaceans, which tend to upregulate these genes during salinity transfer. These and previous results suggest that alternative or novel osmoregulatory genes, pathways, or mechanisms may be utilized by H. rubra to cope with the rapidly changing salinities experienced in anchialine habitats. Ongoing experiments utilizing RNA-Seq will investigate salinity–induced gene expression changes across the entire H. rubra transcriptome and shed light on this possibility.

Hazard, L.C.; Montclair State University, NJ; hazardl@mail.montclair.edu

Integrating physiology and conservation: Lessons from the Nagy lab

The developing field of conservation physiology has roots in field studies in physiological ecology, including techniques and approaches pioneered by Ken Nagy. Some recent research projects illustrate the increasing relevance of physiological ecology for conservation issues. Threatened desert tortoises in the Mojave Desert are incorporating non-native, sometimes invasive plant species into their diets. In a laboratory study, we examined the nutritional impact of this shift and found that food type (forb vs. grass) was a better predictor of nutritional value than food origin (native vs. exotic). However, in some areas native forbs are being replaced by less nutritious exotic grasses, leading to a potential shift in available nutrients. This may be of conservation concern if tortoises must forage longer or farther to find suitable foods, and will help determine habitat needs of this declining species. In the temperate forests of the northeastern U.S., anthropogenic salinization of freshwater habitats directly impacts some amphibian populations. We are integrating physiology, behavior, and ecology to evaluate how adults of several sympatric amphibian species respond to increased salinity of their breeding habitat. We have found significant variation in salinity aversion among species, suggesting that adults of some species may not avoid salinities that would be detrimental to them or to their eggs/larvae, and may therefore be more likely to suffer population declines. Knowledge of the physiological basis for these interspecific differences in behavioral salinity tolerance may help predict susceptibility of other species. To conserve declining species, a physiological approach will be critical in predicting, measuring, and hopefully mitigating the effects of local or global anthropogenic influences on populations at risk.

Head, J.J.*; Polly, P.D.; University of Nebraska-Lincoln, Lincoln, Indiana University; jhead2@unl.edu

Conservation of primaxial regionalization in the evolution of the snake body form

Shifts and reduction in Hox gene expression domains have been proposed as a primary mechanism in the evolution of the elongate, dorsoventrally flattened snakes and other squamates. Mapped domains do not show a consistent change in expression in the axial skeleton of snakes, however, and the extent of morphological homogenization has not been examined specifically for the primaxial and abaxial regions of the skeleton. To test for morphological changes along the primaxial skeleton and their implications for inferring Hox patterning in the snake body form, we quantified vertebral shape in a sample of amniotes including taxa with highly differentiated axial regions and resolved Hox boundaries (Mus, Alligator) and representatives of all major squamates clades including elongate taxa. Geometric morphometric analyses of intracolumnar changes in vertebral morphology along the anterior–posterior axis were used to test against models of differing regionalization and to search for regional boundaries. Testing the method on Mus and Alligator produced perfect correspondence between Hox boundaries and quantified shape variation for a four-region model representing cervical, anterior thoracic, posterior thoracic and lumbar regions. Morphometric variation in squamates, including elongate taxa, also best fit a four-region model, despite the absence of additional regional morphologies. Comparisons of morphologically preserved regions in the snake skeleton with mapped domains revealed an exact correspondence between Hox gene expression and morphometric boundaries in the cervical and thoracic regions and a loose correspondence in the lumbar region. These results strongly suggest that primaxial regionalization is retained in the evolution of elongate body forms, and that deregionalization results from reduction or loss of the abaxial skeleton.
S7−2.2 HEATH−HECKMAN, Elizabeth A.C.*; PEYER, Suzanne M.; MCFALL−NGAI, Margaret J.; University of Wisconsin − Madison; heathheckman@wisc.edu

Symbiont luminescence entrains daily host−tissue rhythms through direct regulation of a host cryptochrome gene

All animals exist in the presence of beneficial microbial symbionts, however the extent to which these microbes control, or are controlled by, host circadian rhythms has not been addressed. We studied the role of bacterial partners in regulating biological rhythms in the symbiosis between the squid Euprymna scolopes and its luminous symbiont Vibrio fischeri. This binary model for the chronic bacterial colonization of animal epithelia is characterized by daily transcriptional rhythms in both partners, as well as by daily rhythms in symbiont luminescence. Two transcripts encoding cryptochromes, blue−light receptors that entrain circadian rhythms in all invertebrates, were identified in the host. We first determined whether these genes, escry1 and escry2, cycle in host tissues. Whereas both cycled in the head with a similar pattern to that found in other animals, escry1 cycles in the symbiont−colonized light organ with an 8−fold up−regulation coincident not with environmental light but with the rhythms of bacterial luminescence. Manipulating the colonization process revealed that escry1 transcription patterns in the light organ were dependent upon the presence of symbionts. Mutants of V. fischeri defective in luminescence ("lux") failed to induce escry1 expression to wild−type levels, providing evidence that bacterial luminescence entrains host cryptochrome expression. In addition to being the first known characterization of cryptochromes in a mollusc, this study demonstrates that bacterial symbionts have the potential to be active participants in the setting of host biological rhythms. The conservation of both epithelial−bacterial interactions and circadian gene regulation across the metazoa suggests that symbiont−induced circadian rhythms may be widespread.

143.5 HEDRICK, MS*; CROSSLEY II, DA ; University of North Texas; michael.hedrick@unt.edu

Development of the cardiac and peripheral limbs of the baroreflex in embryonic chickens

The baroreflex is the primary short−term compensatory mechanism to buffer arterial pressure (Pa) changes and maintain cardiovascular homeostasis. Compensatory adjustments in mechanisms include both parasympathetic and sympathetic efferent activity acting on the heart (cardiac limb) as well as sympathetic efferents that modify vascular resistance and perfusion. Although the afferent and efferent limbs of the baroreflex are well−characterized in adult vertebrates, the developmental onset of function in most vertebrates is poorly characterized. Moreover, measurement of the baroreflex in fetal animals is normally limited to the cardiac limb of the reflex in response to changes in Pa. We sought to measure both cardiac and peripheral limbs of the baroreflex using fetal chickens as a model to examine the onset and development of the baroreflex. Fetal chickens were instrumented with chorioallantoic membrane (CAM) arterial catheters to measure Pa and heart rate (fH), Doppler flow probes to measure peripheral blood flow (femoral artery) and miniature bipolar electrodes to measure whole vagal (parasympathetic) nerve activity and peroneal (sympathetic) nerve activity. These measurements were made in day 18/19 (of 21 day development) in white leghorn embryos. Pa was altered using the Oxford method with drugs injected into the CAM artery to increase (Phenylephrine; Phe) or decrease (sodium nitroprusside; SNP) Pa. Injection of SNP resulted in reductions in Pa and vagal afferent activity and increased fH. Nerve activity in the peroneal nerve was associated with increases in Pa and fH, indicating an intact sympathetic limb of the baroreflex at day 18/19 of development. These are the first data to characterize the peripheral limbs of the baroreflex in a developing chicken and show that afferent and efferent components of the baroreflex are functional by day 18/19.

19.4 HEDRICK, MS*; HILLMAN, SS; DREWES, RC; HANCOCK, TV; University of North Texas, Portland State University, California Academy of Sciences, Eastern Washington University; michael.hedrick@unt.edu

Physiological vagility, vertebrate dispersal and population genetic structure of amphibians

Physiological vagility (m h−1) is the ability to move sustainably. We provide a quantitative metric for vagility that incorporates aerobic capacity (VO2max), body mass, body temperature and the minimum cost of transport (Cm). A meta−analysis of four vertebrate classes was used to test our vagility metric with data for dispersal distance (Dmax) and body mass. We also tested our metric with data for genetic heterogeneity (Fst) for amphibians and reptiles. Vagility increased with increasing body mass in amphibians (r=0.73), reptiles (r=0.59) and terrestrial mammals (r=0.81), but was independent of body mass (P=0.99) in flying birds. Within terrestrial locomotors, endothermic mammals have greater vagility at equivalent body masses than amphibians or reptiles owing to greater VO2max. Vagility is higher in reptiles at equivalent body masses than amphibians owing to greater VO2max at higher body temperatures. Dmax was significantly related to body mass for amphibians, reptiles and terrestrial mammals, but was not related to body mass for flying birds. Vagility and Dmax were correlated and both scaled similarly with body mass. There was a significant negative correlation (P<0.001) between Fst and vagility for amphibians with vagility accounting for 56% of the observed genetic heterogeneity. The degree of genetic differentiation with distance (Fst km−1) was greater for amphibians compared with reptiles (P<0.001) and likely due to reduced activity duration or lower VO2max at lower operating temperatures. Recent studies with amphibian populations validate our vagility hypothesis. Our results suggest that interspecific differences in vagility resulting from physiological and anatomical phenotypes play a significant role in limiting or enhancing genetic exchange among amphibian populations.

114.3 HEERS, A M*; DIAL, K P; University of Montana; ashheers@gmail.com

Wings versus legs: mechanistic underpinnings of variation in locomotor strategies among birds

Among the 10,000 species of living birds and their extinct dinosaurian ancestors, relative musculoskeletal investment in wings versus legs is highly variable, varying both across species and throughout ontogeny. Such variation likely has profound effects on locomotor performance and many related aspects of bird ecology, including habitat preferences, foraging strategies, migration patterns, and parental care. During aerial locomotion, high leg investment may hinder wing performance. Likewise, high wing investment may hinder leg performance during terrestrial locomotion. Given these potential relationships between body modules, do tradeoffs between wings and legs influence locomotor ontogeny and evolution? To explore this question and better understand the ecological ramifications of how wings and legs function both independently and cooperatively during ontogeny and evolution, we used published and new data to compare wing and leg morphology and locomotor performance (i) across adult birds of different species and (ii) during ontogeny, in three precocial anseriform−galliform species with distinctly different sequences of locomotor development. Our findings suggest that birds with high wing investment may have reduced mass−specific leg performance and rely on wing−dominated locomotor behaviors, while birds with high leg investment may have reduced wing performance and rely on leg−dominated locomotor behaviors. For example, among adults, wing and leg investment are negatively correlated. Similarly, ontogenetic increases in wing investment and performance can compromise leg investment and performance, and vice versa. Collectively, these results provide new insight into the mechanistic underpinnings of variation in locomotor strategies among birds, and suggest that performance tradeoffs between different body modules may be important during ontogeny and evolution.
38.2 HEIN, A. M.*; MCKINLEY, S. A.; University of Florida; amhein@ufl.edu

Sensory signals and predator search performance at the low prey density limit

Organisms of all types collect sensory measurements from their environments. In some cases, these measurements contain information about the locations of resources such as prey. We show how simple mathematical models of predator sensing and search decision–making can be scaled up to describe one of the fundamental rate functions associated with predator–prey interactions: the predator functional response, which describes how the per–capita rate at which predators encounter and consume prey depends on prey density. Most classic models of functional response assume that, until a predator locates a prey item, the predator moves through its environment in a manner that is independent of the locations of prey. We show that relaxing this assumption and allowing predators to detect and modify search behavior in response to noisy sensory signals emitted by prey causes a qualitative change in functional response. Predators that alter their movement behavior in response to sensory signals encounter prey more frequently than predators that search without using information about prey positions. Interestingly, this difference in search performance is strongest at low prey densities, where predators that utilize even minimal noisy sensory signals have a huge advantage over predators that forage without using sensory data. We suggest that evolution of long–range prey sensory mechanisms such as sensitive olfaction and the corresponding decision–making machinery may be driven by the need to reliably locate prey when prey density is extremely low. More generally, our methodology provides a means of scaling up individual–level sensory processes to describe a fundamental population–level rate parameter that has bearing on species interactions, population dynamics, and food web stability.

39.2 HEINIGER, J.*; DICKMAN, C; WILSON, R S; The University of Queensland, University of Sydney; r.wilson@uq.edu.au

The frenetic sex life of males; northern quoll, performance degrade when the sex becomes too demanding?

The northern quoll (Dasyurus hallucatus) is a medium–sized (approx. 1 kg) predatory marsupial previously common across the entire top–end of Australia. It is the largest known semelparous mammal in the world, which means mating is highly synchronous, males live for only one year, and males undergo total die–offs soon after the mating season. Such population–wide male die–offs are most likely due to the physiological stress of procuring copulations and the intense fighting among males. Given the importance of procuring mates in such a short period (approx. 2 weeks), the ability for males to win fights and cover long distances to find reproductively mature females is presumably of critical importance. As such we would expect the performance of males of high quality males to be high throughout the breeding season while those of poor quality males rapidly decrease. We explored this idea using a mark–capture study of more than 150 individual northern quolls located within a 125ha area on Groote Eylandt. For each individual, we measured the morphology, growth, maximum bite force and maximum running speed throughout their life cycle. We found that not only are there large changes in both male performance throughout their life cycle but there are also substantial variation among individuals that may profoundly influence their reproductive success.

85.2 HEINRICH, EC*; BRADLEY, TJ; Univ. of California, Irvine; eheinric@uci.edu

Temperature dependent variation in respiratory patterns and spiracular control in Rhodnius prolixus

Our current understanding of insect respiratory control indicates that spiracular activity is regulated by two interacting feedback loops which monitor and respond to changes in internal pCO2 and pO2. Spiraltes open when pCO2 reaches a critically high threshold (2–6 kPa) or when pO2 becomes critically low (4–5 kPa). Given that the spiracles open in response to a specific pCO2, the volume of CO2 released in a burst by a discontinuously respiring insect should remain constant independent of metabolic rate. However, previous studies which manipulated metabolic rate via temperature found that burst volume decreases at higher temperatures. We used Rhodnius prolixus to determine if this variation is caused by changes in metabolic rate or by an effect of temperature on spiracular control. We increased metabolic rate by either increasing ambient temperature or by feeding Rhodnius a bloodmeal. Burst volume decreased significantly as temperature increased from 18°C to 38°C (ANOVA, F=89.58, p<0.001) but showed no relationship to metabolic rate in fed animals measured at 24°C (BV= −0.0016MR + 85.2). Burst duration and time between bursts decreased in both treatment groups. Additionally, insects that experienced temperature variation abandoned discontinuous respiration at lower metabolic rates than those in the fed treatment group. Our study suggests that the set point at which the spiracles open in response to CO2 is dependent on ambient temperature. It is clear that the respiratory patterns produced by insects are influenced by both temperature and metabolic rate. These results provide a window for examining the mechanisms by which insects sense and respond to pO2 and pCO2. This work was supported by the NSF grant IOS–0920683 (TJB).

77.4 HEISS, E*; VAN WASSENBERGH, S; University of Antwerp, Belgium; Egon.Heiss@ua.ac.be

Prey capture throughout the seasons: functional demands of a multiphASIC lifestyle in the Alpine newt Ichthyosaura alpestris (Salamandridae)

Evolutionary transitions between aquatic and terrestrial environments were, and still are, significant steps in vertebrate evolution. These transitions require major changes in most biological functions, including feeding. The Alpine newt, Ichthyosaura alpestris is known to show a multiphasic lifestyle where the adult newt changes from a terrestrial to an aquatic life, and again to its terrestrial habitat every year due to its breeding activity. These seasonal transitions induce dramatic changes in morphology, resulting in a distinct aquatic and terrestrial morphotype. We hypothesized that the morphological change between both phases goes along with changes in prey–capture mechanics to maintain performance in both environments. We provide a reconstruction of the complex cranio–cervical myo–skeletal system and simulate its movements during prey–capture. We also analyze the prey capture kinematics in two natural modes (aquatic strike in aquatic phase, terrestrial strike in terrestrial phase) and two induced modes (aquatic strike in terrestrial phase, terrestrial strike in aquatic phase) and perform a multivariate comparison between all 4 modes. In the terrestrial phase, I. alpestris uses its quickly protruding tongue to capture prey, but a suction mechanism when feeding in water. In the aquatic phase, it uses a jaw–based grasping mode on land, but suction feeding underwater. We conclude that I. alpestris shows a so far unknown amount of behavioral plasticity during prey–capture, and that the functioning of its prey–capture system is tuned to seasonal performance demands.
Found or Fly: flight, reproduction and biomechanical tradeoffs in ant queens

Because of a diversity of reproductive strategies, the ants [Formicidae] are an ideal system to study reproductive tradeoffs. In a typical species, a young queen performs two competing, yet intimately related tasks. First, in the flight phase, she must fly to mate, disperse and locate a new nest site. Second, in the foundation phase, she must found a colony, lay eggs and rear the first batch of workers. Many colony foundation strategies are known, but we lack a quantitative framework linking reproduction to flight morphology. Here we introduce the Found or Fly (FoF) Hypothesis, which posits a fitness tradeoff in ant queens between colony foundation and flight performance, manifest through investment in gaster mass. We investigated queen morphology of a common Neotropical species, Azteca instabilis, to evaluate the assumptions of FoF. Gaster mass varied among queens, with time of year, and independently of body size, consistent with individual or colony level manipulation. Several measures of flight ability—flight muscle ratio, wing loading, and drag—were adversely affected by increased gaster mass. Second, we characterized the flight morphology of a hyperdiverse tropical assemblage. Flight morphology accurately predicted colony foundation strategy among the ants. Due to gaster investment, several species carried extremely large loads relative to flight muscle mass, pushing theoretical limits of insect flight. These results confirm the tight relationship between foundation and flight, and suggest that biomechanical flight requirements may constrain reproductive strategies in the ants.
Efﬁciency of lift production in six species of hawk moths

The efﬁciency of lift production is important for all flying animals because it directly inﬂuences the limits of performance. For both ﬁxed-wing vehicles and ﬂapping animals the efﬁciency of lift production, span efﬁciency ($\eta$), can be estimated using quantitative ﬂow diagnostics and fundamental aerodynamic theory. Wings generating lift in the most aerodynamically efﬁcient way do so by deﬂecting the oncoming airﬂow uniformly across the span, creating a uniform spanwise induced ﬂow distribution. Any deviation from uniformity is associated with an extra cost as induced drag increases.

By quantifying how large this deviation is, the increase in drag and the reduction in span efﬁciency can be calculated. We used high speed stereo Particle Image Velocimetry (stereo–PIV) with a repetition rate of 1 kHz to capture the near wake from six species of hawk moths ﬂying tethered in a wind tunnel in forward flight. The selected species represent a range in wingspan from 40mm to 110mm (2.75 times) and in mass from 0.2g to 1.5g (7.5 times). From the high spatio-temporal resolution ﬂow ﬁelds we extracted downwash distributions behind the animals and calculated instantaneous values of $\eta$ throughout the wingbeat cycle as well as multi-wingbeat averages. Here we present how span efﬁciency differs between the six moth species and discuss the effect of force generation and kinematics.

S2–1.5 HERB, Brian R.; WOLSCHIN, Florian; HANSEN, Kasper D.; ARYEE, Martin J.; LANGMead, Ben; IRIZARRY, Rafael; AMDAM, Gro V.; FEINBERG, Andrew P.; Johns Hopkins University, Norwegian University of Life Sciences, Arizona State University, Gro.Amdam@asu.edu

Reversible switching between epigenetic states in honeybee behavioral subcastes

Female honey bees provide a model of social organization and behavior, with developmental separation of castes into reproductive queens and workers, the latter of which emerge as nurses caring for the brood, and then often shifting behavior to become foragers which gather pollen and nectar outside the hive. Epigenetics, or non-sequence based information heritable during cell division, is an attractive potential substrate for these caste differences and behavioral changes, and we tested the hypothesis that differential DNA methylation might distinguish the brains of queens from workers, or foragers from nurses. Using CHARM microarray analysis and whole genome bisulfite sequencing, we found no evidence of worker–queen differences, but substantial changes were detected in the brains of foragers compared to nurses, in genes involved in chromatin remodeling and RNA processing. To test the link between these changes and worker subcaste phenotypes, we reverted foragers to nurses by a technique of hive trickery. Half of these reprogrammed loci were among the nurse–to–forager subset ($P$-value < 2.2 x 10^-16), and included genes for nuclear transport and organization. These data provide the ﬁrst evidence of reversible epigenetic changes associated with behavior in a model organism.

S2–1.6 HERNSHON, J.R.*; FREEMAN, D.A.; Univ. of Memphis; jrhenson@memphis.edu

Widespread distribution of the palatal organ across Cypriniformes suggests multiple roles in feeding

The cypriniform palatal organ has long been thought to play a role in selectively feeding on the benthos. Composed of a dorsal mass of muscle ﬁbers that spans the entire buccal cavity, it is strongly tied to the branchial elements laterally. Previous work on carp and goldﬁsh has shown that this taste bud–studded muscular pad produces localized protrusions that are used to sort and select edible items while bottom feeding. While the neurobiology and physiology of palatal organ function in the goldﬁsh has been well described, there is little data on palatal organ functional morphology across Cypriniformes. While previous reports have suggested that this important feeding structure is limited in its distribution these data show it is present in nine subfamilies of Cypriniformes. Importantly, an obvious palatal organ was present in species that are known to feed within the water column. Ontogenetic data show that this structure forms early in development. Moreover, data from miniaturized species (e.g. Paedocypris), in which many morphological structures are commonly lost, show that even these species have a patent palatal organ. To date the palatal organ is proposed to function solely to selectively feed on the benthos. While sorting during benthic feeding may have been the primitive function, it is likely that the palatal organ has secondarily become adapted for suction generation during the course of cypriniform evolution. Data is presented on muscular architecture and myosin composition of palatal organs of species within 9 subfamilies. Contrary to previously published results all species examined have some type of palatal organ. Although not as well developed or highly innervated as that of goldﬁsh, a complex mesh of predominantly fast muscle ﬁbers characterized nearly all cypriniform palatal organs.
100.6 HERREL, A. *; PERRENOUD, M.; ABDALA, V.; MANZANO, A.; POUDWEB, E.; CNRS; anthony.herrel@mnhn.fr

The effect of substrate diameter and incline on locomotion in arboreal frogs

Frogs are characterized by a unique morphology associated with their saltatory lifestyle. Yet, arboreal species show morphological specializations relative to other ecological specialists allowing them to hold on to narrow substrates. Here we study the limb and brain morphology in arboreal frogs of the genus Phyllomedusa. In addition, we quantified the 3D kinematics of forelimb movement for frogs moving across branches of different three diameters (1, 4, 40mm) and two different inclines (horizontal and 45 degrees). Our data show anatomical differences between arboreal species compared burrowing, terrestrial and aquatic species in the forelimb anatomy and the size of the cerebellum. Moreover, our results show that grip types differed across diameters and inclines. The kinematics of the wrist, elbow and shoulder as well as the body position relative to the substrate showed significant effects of individual, diameter and incline. Kinematic differences involved the durations, velocity of movement and angular excursions with differences being more pronounced for the distal joints. Interestingly, the effects of diameter and incline on both grip type and kinematics are similar to what has been observed previously for primates suggesting. Thus the mechanics of narrow substrate locomotion appear to drive the kinematics of movement independent of morphology and phylogeny.

100.5 HEWS, DK*; VITAL, C; ZÚÑIGA-VEGA, JJ; MARTINS, EP; Indiana State University, Universidad Autonoma de Ciudad Juarez, Mexico, Universidad Nacional Autonoma de Mexico, Indiana University; diana.hews@indstate.edu

Staged territorial intrusions and aggressive visual signaling in males of three Sceloporus lizard species that differ in abdominal patches

As in many animals, Sceloporus lizards use multicomponent visual signals involving color and motion. Most Sceloporus are sexually dichromatic: only males have paired blue abdominal patches and use posture to emphasize the abdominal color during male–male aggression. However, there are several independent evolutionary losses or reductions of the blue belly patches in Sceloporus. We examined behavioral responses of males to standardized staged territorial intrusions (STIs), in two white–bellied Sceloporus species, which also differ in lineage age (S. virgatus recent white, S. siniferus older white), and in a third species with partially–blue abdominal patches and which is in a relatively old lineage (S. merriami older partial blue). Previous work found that male S. virgatus (recent white) were less likely to escalate to using aggressive visual displays in standardized STIs compared to males of a blue–bellied species, S. jarrovi. Here we report that male virgatus (recent white) were more likely to use broadcast displays (push-ups) and less likely to use more aggressive displays (full show, full show hold). By contrast, males in both siniferus (older white) and merriami (older partial blue) were less likely to use broadcast displays (push-ups) and more likely to use highly aggressive postures (full show), although usually only after moving towards the intruder male. We discuss these species differences in use of broadcast display versus high–intensity aggressive display in the context of considering differences in habitat complexity and in the risk of predation.

136.2 HIEBERT, T. C.*; VON DASSOW, G.; HIEBERT, L. S.; MASLAKOVA, S. A.; Oregon Institute of Marine Biology, University of Oregon; ttereb@uoregon.edu

Long–standing larval mystery solved Pilidium recurvatum is the larva of Riserius sp., a basal heteronemertean (Heteronemertea; Pilidiophora; Nemertea)

The typical pilidium larva of nemertean worms looks like a hat with earflaps. P. recurvatum looks like an athletic sock, swimming around heel first with the toe trailing behind. It was discovered in 1883 in the NW Atlantic off Rhode Island, and has since been reported from Gullmarfjord (Sweden), the Bay of Nha Trang (Vietnam), the Sea of Japan (Russia) and the NE Pacific off Washington and Oregon, but its identity remained mysterious until now. We identified p. recurvatum larvae from Coos Bay, OR based on molecular phylogenetic evidence and the morphology of the metamorphosed juveniles as belonging to the genus Riserius, an unusual mesopsammic heteronemertean. Gösta Jägersten suggested that p. recurvatum may represent an evolutionary intermediate between the planuliform nemertean larva and the typical pilidium. The fact that Riserius is basal within the Pilidiophora supports the evolutionary significance of this larval form. We found two morphologically distinct kinds of p. recurvatum larvae in Coos Bay. Based on the 16S rDNA sequence divergence they represent two separate species, each distinct from the only described species of Riserius, with which they form a monophyletic clade. We have yet to find the adults of these two apparently undescribed species of a previously monotypic genus. We also report on the remarkable choice of prey by the juveniles of Riserius sp. They feed exclusively on the larvae and juveniles of the hoplonemertean Carcinonemertes errans, which itself is an egg predator and parasite of the Dungeness crab, a commercially important species.

124.4 HILL, G. E.*; JOHNSON, J. D.; Auburn Univ.; ghill@auburn.edu

The biochemical basis for honest signaling via carotenoid pigments

Tradeoffs in allocation of carotenoid pigments between use in immune defense versus use in ornamentation have been widely stated as the means by which the honesty of ornamental coloration is maintained. While this Resource Tradeoff Hypothesis has been supported in some empirical studies showing loss of carotenoid pigmentation following immunostimulation, alternative explanations are equally plausible. Moreover, the quantities of carotenoids used by leukocytes is five orders of magnitude lower than the quantities of carotenoids in circulation, a disparity that is hard to reconcile with a direct tradeoff in carotenoid allocation. An alternative to this Resource Tradeoff Hypothesis is the Shared Pathway Hypothesis, whereby production of ornamentation is linked to the biochemical efficiency of vital cellular processes. We present a biochemical model for regulation of ornamental coloration based on interdependencies of carotenoid and retinoid biochemistry. We propose that vitamin A regulatory mechanisms, redox systems, and carotenoid pigmentation pathways link carotenoid coloration to oxidative state and to a host of important aspects of performance such as immune function. Finally, many animals oxidize dietary pigments to produce ornamental coloration. We hypothesize that these oxidation reactions occur in the inner mitochondrial membrane and that pigmentation ultimately reflects the efficiency of cellular respiration.
Hill, M.*; Hill, A.; Cotman, C.; Friday, S.; Heist, T.; McCauley, M.; Peterson, K.; Richardson, C.; Riesgo, A.; Strehlow, B.; Univ. of Richmond, Univ. of Richmond, Univ. of Mississippi, Univ. of Virginia, CEAB, Spain; ahill2@richmond.edu

Evolutionary and ecological significance of sponge-Symbiodinium symbioses: genetic regulation of uptake and maintenance in sponges.

Symbioses involving Symbiodinium are arguably the most important ecological interaction on coral reefs because zooxanthellae energetically subsidize the entire community. These algal symbionts also enhance rates of calcification, and thus facilitate the creation of three-dimensional structure for all organisms. Nonetheless, we have a remarkably limited understanding of the symbiont’s niche (e.g., why is zooxanthella distribution so restricted among sponge hosts?). We will present two novel hypotheses derived from our work with sponges (the Magnesium Inhibition Hypothesis and the Arrested Phagosome Hypothesis) that help explain well-known aspects of Symbiodinium associations regardless of taxonomic status of the host. We will argue that sponges afford unique methodological opportunities and broad-reaching insights into the associations found in all other Symbiodinium-based symbioses. We will present research examining the genetic regulation, physiological integration, and ecological/evolutionary significance of Symbiodinium symbioses involving sponge hosts. We will present data from suppressive subtractive hybridization and transcriptomic-based approaches that identify genes differentially regulated during zooxanthella uptake. Gene expression profiles will be correlated with various stages of reinfection as apysymbiotic sponge hosts re-acquire their algal partners. The physiological integration of partners and capacity of Clade G Symbiodinium to tolerate stressful conditions will be presented. Finally, we will evaluate in hospite “residence time” as a useful heuristic for studying zooxanthella symbioses.

Hiller, M.*; Bejerano, G.*; Stanford University; bejerano@stanford.edu

A forward genomics approach links genomic and phenotypic evolution in a clade of related species

Genotype to phenotype association is a holy grail of the genomic era, hampered by the lack of clear mappings between the millions of genomic changes and thousands of trait differences apparent even when comparing closely related species such as human and chimpanzee. Efforts to link DNA base pair changes to whole organism phenotypes have recently focused on experimentally mapping genomic regions involved in a given trait or testing genomic regions that show accelerated changes between lineages. Here we introduce a computational forward genomics strategy to detect phenotype-genotype associations by matching a phylogenetic pattern of trait evolution with a corresponding pattern of orthologous genomic regions evolution. Simultaneously searching dozens of mammalian genomes we are able to correctly associate individual genes with the phenotypic traits to which they contribute. We show that our method is robust to missing phenotypic data, and applicable for both discrete and continuous, monogenic and polygenic traits. Using simulation studies, analysis of existing phenotype surveys and the coming availability of genomes of many additional species we show that forward genomics can be applied to many phenotypes, including those relevant for human evolution and disease. A portal allowing researchers to query their phenotypes of interests for matching genomic regions is developed at http://bejerano.stanford.edu/phenotree/

Hiller, A.*; Rivera, A.; Winters, I.; Rued, A.; Ding, S.; Posfai, D.; Gentle, L.; Webb, E.; Trok, W.; Univ. of Richmond, Richmond, VA, Univ. of the Pacific, Stockton, CA, Stanford Univ. School of Medicine, Stanford, CA, Univ. of Pittsburgh Medical Center, Pittsburgh, PA, Univ. of Oxford, Oxford, England; ahill2@richmond.edu

The freshwater sponge, Ephydatia muelleri, as a model to study the evolution of developmental regulatory programs

Sponges possess an extensive repertoire of animal-specific transcription factor, signal transduction and structural genes that first appeared at the dawn of animal multicellularity and continued to expand and diversify as the animals evolved ever increasing levels of complexity. We are using the emerging freshwater sponge model, Ephydatia muelleri, to study the evolutionary origins and functions of developmentally important gene families and networks. Through the development of methodologies (e.g., RNAi and expression vectors) as well as directed studies on specific genetic pathways, our lab is contributing to the growing body of knowledge and resources for this model organism. For example, expression studies as well as gene knockdown experiments demonstrate a role for Pax and Six genes in the endothelial lining of the canal system and the development of the choanoderm in these freshwater sponges. Current work is exploring the regulatory relationships and downstream targets of a putative Pax-Six (PS) component of the evolutionarily conserved Pax/Six/Eya/Dac (PSED) gene regulatory network.

Hodin, J.*; Ferney, M.C.; Gaylor, B.; Hopkins Marine Station, Stanford Univ., Pacific Grove, CA, USA, Romberg Tiburon Center, San Francisco State Univ., CA USA, Bodega Marine Laboratory, Univ. of California at Davis USA; seastar@stanford.edu, mferner@sfdu.edu

Shake, Settle and Hold: Turbulent shear stimulates settlement in sea urchin larvae

For nearshore invertebrates with dispersing larvae, the greatest set of challenges facing such larvae is to return to and recognize suitable nearshore habitat, to successfully settle there, and to do so at a developmental stage that maximizes the likelihood of survival to reproduction. Much progress has been made identifying environmental cues that larvae use to identify settlement sites; such cues typically operate at or around the scale of a larva. Is it possible that larvae are also sensitive to habitat-scale cues on the order of meters to kilometers that would indicate approach to potentially rare settlement sites? Here we show for the first time that marine invertebrate larva increase their settlement rate following exposure to intense turbulent shear characteristic of high-energy nearshore habitats. We exposed purple urchin larvae (Strongylocentrotus purpuratus) to turbulent shear spanning the range found in open ocean conditions to levels they would experience when approaching wave-swept rocky shores. We then immediately subjected the larvae to a settlement test using elevated KC1 in seawater. We found that exposure to strong turbulence causes previously refractory, pre-competent larvae to respond to KC1 and settle. In other words, turbulent shear appears to trigger these larvae to enter the competent state, thereby allowing them to respond to chemical or other surface cues if they arrive in a suitable area, and then complete settlement and metamorphosis. We discuss a planned comparative approach to further explore turbulence as a habitat indicator, as well as functional tests of settlement timing on juvenile performance.
Physiological mechanisms of pleiotropy revealed by the accelerating effect of temperature

Organisms respond to environmental change with coordinated changes in metabolic processes. Plasticity in metabolic performance can create a dynamic context for the effects of mutations, particularly for mutations affecting energy use. Here we use Drosophila melanogaster nuclear genomes paired with divergent Drosophila mitochondrial genomes to explore the effects of mitochondrial–nuclear genetic variation across different thermal environments. Previously, an incompatibility between a particular D. melanogaster nuclear genome and D. simulans mitochondrial genome was identified that significantly impacts several life history traits when reared under normal laboratory conditions. Mapping the causal mutations revealed that this incompatibility compromises mitochondrial protein translation and oxidative phosphorylation activity. Here we demonstrate that the phenotypic effects of this mitochondrial–nuclear incompatibility are conditional on environmental temperature. Development time and pupation height, both traits associated with energy state, are adversely affected by interactions between mitochondrial–nuclear genotype and increasing developmental temperature. Using flow-through respirometry to measure larval metabolic rate, we find that mitochondrial–nuclear genotype significantly affects the ability of larvae to match their metabolic rate to their thermal environment. Overall we find that the deleterious effects of mitochondrial–nuclear incompatibility increase with temperature, but also that developmental plasticity provides some homeostasis for metabolic rate. Together these results demonstrate thermodynamic constraint on performance via energy limitation, such that inefficiencies in metabolic processes are revealed when temperature accelerates the rate of life.
142.6 HOLLIDAY, CM*; GANT, CA; NESBITT, SJ; University of Missouri, University of Washington; hollidayca@missouri.edu. Non−iridescent individuals occur occasionally in wild in vivo measures of muscle force.

HOLMAN, S.D.; GERMAN, R.Z.*; Johns Hopkins the sciatic nerve, to activate via holt@lifesci.ucsb.edu HOLT, A.L.*; GAGNON, Y.; VAHIDINIA, S.; MORSE, D.E.; Alligator mississippiensis (Supported by NIH AR055648) this model validated against properties. These data will be incorporated into a Hill−type model reflecting the lower number of active fibres and their mechanical result in lower maximum isometric force (1.98 Ncm−2).

Preliminary data show that activation of only slow muscle fibres for recruitment in Hill−type models. The plantaris muscles of the effect of recruitment of fast and slow−twitch fibres on muscle force−velocity properties. This study aims to determine the prediction of dynamic forces. However, no data exist to show the activation state. Failure to account for this is likely to lead to errors in muscles force−velocity properties depend on its instantaneous length and force−velocity properties. However, muscles are not, as these models assume, homogenous and maximally activated. Instead, they are composed of mechanically distinct fibre types; a subset of which is recruited to meet mechanical demand. Therefore, a muscles force−velocity properties depend on its instantaneous activation state. Failure to account for this is likely to lead to errors in the prediction of dynamic forces. However, no data exist to show the effect of recruitment of fast and slow−twitch fibres on muscle force−velocity properties. This study aims to determine the force−velocity properties of a muscle with selective activation of different muscle fibre types and to evaluate the effect of accounting for recruitment in Hill−type models. The plantaris muscles of anesthetized rats were stimulated, via the sciatic nerve, to activate all muscle fibres or, selectively activate slow−twitch fibres. Isometric and after−loaded isotonic tetani were performed, muscle force and muscle length change recorded, and electromyography performed. Preliminary data show that activation of only slow muscle fibres resulted in lower maximum isometric force (1.98 Ncm−2 vs. 4.49 Ncm−2) and maximum shortening velocity (1.11 LS−1 vs. 4.10 LS−1) reflecting the lower number of active fibres and their mechanical properties. These data will be incorporated into a Hill−type model which accounts for muscle fibre recruitment and the predictions of this model validated against in vivo measures of muscle force. (Supported by NIH AR055048)
S1–2.3 HOLZMAN, Roi; Tel Aviv University; holzman@post.tau.ac.il
Predation by fish is a major ecological force in aquatic ecosystems, with fish targeting prey from diverse functional groups and taxonomic affiliations. This remarkable trophic diversity presumably underlies the diversity of skull morphologies and predatory behaviors in fishes. However, making implicit connections between specific aspects of morphology or behavior and their effect on feeding can be difficult. This is because prey capture in fishes is mediated by the viscous medium in which they operate. In such medium, the effects of prey and predator form and behavior are often non-monotonous and non-intuitive. Recently, an approach emerged that treats the aquatic predator–prey encounter as a hydrodynamic interaction between a solid particle (representing the prey) and the unsteady suction flows around it (produced by the fish). Using first principals and engineering theory, it is possible to integrate the effects of morphology, physiology, skull kinematics, ram, and fluid mechanics on suction feeding performance. I review how this approach, manifested in the Suction Induced Force Field model (SIF), can be used to study the adaptive significance of prey morphologies, behaviors and sensory abilities. SIF can also illuminate how different prey types impose different challenges on the predator, and how prey escape response can be modified to maximize prey escape probabilities. Including the hydrodynamic interaction between the suction flows and the prey strengthens the general theory of aquatic predator–prey interactions, and augments our understanding of the evolution of aquatic feeding performance.

S8–1.7 HOOPER, J., N.A.*; HALL, K.A.; EKINS, M.; ERPENBECK, D.; WORHEIDE, G.; JOLLEY–ROGERS, G.; Ludwig–Maximilians–University, Munich, Germany, CSIRO Plant Industry, Canberra, Australia; john.hooper@qm.qld.gov.au
Managing and sharing the escalating sponge unknowns: the SpongeMaps project
Collections of sponges in the Indo–west Pacific have escalated substantially due to pharmaceutical discovery, national bioregional planning, and compliance with international conventions on claims over the seabed and its marine genetic resources beyond existing national jurisdictions. These partially processed OTU collections now vastly outweigh the expertise available to make them better known via complete taxonomy, yet for many bioregions they represent the most significant body of knowledge. Increasing numbers of cryptic species are also being discovered from molecular and chemical studies, undetected morphologically, and the uncoordinated and fragmented collection efforts mean that knowledge and expertise gained from a particular project is often lost to future projects without a biodiversity informatics legacy. Integrating these diverse data (GIS, OTUs, images, molecular and other datasets) required a two–way iterative process so far unavailable for sponges with existing biodiversity informatics tools. SpongeMaps arose from the need for online collaboration to integrate morphometric data with barcodes for the MarBOL and SBD projects. It provides: interrogration of existing data to better process new collections; create new OTUs; publish online species pages to interpret GIS and other data for SBD, EoL, ALBIS and other databases; and link automatically to external datasets for taxonomic hierarchy (WP), specimen GIS and mapping (via OZCAM), molecular (via SBD and Genbank), and images (via Morphbank).

128.1 HOWEY, C.A.*; ROOSENBURG, W.M.; Ohio University; chris.howey@gmail.com
The Effects of Prescribed Burning on the Landscape and Reptile Abundance
Prescribed burning has become a popular management tool throughout North America; a tool that creates a landscape representative of earlier successional forest. However, little is known regarding how reptile abundances may respond to these landscape changes. Over the past three years, we measured structural and thermal characteristics in addition to the abundance of reptiles in four burned plots and four unburned plots at Land–Between–The–Lakes NRA, Kentucky. We compared habitat characteristics and reptile abundances within plots between years and among plots within years using nonmetric multidimensional scaling and ANOSIM. We determined that habitat characteristics differed for all comparisons (P = 0.001). Burn plots had an increased percentage of grasses and forbs and less canopy cover than control plots. Snakes were able to achieve warmer body temperatures in burn sites. Whereas this was beneficial earlier in the year, it would constrain reptile activity later in the summer. Relative reptile abundance differed between treatments (burn vs. unburned; P = 0.029) and between years within the burn treatment (P = 0.010). In addition to a treatment effect, some reptile abundances were correlated to the thermal and habitat characteristics of plots. As abundance of leaf litter and percent canopy increased, abundance of Agkistrodon contortrix, Thamnophis sirtalis, Pantherophis spiloides, and Scincella lateralis increased. Additionally, as percent canopy and vegetation density decreased and percent grass, bare ground, and ground temperatures increased, abundance of Diadophis punctatus, Storeria dekayi, and Sceloporus undulatus increased. These changes also correlate to preferred body temperatures measured in the lab. We suggest that reptiles may not necessarily respond to the actual disturbance, but to the changes in habitat characteristics within the landscape.

Flight modalities in the group behavior of free–tailed bats.
From the seemingly chaotic movement of unicellular organisms to the grandiose migrations of ungulates, the collective behavior of organisms underlies the diversity of skull morphologies and predatory behaviors in fishes. However, link is known regarding how reptile abundances may respond to these landscape changes. Over the past three years, we measured structural and thermal characteristics in addition to the abundance of reptiles in four burned plots and four unburned plots at Land–Between–The–Lakes NRA, Kentucky. We compared habitat characteristics and reptile abundances within plots between years and among plots within years using nonmetric multidimensional scaling and ANOSIM. We determined that habitat characteristics differed for all comparisons (P = 0.001). Burn plots had an increased percentage of grasses and forbs and less canopy cover than control plots. Snakes were able to achieve warmer body temperatures in burn sites. Whereas this was beneficial earlier in the year, it would constrain reptile activity later in the summer. Relative reptile abundance differed between treatments (burn vs. unburned; P = 0.029) and between years within the burn treatment (P = 0.010). In addition to a treatment effect, some reptile abundances were correlated to the thermal and habitat characteristics of plots. As abundance of leaf litter and percent canopy increased, abundance of Agkistrodon contortrix, Thamnophis sirtalis, Pantherophis spiloides, and Scincella lateralis increased. Additionally, as percent canopy and vegetation density decreased and percent grass, bare ground, and ground temperatures increased, abundance of Diadophis punctatus, Storeria dekayi, and Sceloporus undulatus increased. These changes also correlate to preferred body temperatures measured in the lab. We suggest that reptiles may not necessarily respond to the actual disturbance, but to the changes in habitat characteristics within the landscape.
Phenotypic integration refers to the pattern and magnitude of covariation among a set of traits, and is thought to substantially influence evolvability. Theory predicts that relatively low levels of integration will facilitate evolution as it allows distinct anatomical units (i.e., modules) to evolve independently from each other. On the other hand, high levels of integration may constrain the rate and/or direction of evolution as it presents a pattern of correlation among traits. To evaluate the genetic basis of phenotypic integration and its role in evolutionary processes, we developed a new method that estimates an individuals integration level as the relative contribution of each individual to a populations integration level.

We then applied this metric to the lower jaws of an F2 hybrid population derived from a cross between two Lake Malawi cichlid species with alternate feeding strategies in order to genetically map integration levels. Our analysis detected two QTLs and two epistatic interactions that potentially contribute to integration within the cichlid mandible. Notably, alleles from the phenotypically derived and ecologically specialized species, which has significantly higher level of integration than the more generalized species, increase integration level in the F2 population. Our results suggest that integration of the cichlid jaw has a tractable genetic basis. They are also consistent with the hypothesis that ecomorphological specialization may arise at the expense of evolvability (i.e., high integration), shedding new light on the mechanisms that both promote and limit craniofacial diversity within this group.

Etiology of spinal deformities in captive sandtiger sharks (Carcharias taurus)

Spinal deformities plague captive sandtiger sharks (Carcharias taurus). Husbandry practices, animal behavior, nutritional physiology, and spinal biomechanics were explored to identify the causes of spinal deformities to develop better husbandry guidelines and reduce dependence on wild stocks for exhibit specimens. Spinal deformity is associated with collection locale and method and usually manifests within 4 years of captivity with affected sharks characterized by lethargy. Aquarium size is negatively associated with disease prevalence and captive sharks (regardless of condition) spend 95.5 % of their time actively swimming and only 0.5 % gliding, suggesting abnormal locomotion that lacks equivalence of phases. Affected sharks spend less time gliding than healthy sharks, which is coupled with constant lateral stress on the spine due to non-linear swimming that accounts for 99.7 % of locomotion (regardless of condition).

Blood chemistry revealed that affected sharks are deficient in potassium, zinc, and Vitamin C, which play critical roles in skeletal development and maintenance. Biomechanical analyses revealed that the flexural stiffness of spinal columns from healthy sharks was greater than that of affected sharks due to greater second moment of area. The force required for spinal buckling, as well as the compressive stiffness, yield strength, yield strain, ultimate strength and mineral content of individual vertebrae were significantly greater in healthy sharks. However, the compressive stiffness and ultimate strength of vertebrae from healthy specimens were lower than those of other species, suggesting an inherent predisposition for spinal deformity in captive settings.

Thermal sensitivity of ectotherm growth: interactions of food quantity and food quality with climate change

How will the thermal sensitivity of growth rates of ectotherms be altered by climate warming? For predators fed ample food, growth rates increase with body temperature up to an optimum level and then drops rapidly at high temperature. But for predators fed restricted food, their growth at all temperatures is reduced; and the optimal temperature shifts lower lower, because energy gain at high temperature is insufficient to compensate for elevated metabolic rates. A simple energetics model (dating to J.R. Brett) predicts that if food levels decline, then ectothermal predators should preferentially select lower body temperatures. Note, however, that if food quantity declines as climate warms, then predators are caught in an energetic bind: climate warming may force them to be active at elevated body temperatures, even though energetics favors lower body temperatures; metabolic meltdown will result. But for herbivorous insects, the limiting resource is often nitrogen, not energy. When feeding on abundant but low−nitrogen plants, insects can grow fastest at relatively high body temperatures, because this facilitates compensatory consumption. Thus if food quality declines as climate warms and as atmospheric CO2 increases (likely reducing leaf nitrogen and increasing secondary defensive compounds), then herbivores may achieve highest growth rates at elevated body temperatures. For herbivores then, climate change may increase consumption rates, growth rates and optimal temperatures. Thus, the effects of climate change on the thermal sensitivity and magnitude of ectotherm growth may reflect complex interactions with trophic level, food quantity, and food quality. Supported by NSF grants to RBH and to JKG.
When Metabolic Scaling Relationships Collapse: The Thermodynamic Nightmare of Development

In a series of unique experiments in which developing Danio rerio were exposed to a combination of chronic and acute high temperature and hypoxia treatments, metabolic scaling relationships collapsed in most conditions. Given the unexpected results, non-equilibrium thermodynamics was applied to understand the underlying mechanics. In this study, larvae were reared in a 2 (28 & 31°C) x 2 (PO₂ of 10 & 21 kPa), factorial design from fertilization to 7 days post-fertilization. Larval oxygen consumption was measured at: 1) normoxia (PO₂ of 21 kPa at 28°C); 2) acute hypoxia (PO₂ of 10 kPa at 28°C); 3) acute high temperature (PO₂ of 21 kPa at 31°C); and 4) acute hypoxia & high temperature (PO₂ of 10 kPa at 31°C). Larvae reared in normoxia when exposed to acute hypoxia showed steep allometric scaling relationships; b of 1.79 ± 0.28 (28°C) & 1.33 ± 0.37 (31°C) compared to b of 0.80 ± 0.29 (28°C) and 0.69 ± 0.23 (31°C). In contrast, larvae reared in chronic high temperature and hypoxia had no significant metabolic scaling relationships. As living systems rely on vascular networks for heat and energy input and dissipation, power law relationships between metabolism and mass may be expected. In development, vascular systems are immature, and rapid changes occur across many gradients (chemical, thermodynamic and pressure), which affect the equilibrium of a dynamic, open (non-linear) system. In our experiments rapidly developing larvae exposed to acute and/or chronic abiotic change may experience energy inputs that exceed rates of dissipation. Thermodynamic gradients and their coupled transport processes may begin to break down resulting in disorder and collapse of metabolic scaling relationships creating conditions inimical to life.
115.2 HUNTER, A*; WILSON, R S; The University of Queensland; r.wilson@uq.edu.au
Can we improve a footballers kicking performance using optimisation theory?

How much effort should an individual use when executing a physical task? And how much effort should one use if a physical task or skill relies on both accuracy and power? In this study, we explored the idea that individual animals possess the capacity to optimise their effort when performing a physical task and their effort is individual–specific. To achieve this, we used soccer players shooting a football towards a goal as our model study system as this task simultaneously requires both power and accuracy; such that, the shooter needs to accurately kick the ball towards the corner of the goal and fast enough to beat the goalkeeper. However, when more effort is put into striking the ball harder it is likely to lead to a compromise in accuracy. Players of different skill level/experience were directed to kick balls at a target using different levels of effort. We used 3D-motion digital video cameras to record foot velocity at 100 Hz during each kick, which was utilised as our index of kicking effort. Based on these data, we could then determine each individual's trade–off between accuracy and power so that we could calculate their optimal kicking effort for a given distance from the goal. All individuals also completed a game relevant task in which they were asked to kick the ball using a level of effort of their choice – with the aim to successfully hit the target and beat the goalkeeper. We then tested whether individuals accurately optimised their kicking effort by comparing their predicted optimum effort with their self-selected effort. We will discuss our results in the context of optimal performance theory and the application of these techniques for studying human performance and evolution.

89.5 HUYNH, TL*; EVANGELISTA, D; MARSHALL, CR; Univ. of California, Berkeley; huynhtony@berkeley.edu
Analysis of the fluid flow through the complex internal respiratory structures of an extinct Paleozoic echinoderm

Blastoids were a group of stalked, sessile echinoderms preserved in rocks that span the middle Ordovician (~470 mya) to the end of the Permian (~250 mya). These extinct echinoderms possessed hydrospires, uniquely complex internal thecal structures with putative respiratory function. Here, we present measurement and visualization of fluid flow within the hydrospires using a 3D-printed and Reynolds–similar physical model of the interior of a hydrospire of the blastoid Pentremites rusticus, to examine in further detail possible functions of the hydrospire. Specifically, the model allows examination of the extent to which the pattern of flow within the hydrospire kept oxygen–rich incumbent water separated from water that had already been depleted of oxygen. If the flow pattern within the hydrospire fails to keep these two bodies of water separate, this would suggest some other function for the hydrospires. In addition, the model also allows for determination of whether active pumping would have been required to achieve optimal respiratory function, or whether passive pumping alone was sufficient. Furthermore, the model allows for testing of the hypothesis that the need for removal of digestive waste, thought to be associated with the hydrospires, is responsible for some unusual aspects of the hydrospires, such as the conical shape of the putative excurrent canals and the presence of cover plates over the remarkably large excurrent openings.
IAMS, SM*; BEATUS, T; GUCKENHEIMER, J; COHEN, I;
Bowdoin College & Cornell University, Cornell University; smi6@cornell.edu
Roll-based sideways motion of mosquitoes in free flight
The mosquito body plan and flight characteristics are qualitatively different than those of other well-studied Dipterans. Mosquitoes have a long and slender body, and often fly with a sideways velocity component, so that their body heading does not align with their flight track. They produce substantial sideways accelerations during flight. While flight kinematics and control have been characterized for moths and for many flies, they have not been studied for mosquitoes. Here we report the first quantitative study of mosquito flight kinematics during free flight. We use high speed video and novel image analysis methods to extract the position and orientation of body, wings and legs. We show that mosquitoes generate sideways thrust almost entirely by banking their bodies, and quantify this relationship to show that the sideways deflection of flight forces is driving this sideways acceleration. We find that mosquitoes are almost always generating some sideways thrust due to roll, making roll stability and control critical to their overall flight control. Although yaw control and pitch control have both been carefully explored in many Dipterans, roll control is not commonly explored. However, for mosquitoes, understanding roll generation and roll dynamics is particularly essential to understanding how they move.

IRSCHICK, D.J.*; CROSBY, AJ; FEDERLE, W; Univ. Massachusetts Amherst, Cambridge University, UK; irschick@bio.umass.edu
The evolution of Gecko adhesion: An integrative perspective
Gecko adhesion has received a great deal of attention in the popular media and among scientists aiming to mimic their adhesive properties for human use. However, while there has been a general neglect of both an evolutionary perspective and one that integrates synthetic and empirical data. Our approach is to examine gecko adhesion on a wider perspective by examining the wide evolution of toepad anatomy, and to understand how the scaling of adhesion can be predicted by morphological and anatomical features. We place this approach in the context of the recent discovery of GeckskinTM, which unites anatomy and a whole-organism perspective, and which represents a breakthrough in synthetic gecko adhesion. This approach differs markedly from other approaches that examine only setae, and which largely ignore the integrative organizational features of the gecko foot. We then provide a prospectus for the future of gecko adhesion through a more integrative perspective.

ISERI, V.J. ; KLASING, K. C.*; Univ. California, Davis; kcklasing@ucdavis.edu
3D kinematics, motor control and bone strain during feeding in non-human primates
In recent years substantial advances have been made in our understanding of the feeding mechanics of non-human primates. On one hand, researchers have investigated the relationship between the three-dimensional displacement of the mandible and food material properties as well as species-specific differences. Muscle activation patterns have also been recorded in multiple species and patterns of variation have been identified at different hierarchical levels suggesting the importance of intra and inter-individual variability. This variability derives in part from the structural complexity and redundancy of the masticatory muscles. However, little work has been done on evaluating how differences in patterns of muscle activation relate to differences in mandibular movement, and how this interplay affects the forces applied on the mandible. Such interaction, although often ignored due to lack of data, is essential to understand how the masticatory apparatus in primates adapts to changes in food material properties and how this affects feeding behavior. Using a large dataset of 3D mandible kinematics, muscle activation patterns and, in some cases bone strains, recorded simultaneously, we investigate the relationship between all these factors in two species of non-human primates, Macaca mulatta (macaques) and Cebus sp. (capuchins). Our data suggest that differences in loading regimes in the mandible are not driven as much by differences in food material properties as by differences in feeding behavior, and its associated variation in muscle activation patterns and mandibular movement.

ROSS, C.F.; University of Chicago; IRSCHICK, D.J.*; CROSBY, AJ; FEDERLE, W; Univ. Macaca mulatta
27.2 IRSCHICK, D.J.*; CROSBY, AJ; FEDERLE, W; Univ. Massachusetts Amherst, Cambridge University, UK; irschick@bio.umass.edu
The evolution of Gecko adhesion: An integrative perspective
Gecko adhesion has received a great deal of attention in the popular media and among scientists aiming to mimic their adhesive properties for human use. However, while there has been a general neglect of both an evolutionary perspective and one that integrates synthetic and empirical data. Our approach is to examine gecko adhesion on a wider perspective by examining the wide evolution of toepad anatomy, and to understand how the scaling of adhesion can be predicted by morphological and anatomical features. We place this approach in the context of the recent discovery of GeckskinTM, which unites anatomy and a whole-organism perspective, and which represents a breakthrough in synthetic gecko adhesion. This approach differs markedly from other approaches that examine only setae, and which largely ignore the integrative organizational features of the gecko foot. We then provide a prospectus for the future of gecko adhesion through a more integrative perspective.

KLASING, K. C.*; Univ. California, Davis; joshi@ucdavis.edu
The cost of an immune response to Escherichia coli in Gallus gallus
There are a variety of costs associated with an immune response to potential pathogens. These costs were quantified in a model using the domestic chicken challenged with an i.v. dose of dead E. coli that was sufficient to cause a vigorous innate immune response and protective levels of immunoglobulins, but did not trigger immunopathology. In young growing chicks, a systemic E. coli challenge results in a 29% decrease in growth. About 2/3 of this decrease is due to decreased food consumption and about 1/3 is due to the immune response and accompanying metabolic inefficiencies that include impaired digestion and increased metabolic rate. Quantification of the amount of lysine, which was used as a sentinel for nutrient flux, in the cells and proteins of the systemic immune system indicates that they contain only 0.39% of the chickens entire lysine content; however this amounts doubles during the acute phase response to E. coli (first day). The adaptive response (cellular and antibody) occurs much later, is much smaller and is fueled by the decline in the innate response. To put this in perspective, the additional lysine needed to support the acute phase response is equivalent to 5% of the lysine in the two major pectoralis muscles. Thus, the costs of a protective immune response are very high but they are not dominated by direct consumption of nutrients by the systemic immune system.
103.2 IVENGAR, E.V.; Muhlenberg College; iyengar@muhlenberg.edu

The function of shell wiping in the marine snail Calliostoma ligatum

Individuals of the marine snail Calliostoma ligatum, similar to other congeners, are unusual in that they can extend their foot over the apex of their shells and use the back of the foot to wipe the entire surface of the shell. Shell-wiping leaves behind a thin film of mucus; the removal of the mucus using a paper towel renders the shell less slippery. Various functions have been proposed for the purpose of shell-wiping in Calliostoma spp., including defense from predators and procurement of food. Because of this wiping behavior, Calliostoma ligatum shells are typically cleaner than surrounding surfaces. However, certain epibiotic species, most notably the slipper limpet Crepidula adunca, specialize on this host species. In choice experiments, individuals of Crepidula adunca were neither more or less likely to attach to wiped compared with unaltered shells of Calliostoma ligatum, nor did predators (sea stars and crabs) discriminate based on this parameter. Host snails wipe their foot over the shell of established epibiotic Crepidula adunca. At the end of a wiping bout, individuals of Calliostoma ligatum retracted their foot before it passed over the mouth, so procurement of food is an unlikely reason for shell wiping. Time lapse video documented that animals did not increase their rate of shell-wiping after the mucus had been removed from the shell. After contact with predators, snails were more likely to increase their rate of movement and did not seem to increase the frequency of shell wiping, but there was variation in this response. Thus, the shell wiping behavior in Calliostoma ligatum is more likely to have evolved to remove non-specialist fouling organisms than to encourage or discourage specialist epibionts, discourage predators, or provide food to the snail.

3.3 JACOBS, H.O.; Imperial College London; h.jacobs@imperial.ac.uk

On the interpretation of swimming as a limit cycle

When the wind blows through the venetian blinds in your house, it is not uncommon for them to flutter. The next time this happens, note two things. Firstly, the fluttering is really the sound of a periodic oscillation at a fixed frequency. Secondly, if you hold one of the blinds between your fingers and then release it, the fluttering will stop and then restore itself. This stable oscillatory behavior is known by mathematicians as a limit cycle. Given the complex dynamics which are possible in fluids, it is remarkable that fish, frogs, tadpoles, and humans can obtain regular motion in a given direction by periodically flexing muscles. Perhaps motion in a fixed direction is stable under the influence of a periodic force. In other words, perhaps swimming is a limit cycle. The stability of a limit cycle implies that locomotion in a fixed direction can be achieved by exploiting passive physical dynamics and relatively simple motor patterns. In this talk I will provide a sketch of the physics and mathematical proofs which suggest this to be the case for neutrally buoyant bodies of arbitrary shape immersed in a Newtonian fluid in the middle Reynolds number regime (Re ~ 100 to 10,000). The theory should be of interest to those wishing to understand and mimic the orderliness of swimming in this regime or understand the robustness of fluid locomotion across body type and size.

39.1 JACKSON, B*; HEDRICK, T.L.; Univ. of North Carolina at Chapel Hill; jacksobe@live.unc.edu

Hovering with a high speed wing: How cliff swallows push the envelope of wing shape

The energetic demands of flight impose strict constraints on the morphology of flying animals. As a result, functional morphologists often predict tight form-function relationships between wing shape and flight ability, and place wings into shape-performance categories based primarily on fixed-wing aerodynamic theory. For example, swallows possess wings in the high-speed flight category with a narrow and pointed shape predicted to reduce drag while producing sufficient lift at high speeds as the birds chase insects on the wing. Such high-speed performance should come at the cost of reduced force production, and hence limited behaviors, at low speeds. Like most birds however, swallows have a vast array of flight behaviors. Their elaborate elevated mud nests require precise low speed maneuvering and hovering during construction and nesting feeding. How do swallows perform such a diversity of flight behaviors with an apparently single-purpose wing? We filmed cliff swallows ( Petrochelidon pyrrhonota ) in the field with high speed video while they foraged at speed and while they hovered near nests. Here, we present the first field 3-dimensional kinematic comparison between these extremes of flight in a single species. When hovering, the swallows increased both stroke amplitude (from less than 120° in steady flight to greater than 170° in hovering) and wing beat frequency (from 6–7 Hz to 9.5 Hz). They also use very high geometric angles of attack (>40°) during hovering. Together, these results suggest that wing-shape categories based on fixed-wing theory do not accurately describe the aerodynamic capacity of flapping wings, nor constrain the diversity in flight behaviors within species even in cases where aerodynamic predictions appear to match aspects of flight ecology.

74.2 JAMES, C.J.*; MCELROY, E.J.; College of Charleston; ccjames@g.cofc.edu

The effect of autotomy on locomotor performance in the green anole, Anolis carolinensis.

Autotomy is the practice of losing the tail in an effort to escape a predator. Though the immediate threat of predation is avoided via autotomy, the costs of tail loss may have a significant impact on locomotive performance; this could jeopardize the animals ability to feed, escape from future predators, and reproductive capacity. Many studies have examined the impact of autotomy on running performance, but few studies have looked at other aspects of performance capacity. This study examined locomotor ability in the green anole, Anolis carolinensis, to better understand the effects of tail autotomy on both climbing and running performance. Maximum speed and acceleration were measured as lizards burst from a standstill to maximum speed and these measures were repeated before and after autotomy. Autotomy was found to have a significant impact on climbing performance, while terrestrial locomotion was unaffected. These results implicate a significant role for the tail in climbing locomotion in anoles, as has been previously reported for geckos.
Influence of temperature on non-breeding HPG-axis activity in northern cardinals.

In seasonally breeding birds, change in day length is a very common cue used to track seasonal change and initiate breeding, however, not all species use changing day length as their primary environmental cue. Many species rely on resources that are irrationally spaced in time and location for reproduction and these non-photic cues can be more influential than changes in day length. Northern Cardinals (Cardinalis cardinalis) show year-round levels of testosterone as well as broad timing in when they initiate reproduction and the behaviors associated with reproduction, suggesting that they may not use changes in day length as the sole control for transitions between non-breeding and breeding states. Here we used exogenous gonadotropin-releasing hormone ( GnRH ) challenges to investigate hypothalamic-pituitary-gonadal (HPG) axis activity and compare HPG axis activity with daily temperature prior to the winter solstice, when day lengths begin to increase. We found that male response to GnRH did not co-vary with temperatures in a predictable pattern. In all species use changing day length as their primary environmental cue, yet detected an unmistakable acceleration in mortality rate with age in these female turtles. To our knowledge, these findings provide the first evidence of reduced fitness at old age in putatively immortal reptiles, and suggest that senescence may be observed in populations that exhibit long chronological life spans.

Running in confined spaces by the American cockroach

A composite exoskeletal system with an integrated array of sensors and muscles enables arthropods to locomote through the most restrictive environments. Here we found that the tough yet compressible exoskeleton of the cockroach, Periplaneta americana, enabled the animal to run through confined spaces less than a third of its standing height (12–15mm). We ran animals through a variable ceiling height rectangular tunnel at 4, 6, 9 and 12mm heights. Surprisingly, animals ran within the vertically restricted space with equal ease at high speeds (52.15±2.68cm/s), only showing a decrease at the lowest height of 4mm (12.56±2.45cm/s, P<0.01). Further, animals maintained a tripod gait at all heights except 4mm when feet often slipped on the surface (medium-grit sandpaper) and stereotyped leg trajectories were altered. Kinematic analysis revealed no significant change of leg cycling frequency (16.12±1.24Hz, P>0.05) across the ceiling heights. However, cockroaches used significantly (P<0.01) shorter stride lengths at 4mm. At the smallest ceiling height, animals chose a more serpentine path of travel and lost foothold traction in 40.2±3.49% (P<0.01) of the strides leading to significantly less effective propulsion. Although navigating through confined spaces likely increases the normal load, remarkably animals showed limited adjustments of the tarsal (hind leg) extreme positions relative to the body centerline, contrary to our expectations. Insights obtained into strategies of high-speed, confined space navigation not only increases our understanding of the mechanical design principles of these organisms, but it also is inspiring the development of novel robots that will go where no robot can at present.
Mechanism of phototaxis in marine zooplankton and origin of simple visual circuits
Eyes and nervous systems evolved in a marine environment at the dawn of animal life and diversified during the Cambrian explosion, one of the most spectacular events in the history of life. Little is known about early stages of eye and visual circuit evolution. Simple marine planktonic organisms, in particular ciliated larvae of various marine invertebrates, can give us insights into how simple eyes and circuits of marine organisms function and may have evolved. We investigate the nervous system of the marine annelid model, Platynereis dumerilii. The ciliated, planktonic larvae of Platynereis have three pairs of eyes forming simple reflex circuits. The eyes control phototactic swimming, a key behavior regulating larval depth in the water column. We use a combination of behavioral, molecular genetic and ultrastructural studies to map and characterize phototactic circuits in Platynereis larvae. We believe that the simple circuitry we uncover in these ciliated larvae could give us insights into how neural circuits function and may have evolved.

Do Wave Impact Forces Limit the Size of Intertidal Organisms?
Do Wave Impact Forces Limit the Size of Intertidal Organisms? In this case, force increases at a faster rate than attachment strength, potentially limiting the organisms size. While scaling behavior of other hydrodynamic forces is known, the scaling exponent of impingement has remained unstudied. To test the scaling behavior of impact forces, rectangular prisms of various sizes were exposed to impingement forces using simulated waves from a gravity–driven water cannon. Data show that impingement scales with both area and drag coefficient of shapes tested. Analysis of the water cannon jet shows a spike in jet velocity coincident with measured impingement forces, further suggesting that transient wave impacts are caused by brief increases in drag. Thus, impingement is not likely to limit organism size — leaving intertidal size limitation a mystery.

Cellular metabolic rate is influenced by life–history traits in tropical and temperate birds.
Tropical and temperate bird species tend to live on opposite sides of the life–history continuum, with tropical birds falling on the slow end of the spectrum characterized by low annual reproductive output, low mortality rate, and temperate birds on the fast end characterized by rates of reproduction and mortality that are high. Although it is thought that physiological processes underlie many life–history trade–offs, the precise linkages between an organism’s life–history and the function of its organs, tissues, and cells remain unclear. Previous work in our lab has demonstrated that tropical birds have a significantly lower basal metabolic rate and peak metabolic rate compared with their temperate species counterparts. We have also found that a contributing factor to the reduced rate of metabolism in tropical birds is that they have smaller metabolically–active organs, such as heart, liver, kidneys, and pectoral muscles, compared with similarly–sized temperate species. However, a fundamental challenge facing physiological ecologists is an understanding on how variation in life–history at the whole–organism level might be linked to cellular function. Here, we compared various parameters of cellular metabolism in 34 species of phylogenetically paired tropical and temperate bird species. Using an XF24 Seahorse extracellular oxygen analyzer, we measured basal and maximal cellular oxygen consumption (OCR) and the rate of glycolysis (ECAR). We found that in most bird pairings, there was a lower basal and maximal oxygen consumption in tropical species, which is in accordance with a slower pace–of–life.
Dihydrotestosterone Reduces Growth in a Female−Larger Lizard

Sex differences in adult body size (sexual size dimorphism; SSD) are widespread, and both male− and female−larger SSD is observed even among closely related species. Earlier investigators focused largely on sex differences in the balance of selective forces on body size, but more recent workers have investigated proximate regulation of growth leading to SSD. A growing body of evidence in squamate reptiles has shown a correlation between patterns of SSD and effects of testosterone (T) on growth, wherein T stimulates growth in male−larger species and inhibits growth in female−larger species. These data have given rise to the bipotential growth regulation (BPGR) hypothesis to explain SSD in squamates and perhaps more broadly. However, mechanism(s) of BPGR, including possible conversions of T to estradiol and dihydrotestosterone (DHT), are conjectural. The present study tests whether growth inhibition by T in a female−larger lizard (Sceloporus undulatus; Eastern Fence Lizard) is an androgenic effect not involving aromatization of T to estradiol. Experiments were conducted on yearling males and females of S. undulatus. DHT was administered via implanted Silastic tubes in intact females and in intact and surgically castrated males. Body size was measured at regular intervals for six weeks. Compared to controls, growth rate was reduced by DHT in females and in males. Body condition, measured by regressing log mass on log snout−vent length, was unaffected by DHT, indicating that growth reduction was not caused by negative energy balance. Our results help to clarify the androgenic mechanism(s) of BPGR, wherein T inhibits growth in males of female−larger lizards.
74.4 JUSUFI, A.*; BYRNES, G.T.; FULL, R.J.; Univ. of California, Berkeley, arbianj@berkeley.edu
Gliding Geckos Perch on a Tree Trunk Assisted by Active Tails
Laboratory studies of air−righting and equilibrium gliding revealed that geckos could use tail movements for maneuvering (Jusufi et al. 2008, 2010). We measured geckos, H. platyurus, in a Southeast Asian rainforest to study tail function during aerial descent and gliding in nature. Field video revealed that geckos traveled horizontal distances from tree to tree of up to 4m with gliding speeds ranging from 5.4 to 7.5 m/s and angles of attack of approximately −15° to −20° at mid−glide. Preparing to land, geckos pitched their body up to 32° to 35° and decelerated to speeds ranging from 4.4 to 6.3 m/s. Gliding geckos initiated their perching maneuver with a 15° angle of attack relative to horizontal. Near head−on collisions with the tree trunk pitched the torso vertically as high landing forces were absorbed by the body and tail. After vertical alignment with the tree trunk, the anterior section of the body pitched up to 100° away from the trunk, anchored by only the hind limbs and tail. Tail forces allowed recovery from the extreme pitch back angles by reducing stress on the rear legs. Of the gliding geckos that reached the tree target (n=7), the majority (86%) of trials) alighted safely on the vertical target. By contrast, tailless geckos experienced catastrophic falls in 75% of trials after crashing into the tree (n=4). Results reveal geckos use tails as shock−absorbers and stabilizers to reduce and control high impact forces acting on the limbs allowing effective landing at high speeds. Geckos perching behavior could be initiated by the same reflex discovered during climbing where foot soggage stimulates tail depression. Strategies incorporating tail assisted responses can improve the vertical landing performance and stability of both animals and robot planes.

35.5 KAHN, A.S.*; YAHEL, G.; TUNNICLIFFE, V.; LEYS, S.P.; Univ. of Alberta, Edmonton, Ruppin Academic Center, Michmoret, Israel, Univ. of Victoria, British Columbia; kahn@ualberta.ca
Glass sponge reefs significantly impact water properties in a marginal sea, the Strait of Georgia
Glass sponge forms unique reef habitats similar to coral reefs in the Strait of Georgia (SOG), a marginal sea surrounded by major cities such as Seattle and Vancouver. Individual sponges can affect localized water properties; since reefs are so vast, they may alter water properties on a regional scale. Reef sponges in the SOG (some 11 million oscula) filter over 6 billion liters of water per hour, removing bacteria and other particulates while adding ammonium to the water. We used SIP samplers to compare ambient water near reef sponges with water exhaled from oscula of Aphrocallistes vastus, the dominant reef−forming species in the SOG. Whether living in reefs or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water, or solitarily, each osculum adds ~ 200 nmol/l of NH4+ to expelled water. Our calculations show that the 12 known reefs in the SOG remove hundreds of kilograms of carbon per year in the form of bacteria, and lesser amounts of Synchococcus−like and large eukaryotic cells. Though they are live habitats and their effects are not nearly as great as Fraser River inputs, the sponge reefs alter water properties by removing bacterioplankton and oxygen, and adding ammonium. Our findings suggest that the water properties of the SOG may depend heavily on sponge reefs being present just as the reefs rely on SOG water properties.
KAPLAN, M.B.*; MOONEY, T.A.; Woods Hole Oceanographic Institution; mkaplan@whoi.edu
Adverse effects of elevated CO2 concentrations on squid (Doryteuthis pealeii) development and early life
Increasing quantities of anthropogenic carbon dioxide (CO2) are being absorbed into the ocean, altering seawater chemistry and impacting diverse marine life in many ways. At particular risk may be the early life stages of fish and invertebrates with internal and external aragonite structures. Impacts on cephalopods are of major concern because of the central role they play in many ocean ecosystems and because of their importance to global fisheries. The objective of this work was to determine whether elevated CO2 concentrations impact squid and the manners in which potential effects may be exhibited. Atlantic longfin squid (Doryteuthis pealeii), an ecological and economical valuable taxon, were reared from eggs to hatchlings (paralarvae) in ambient (390 ppm) and elevated (2300 ppm) CO2 concentrations in replicated experimental trials. Animals raised under elevated pCO2 demonstrated developmental changes. The distribution of the proportion of paralarvae hatching by day differed significantly between treatments in both trials. In addition, body (mantle) length differed significantly between treatments. Aragonite statoliths, used for balance and detecting movement, were significantly shorter, had decreased surface area, and were typically malformed in paralarvae reared under elevated pCO2. These results indicate that squid may be adversely impacted by ocean acidification conditions in multiple ways. These effects could impact squid paralarvae behavior and survival in the wild, which raises concern for direct and indirect consequences to marine food webs and commercial fisheries.

KATZ, S.*; TRESGUERRES, M.; ROUSE, G.W.; Scripps Institution of Oceanography, UCSD, San Diego; skatz@ucsd.edu
Research paradigms in nutritional ecology inspired by Ken Nagy
Although the majority of Ken Nagys work focused mainly on energy expenditure in free–living vertebrates, more than 20% of his journal publications were concerned with nutritional ecology. His highly empirical studies involving detailed budgets of energy, mass, and specific elements and nutrients advanced knowledge about topics such as the cost of growth, the digestibility of foods of wild vertebrates, the mechanistic bases for observed digestibilities, and the nutritional qualities of whole diets. A hallmark of the work was the way it was integrated with the ecological and sometimes evolutionary contexts of the animals he studied, resulting in in–depth understanding of the nutritional ecology of diverse organisms such as ectothermic and endothermic desert herbivores, marine iguanas, and tropical howler monkeys. I will elaborate on how the work was also foundational for development of new tools and research directions in ecology. For example, the water economy index (ratio of water influx to field metabolic rate) became a new tool to indicate the likelihood of surviving without supplemental water. The estimates of the ecological cost of growth can advance models of growth in the emerging field of metabolic ecology. The budgeting approach lent itself to the subsequent integration of how natural toxins and contaminants relate to animal energetics and nutritional ecology.

KARASOV, WH; Univ. of Wisconsin, Madison; wkarasov@wisc.edu
Drilling for nutrition: The physiological mechanism of bone penetration by Osedax
Annelids belonging to Siboglinidae lack a gut and obtain nutrition via bacterial symbionts housed in a specialized organ called the trophosome. While most siboglinids host chemosymbiotic symbionts, which allow them to thrive in reducing habitats such as hydrothermal vents or methane seeps, Osedax exploits vertebrate bones lying on the seafloor. Furthermore in contrast to other siboglinids, Osedax house heterotrophic Oceanospirillales bacteria in their posterior body, which is modified into so–called roots. These roots penetrate and ramify through the bone, which serves as their food source (Goffredi et al., 2007). However, Osedax lack any obviously bioabrasive structures and the physiological mechanism of bone erosion and nutrient absorption has been virtually unknown. The ultrastructure of the root epidermis suggests secretory/absorptive functions of this region and we hypothesized Osedax demineralize the bone by secreting acid, followed by absorption of bone collagen and lipids for nutrition. Our analysis of putative acid–secreting proteins, namely vacular H+–ATPase (VHA) and carbonic anhydrase (CA), by immunohistochemistry and quantitative immunoblotting, shows preferential location and high abundance of VHA in the root epidermal cells. Analysis of transcriptome data of the root vs. the trunk region also confirms this pattern. CA is co–occurring with VHA in the root epidermis, and additionally found in other cells and body regions, suggesting CA is also involved in maintaining acid/base balance throughout the worm. These results support our hypothesis on bone erosion via acid secretion by Osedax, which is similar to chemical mechanisms employed for boring by some gastropods and for bone demineralization by human osteoclasts.
94.4 KAVANAGH, KD*; WINSLOW, B; LEARY, B; Univ. of Massachusetts Dartmouth; kkavanagh@umassd.edu

Evolutionary and Developmental Modularity in the Digits of Vertebrates

The toe bones of most tetrapods include the metatarsal followed by a series of phalanges bones. In the embryos, these bones develop in sequence as chondrogenic condensations that grow out distally and segment behind the growing tip to position the joints. By the time the tip is formed, the final adult proportions of the toes are achieved. Among taxa, phalanges sizes covary in a highly predictable way, with variations ranging from equal—sized to a proximodistal gradient. The metatarsal variation does not follow this rule, indicating separate evolutionary modules. However, evidence of developmental modularity that establishes independence of MT and phalanges has been elusive. Previous analyses of gene expression and morphogenetic processes consistently show no differences between formation of metatarsal and phalanges. Here, we have found evidence of emergent modularity in the digit. Using experimental perturbations and DiI cell tracing in the chick, we establish the timing of very early separation of MT and phalanges compartments. In contrast, formation of individual phalanges remains plastic until late phalangeogenesis. We propose a two-stage evolutionary scenario for the tetrapod digit.

57.3 KEISER, C.N.*; MONDOR, E.B.; University of Pittsburgh, PA. Georgia Southern University, Statesboro, GA; Georgia Southern University, Statesboro, GA; cnk21@pitt.edu

Maternal predation risk induces transgenerational behavioral plasticity in a parthenogenetic insect

It is becoming increasingly evident in many organisms that cues of immediate and latent predation risk in one generation can induce defensive phenotypes in the next generation. This predator–induced transgenerational phenotypic plasticity has been widely documented in the induction of defensive morphologies in naïve offspring, though relatively little is known about transgenerational plasticity in offspring behavior. To address the possibility of transgenerational behavioral plasticity in the pea aphid, Acyrthosiphon pisum, a group–feeding parthenogenetic insect, we exposed pre-reproductive individuals of two clonal lines (green and pink color morphs) to the aphid alarm pheromone (E)-(−&beta;–Farnesene (EBF), a reliable cue of increased predation risk. Compared to controls groups, offspring of aphids exposed to a single alarm pheromone emission altered their feeding site choices relative to the location of the maternal aphids, occupying lower–risk feeding sites. The two clonal lines responded differently; green juveniles occupied safer feeding sites in the natal colony, while pink offspring were more likely to disperse to feeding sites on neighboring plant leaves. Offspring responses were also different depending on the cultivar of broad bean, Vicia faba, upon which they were feeding. This may indicate an influence of host–plant quality on aphid defensive behavior. Further studies are needed to clarify the association between the transgenerational induction of morphological and behavioral defenses, and how transgenerational behavioral plasticity augments survival of the clonal lineage.

94.4 KAVANAGH, KD*; WINSLOW, B; LEARY, B; Univ. of Massachusetts Dartmouth; kkavanagh@umassd.edu

Evolutionary and Developmental Modularity in the Digits of Vertebrates

The toe bones of most tetrapods include the metatarsal followed by a series of phalanges bones. In the embryos, these bones develop in sequence as chondrogenic condensations that grow out distally and segment behind the growing tip to position the joints. By the time the tip is formed, the final adult proportions of the toes are achieved. Among taxa, phalanges sizes covary in a highly predictable way, with variations ranging from equal—sized to a proximodistal gradient. The metatarsal variation does not follow this rule, indicating separate evolutionary modules. However, evidence of developmental modularity that establishes independence of MT and phalanges has been elusive. Previous analyses of gene expression and morphogenetic processes consistently show no differences between formation of metatarsal and phalanges. Here, we have found evidence of emergent modularity in the digit. Using experimental perturbations and DiI cell tracing in the chick, we establish the timing of very early separation of MT and phalanges compartments. In contrast, formation of individual phalanges remains plastic until late phalangeogenesis. We propose a two-stage evolutionary scenario for the tetrapod digit.

57.3 KEISER, C.N.*; MONDOR, E.B.; University of Pittsburgh, PA. Georgia Southern University, Statesboro, GA; Georgia Southern University, Statesboro, GA; cnk21@pitt.edu

Maternal predation risk induces transgenerational behavioral plasticity in a parthenogenetic insect

It is becoming increasingly evident in many organisms that cues of immediate and latent predation risk in one generation can induce defensive phenotypes in the next generation. This predator–induced transgenerational phenotypic plasticity has been widely documented in the induction of defensive morphologies in naïve offspring, though relatively little is known about transgenerational plasticity in offspring behavior. To address the possibility of transgenerational behavioral plasticity in the pea aphid, Acyrthosiphon pisum, a group–feeding parthenogenetic insect, we exposed pre-reproductive individuals of two clonal lines (green and pink color morphs) to the aphid alarm pheromone (E)-(−&beta;–Farnesene (EBF), a reliable cue of increased predation risk. Compared to controls groups, offspring of aphids exposed to a single alarm pheromone emission altered their feeding site choices relative to the location of the maternal aphids, occupying lower–risk feeding sites. The two clonal lines responded differently; green juveniles occupied safer feeding sites in the natal colony, while pink offspring were more likely to disperse to feeding sites on neighboring plant leaves. Offspring responses were also different depending on the cultivar of broad bean, Vicia faba, upon which they were feeding. This may indicate an influence of host–plant quality on aphid defensive behavior. Further studies are needed to clarify the association between the transgenerational induction of morphological and behavioral defenses, and how transgenerational behavioral plasticity augments survival of the clonal lineage.

S3–2.3 KAWANO, S.M.*; BLOB, R.W.; Clemson Univ.; skawano@clemson.edu

Comparative appendicular function during terrestrial locomotion: implications for the invasion of land

The invasion of land was a pivotal event in vertebrate evolution that was associated with major appendicular modifications. Although fossils indicate that the evolution of fundamentally limb–like appendages may have occurred in aquatic environments, the functional consequences of using early limbs, rather than fins, for terrestrial propulsion have had little empirical investigation. Moreover, while many fossil specimens have indicated that terrestrial adaptations first arose anteriorly in tetrapodomorphs, some experimental data have suggested a greater antiquity to hindlimb driven locomotion. To examine these aspects of vertebrate locomotor evolution during the invasion of land, we measured three–dimensional ground reaction forces (GRF) produced by isolated pectoral fins of mudskipper fishes (Periophthalmus barbarus) during terrestrial crutching and compared these to isolated walking footfalls by the fore– and hindlimbs of tiger salamanders (Ambystoma tigrinum). As a proportion of body weight, isolated fins of mudskippers bear similar peak net GRF magnitudes as salamander limbs, but GRFs are inclined more nearly. Comparing salamander fore– and hindlimbs, although the peak net GRF occurs later in stance for the forelimb, both limbs experience nearly identical mediolateral and vertical GRF components, suggesting they make comparable contributions to support. Thus, a major locomotor role for the forelimb may have persisted extensively among basal tetrapods. However, the salamander forelimb was typically deceleratory at peak GRF, whereas the hindlimb and mudskipper pectoral fin were mainly acceleratory. Together, data from these extant taxa help clarify how structural change may have influenced locomotor function through the evolutionary invasion of land by vertebrates.

S3–2.3 KELLEY, AL*; DERIVERA, CE; Portland State University; amandak@pdx.edu

Intraspecific variation in heat shock response and cell–cycle modulation in the invasive Carcinus maenas, the European green crab, on the west coast of North America

Physiological studies have long been utilized to understand the role of abiotic features in the distribution of native organisms within marine communities. For the invasive decapod Carcinus maenas, environmental temperature has been implicated as the main predictor of establishment success across temperate regions. Therefore, investigations into the regulation of thermotolerance are paramount to identifying those physiologic mechanisms that may facilitate invasion success. A comparative laboratory analysis of Carcinus maenas, the European green crab, sampled from the northern, cold acclimated (British Columbia–BC), and southern, warm–acclimated (California–CA), investigated how these disparate thermal environments resulted in differential expression of proteins involved in the heat shock response and cell–cycle regulation when given heat and cold stresses. This work clearly illustrates that a divergence in physiological phenotypes exist across this meta–population despite having the smallest degree of genetic diversity of all invasive and native populations, and a relatively short invasion timeline of only 20 years.
BassBot: A Biorobotic Model of the Teleost Feeding System

Comparative morphologists have studied aquatic prey capture in fishes for nearly two centuries. Although current approaches continue to yield fruitful insights into the relationships between form, function, and performance, studies of live fishes are limited in their ability to isolate and manipulate individual variables. Biorobotic models of vertebrate systems have risen to the fore as valuable and transformative tools that permit investigators to study comparative biomechanics in entirely new ways. Here we present a biorobotic model of the teleost feeding system based on the largemouth bass, Micropterus salmoides, a combination RAM–suction feeder. BassBot incorporates a three-dimensional armature of the bass head fabricated from poly(methyl methacrylate) plastic. The hard anatomy of the model represents the functional units of the teleost head including the neurocranium, maxillary apparatus, lower jaw, hyoid, suspensorium, and opercular apparatus, with an overlay of skin cut from ultra-thin latex. Constraining the properties and positions of joints found in the bass skull and powered by DC linear motors representing the levator operculi, adductor mandibulare, hypaxial, and epaxial muscles, the three-dimensional kinematic profiles of these functional units are precisely controlled. Programming of linear motors permits repeatable and precise simulation of behaviors (e.g., hyoid depression and lateral expansion of the suspensoria). We also present preliminary results of BassBot feeding experiments that focus on kinematic profiles and suction performance. These results demonstrate a relatively accurate match between feeding in BassBot and live bass and illustrate the promise that robotic models have in understanding the relationship between morphology and performance in fish feeding systems.

Contaminant Effects in Fish: Development of Multiple Measures Screening Approaches

In studies in urban California waters, observed environmental effects in wild fish often reflect specific types of environmental conditions, including presence of chemical contaminants. Since different types or classes of chemicals typically act through distinct phenotypic pathways, development of multiple phenotypic measures have strong potential to serve as screening and diagnostic tools to predict types of active environmental constituents and their health effects. It has been the goal of these studies to develop multiple-measures approaches using proteomics technologies combined with measures of endocrine and physiological status. Proteomes of liver and other tissues are being characterized to discover proteins whose expression is altered in relation to different kinds of contaminant exposures and endocrine system status (endocrine disruption). Since all parameters are measured within the same individuals, it is possible to evaluate contaminant exposures, effects, and endocrine system status using correlated and multivariate statistical analyses. Identification of new protein biomarkers and their expression differences point to changes in toxicological processes, oxidative stress response, hepatic fuel metabolism, and altered signaling (endocrine, intracellular), among others. The multiple-measures approach is providing new insight on the phenotype of animals affected by different kinds of environmental contaminants, and shows promise as a powerful, integrative diagnostic tool to evaluate environmental effects. [Supported by NOAA/USC Sea Grant Program]
45.3 KENNEDY, L. V. *; GUGLIELMO, C. G.; University of Western Ontario; lkenne2@uwo.ca
DYNAMICS OF FAT AND LEAN MASS IN REFUELING MIGRANT PASSERINES MEASURED USING QUANTITATIVE MAGNETIC RESONANCE
Although fat deposition during stopover in migrating passerine birds has been extensively studied, changes in lean mass during refueling are not well understood. I used quantitative magnetic resonance (QMR) analysis to measure the deposition of fat and lean mass for both recaptured and single capture migrant passerines in spring and fall at Long Point, Ontario. Both the recapture analysis and single capture regression analyses indicated a substantial contribution of lean mass to overall increases in total body mass across 18 species. Lean mass contribution changes in total body mass is substantial, ranging anywhere from ~35 to 113% of mass increase and in some cases, was more dynamic than fat mass deposition during refueling at stopover sites. The results of both regression and recapture analyses also suggest that smaller birds deposit relatively less lean mass and more fat per gram gained than larger birds. Our results support recent studies suggesting that lean mass is a dynamic body component during migration in all short-, medium- and long-distance migrant passerines. Thus, the accumulation of protein, and not just energy is an important driver in the foraging ecology of migratory birds.

77.1 KERNEY, R R*; BRITTAIN, A L; HALL, B K; BUCHHOLZ , D R; Gettysburg College, University of Cincinnati, Dalhousie University; rkerney@gettysburg.edu
Cartilage on the Move: Cartilage Lineage Tracing During Tadpole Metamorphosis
The reorganization of cranial cartilages during tadpole metamorphosis is a set of complex processes. The fates of larval cartilage-forming cells (chondrocytes) and sources of adult cartilages are largely unknown. Individual larval cranial cartilages may either degenerate or remodel, while many adult cartilages appear to form de novo during metamorphosis. Determining the extent to which adult chondrocytes/cartilages are derived from larval chondrocytes during metamorphosis requires new techniques in chondrocyte lineage tracing. We have developed two transgenic systems to label cartilage cells throughout the body with fluorescent proteins. One system strongly labels early tadpole cartilages only. The other system inducibly labels forming cartilages at any developmental stage. We examined cartilages of the skull (viscero- and neurocranium), and identified larval cartilages that either resorb or remodel into adult cartilages. Our data show that the adult otic capsules, tecti arterius and posterius, hyale, and portions of Meckels cartilage are derived from larval chondrocytes. Our data also suggest that most adult cartilages form de novo, though we cannot rule out the potential for extreme larval chondrocyte proliferation or de- and re-differentiation, which could dilute our fluorescent protein signal. The transgenic lineage tracing strategies developed here are the first examples of inducible, skeleton-specific, lineage tracing in tadpoles.

BERN.1 KETTERSON, Ellen D.; Indiana University; ketterso@indiana.edu
Bern Lecture: Synthesizing research on the adaptable snowbird: geographic variation, seasonality, and evolutionary endocrinology
Evolutionary endocrinology explores the role of endocrine systems in adaptive evolution by relating hormones to phenotypes to fitness. Three key concepts include hormonal pleiotropy, phenotypic integration, and hormones as agents of change and stasis. The dark-eyed junco, a songbird species, has played historically important roles in our understanding of speciation and seasonality, and continues to provoke curiosity about what a species is and how populations respond to long- and short-term changes in the environment. This talk will consider how selection acts on experimentally induced and naturally varying hormonal phenotypes. It will also address the role of variation in hormonal signal strength and target sensitivity in accounting for varying degrees of phenotypic integration. Populations will be compared to assess the role of timing of reproduction and migration in population divergence, and recent examples of juncos entering novel habitats will demonstrate how endocrine-mediated plasticity can promote successful colonization and adaptation to changing environments. The contributions of many individuals will be highlighted and video clips will serve to illustrate birds, habitats, and history.

S1–3.4 KIRBOE, Thomas; Technical University of Denmark; tk@aqua.dtu.dk
Attack or attacked: The sensory and fluid mechanical constraints of copepod predator–prey interactions
Most animals are both predators and prey. This dual position represents a fundamental dilemma because gathering food often leads to increased exposure to predators. The optimization of the trade-off between eating and not being eaten depends strongly on the sensing, feeding, and motility mechanisms of the parties involved. I here describe the mechanisms of sensing, predator escape, and prey capture in pelagic copepods. Copepods can remotely sense their predators and prey from hydromechanical and chemical cues, they can capture evasive prey in efficient attack strikes or sense and collect prey that are arriving in their feeding current, they have unparalleled escape performances (the strongest animal in the world) and they can propel themselves with unusually high efficiencies (propulsion efficiency > 95%) while minimizing their hydrodynamic footprints. I will describe all this by means of high speed video, flow visualization, and simple fluid dynamical experiments and models. I will conclude by presenting a mechanistically underpinned model that predicts optimal foraging behaviors and rationalizes observed size scaling and magnitudes of zooplankton clearance rates.
Morphology of Phocid Seals

Pinnipeds (seals, sea lions, and walruses) evolved specific feeding strategies to capture and consume prey underwater. Most are generalist feeders, employing pierce or suction feeding. Grip-and-tear and filter feeding are specialized strategies exhibited only by the crabeater seal and leopard seal. Phocids (true seals) are a model group for this study as they are the most diverse pinniped lineage with 18 extant species and employ all four feeding types. The objectives were 1) to determine the feeding strategies used by extant phocids, and 2) to compare generalist and specialist feeding strategies in an evolutionary and ecological context. Three dimensional landmark data were collected from 220 specimens representing all extant phocids. A total of 58 cranial and 24 mandibular landmarks were taken per specimen. Principle Component Analysis and Discriminate Function Analysis were performed. Coalescent-based methods were utilized to generate a molecular phylogeny, and comparative phylogenetic methods determined the ecological factors driving the evolution of each feeding type. The results show that grip—and—tear and filter feeders have evolved distinct feeding characteristics. These morphological adaptations have allowed crabeater and leopard seals to exploit novel niches. However, it has resulted in increased dependence on one or a few prey sources, which could affect survival if prey abundance changes. In contrast to previous studies, the generalist feeding strategies do not correlate with predicted feeding characters. These findings suggest that pierce and suction feeding are not distinct feeding categories or that there are more feeding categories than hypothesized. These results provide a framework to better understand the feeding modes employed by phocids, enabling us to predict how phocids will respond to changing environments.

Impact of food restriction on immune function in altricial house sparrow nestlings

If resources are limiting, then trade—offs may occur between immune defense and life history components such as growth and development. We tested for such trade—offs in food restricted (FR) nestling house sparrows and, particularly, that immune function would be more reduced in a defense considered costly, like the acute phase response to lipopolysaccharide (LPS), compared with one considered less costly, like complement—mediated lysis. We tested birds both early in the nestling period, when growth demands are high, and late in the nestling period, when growth has reached a plateau. We examined the long—term effects of early FR on birds reared and tested late in the nestling period. Masses of alimentary organs and heart were significantly reduced in both early and late FR birds, yet reductions resulting from early FR were reversible in reared birds. Reduced skull length and lean flight muscle mass and maturity were observed with early FR, and reared birds had persistent reductions in muscle size and maturity. As predicted, FR did not significantly impact complement—mediated lysis, a constitutive component of immune function, yet levels of acute phase protein haptoglobin (Hp), an inducible component of the innate immune system, were reduced in early and late FR birds. Early FR had no long—term impact on Hp response, as reared birds challenged with LPS late in nesting period did not significantly differ in Hp response compared with late controls. Thus, innate immune function, like organ growth, appears to be flexible to resource supply during the nestling period, and early FR during the nestling period does not permanently stunt development of the innate immune system.

147.4 KINGSBURY, M A*; GATESY, S; GOLDMAN, D I; Georgia Institute of Technology, Brown University; mkingsbury3@gatech.edu

Sensitivity of foot intrusion kinematics during walking on granular media

Many long-legged organisms walk across granular media (GM), substrates whose properties depend on compaction state and disturbance history. Previous studies of a short-legged hexapodal robot [Li et al, PNAS, 2009], revealed that mobility was sensitive to timing of limb kinematics. However, limbs were short, feet were not biologically realistic (compliant c-shaped) and spatial kinematics were fixed. To begin to understand the role of foot kinematics on locomotion performance of long-legged locomotors, and to simplify analysis, we study walking in a bipedal robot (39 cm tall, 1.6 kg) moving on a GM of poppy seeds. Each leg is composed of 4 motors connected by segments which mimic avian limb morphology. Its feet are flat disks (diameter 9.2 cm), and toe tip trajectories and foot angle can be varied. The robot uses an alternating striding gait in which toe tips trace rectangular trajectories in the body frame. The robot is constrained by bearings that allow horizontal and vertical motion, but do not allow body rotation. We used an air fluidized bed to create loosely packed GM with volume fraction (the ratio of solid to occupied volume) $A=0.58$, and closely packed GM with $A=0.63$. We examined the role of the foot angle $\theta$, (defined as the angle of the foot relative to horizontal throughout its gait) in a range of $-8^\circ$ to $15^\circ$, with positive defined as the toe tip protruding from the GM. Despite its long limbs and large feet, robot performance was remarkably sensitive to $\theta$, and $A$: forward speed in $A=0.58$ was low (1.2 cm/sec) for $\theta<8^\circ$ and increased by a factor of 2 as $\theta$ increased to $15^\circ$. For $A=0.63$ speed was as low for $\theta<0$, but increased by a factor of 3 as $\theta$ increased to $0^\circ$, after which speed was insensitive to $\theta$.

48.6 KINGSTON, A*; HANLON, RT; CRONIN, TW; University of Maryland, Baltimore County, Marine Biological Laboratory, Woods Hole, MA; anakHon1@umbc.edu

Immunolabeling and diverse expression of opsin in the skin of the squid, Doryteuthis pealeii

Cephalopods, including squid, cuttlefish and octopus, have extracellular photoreceptors located in a variety of different tissues. Cephalopods have photoreceptors in the light organ, stellate ganglion and parolfactory vesicles, all of which operate using opsin. Here, we show that opsin is present in many skin regions of the squid, Doryteuthis pealeii (formerly Loligo pealeii), and propose a putative distributed photoreceptive system. RT-PCR revealed opsin transcripts in the retina, ventral mantle, ventral fin, arms 1-4, tentacle, and fin muscle tissue. All opsin transcripts are identical, based on predicted amino acid sequences. Further supporting a putative photoreceptive system, RT-PCR revealed the presence of retinochrome, a photosomerase involved in chromophore recycling in the retina. Retinochrome was found in all tissue regions where opsin was located, and all retinochrome transcripts are identical, based on predicted amino acid sequences. Immunohistochemical staining shows that opsin protein is present in the outer segments of the retina, and in skin from the ventral mantle, dorsal mantle, and dorsal fin. These results lead us to hypothesize that the skin of D. pealeii may function as a distributed photoreceptive system. Future work will include immunohistochemistry for opsin and retinochrome on all untested regions of skin.

24.3 KINGSOLVER, J.G.*; DIAMOND, S.E.; Univ of North Carolina, Chapel Hill, North Carolina State Univ; jgkings@bio.unc.edu

Thermal stress and the fitness consequences of climate change for ectotherms

Recent models of the ecological effects of global warming on insects and other ectotherms predict that mean fitness will decrease in tropical species but increase in temperate species. This occurs because temperate species have larger thermal safety margins (the difference between optimal temperature and mean environmental temperature) than tropical species. These models do not account for mortality due to extreme high temperatures in fluctuating environments: such intermittent heat stresses could reduce the mean fitness of a population to zero. Here, we develop a series of models and an alternative definition of the safety margin that incorporate the effects of heat stress. We parameterize these models for insect species at multiple sites along a latitudinal gradient of environmental temperature. At both tropical and many temperate sites, climate change is predicted to increase the frequency with which species experience extreme summer temperatures above their upper thermal limits. Our simulations suggest that because of increasing heat stress, the negative fitness consequences of climate change may not be limited to tropical ectotherms. The consequences of heat stress will be magnified if climate change increases both mean and seasonal variability in environmental temperatures, especially at higher latitudes.

55.6 KINSEY, S.T.; University of North Carolina Wilmington; kinseys@uncw.edu

Why are muscle fibers so large? Solving diffusion problems to attain maximal cell size

Muscle fibers are among the largest cell types, but while diffusion appears to limit maximal fiber size, the selective pressures that control maximal size are unclear. During animal growth, muscle fibers generally increase in diameter and this size increase is associated with a number of structural and metabolic changes to the cells. Many of these changes compensate for the increasing diffusion distances associated with hypertrophic fiber growth. Experimental measurement of metabolic rates, diffusion distances and diffusion coefficients, coupled with mathematical reaction-diffusion models have revealed that many fibers grow to sizes that put them on the brink of extreme diffusion limitation in the adult. This suggests that fibers become as large as possible and structural alterations allow fibers to attain larger sizes than would otherwise be possible. These results are consistent with the optimal fiber size hypothesis proposed by Ian Johnston and colleagues to explain the very large fibers in cold water fishes. This hypothesis posits that the reduced surface area to volume (SA:V) in larger fibers is favored because it reduces the cost of maintaining the membrane potential. To test this hypothesis, the fiber size dependence of Na$^+$–K$^+$–ATPase cost and activity were measured in white muscle that grows hypertrophically from juveniles and adults of 16 species of crustaceans and fishes that vary dramatically in body mass and fiber size. Changes in Na$^+$–K$^+$–ATPase cost and activity during hypertrophic growth were proportional to changes in SA:V, providing evidence that large fiber size is under positive selection. Ironically, since SA:V is more sensitive to fiber size in smaller fibers, this rule of fiber design may be more relevant to smaller fibers than to the very large fibers for which it was originally proposed.
A circadian clock regulates both crawling and swimming in the nudibranch Melibe leonina

Many animals exhibit circadian (~24 hours) rhythms of activity in natural light/dark (LD) conditions. If these rhythms persist in constant darkness (DD), this is indicative of an internal circadian clock. The purpose of this study was to determine if the nudibranch mollusc Melibe leonina expresses a circadian rhythm of locomotion, specifically crawling and swimming, in DD. Animals were videotaped for three days in LD, followed by at least five days of DD. Videos were quantified visually (n = 30), to determine how often animals swam, or using Ethovision software (n = 8), to measure distance crawled. These data were then analyzed as actograms and analyzed using the program ClockLab to determine the periodicity of locomotor patterns. For crawling, 7 of 8 animals exhibited a circadian pattern of locomotion in DD (tau = 22.8 ± 1.3 hours). Swimming does not occur as often and only 11 of 30 animals regularly swam for the duration of the study. Of these 11 animals, 45% expressed a circadian rhythm of swimming in DD (tau = 23.5 ± 0.7 hrs). Regardless of the mode of locomotion, animals were typically most active just after sunset, or the time when sunset would have occurred in DD. These data indicate the presence of a circadian clock that influences both crawling and swimming behaviors in Melibe. Considering that the neural circuit underlying swimming in Melibe has been previously determined, these data suggest that Melibe may be a good model system for investigating how circadian clocks influence the daily expression of certain behaviors.

Estrogen has an inhibitory effect on the contractility of gastrointestinal smooth muscle, including the gallbladder. This study investigated the effect of 17 &beta;−estradiol (E2), progesterone (P), 17−hydroxyprogesterone (17−P), and a P metabolite, 20 &alpha;−hydroxyprogesterone (20−P) on contraction in female guinea pig gallbladder strips. P, 17−P, 20−P, and E2 each relaxed cholecystokinin and KCl−induced tension; the relaxation was concentration−dependent. E2 and P had a similar effect on KCl−induced tension. When the response to E2 was compared between young female guinea pigs and guinea pigs in late pregnancy, no significant difference in the response to either 50 or 100 &micro;M E2 was seen; however, 10 &micro;M E2 caused a significant increase (p<0.05) in the relaxation in strips from pregnant guinea pigs. Treatment of the strips from young guinea pigs with PKA inhibitor 14−22 amide myristolylated had no significant effect on the E2−induced relaxation. Treatment of the strips with 2−APB produced a significant (p<0.001) increase in the amount of E2−induced relaxation when either CCK or KCl were used. Neither KT5823 nor L−NMMA had a significant effect on the E2−induced relaxation. Bisindolylmaleimide IV and chelerythrine CI− were used in combination with no significant effect on the amount of CCK−induced tension, but significantly (p<0.01) increased the amount of E2−induced relaxation. When either E2 or P were added to the chambers 3 min prior to either CCK or KCl, a significant decrease (p<0.001) in the amount of tension generated was observed. The inhibition of extracellular Ca−2 entry mediates both P− and E2−induced relaxation of CCK− and KCl−induced tension in female guinea pig gallbladder strips.
Temperature is a key factor that affects the rates of growth and development in animals, which ultimately determine body size. While not universal, a widely documented and poorly understood pattern is the inverse relationship between temperature and body size. Among ectotherms, higher temperatures exponentially increase the rate of oxygen consumption over some ranges, while having minimal effects on gas diffusion. This effect forms one basis to the MASROS hypothesis (maintain aerobic scope regulate oxygen supply Atkinson et al. 6) which states that growth and/or development rates will be altered to maintain maximal aerobic scope. The MASROS hypothesis remains one of the prominent explanations for the smaller body size of ectotherms reared at higher temperatures. To test the MASROS hypothesis, we utilize meta-analysis approaches to examine whether the response of an ectothermic species to temperature is associated with sensitivity to oxygen, phylogeny, gas exchange system, flight, or habitat, and how that interacts with other selection regimes that influence body size. eg. sexual selection or anti-predator selection. This research was partially supported by NSF IOS 1122157 to JFH and CJK.
Gut microbes facilitate consumption of toxic diets by herbivores

For decades, ecologists have hypothesized that herbivorous mammals might host beneficial microbes that facilitate the ingestion of diets containing toxic plant secondary compounds (PSCs). However, this idea has never been sufficiently tested in wild herbivores. We studied a small herbivorous rodent, the desert woodrat (Neotoma lepida) that naturally feeds on a toxic shrub, creosote bush (Larrea tridentata). Creosote leaves produce large quantities of a phenolic-rich resin that is lethal to lab mice in the doses consumed by woodrats. Woodrats were fed either a control diet of rabbit chow or rabbit chow plus 2% extracted creosote resin. Animals were dissected and we conducted metagenomic sequencing of the contents of the woodrat foregut. Additionally, a subset of animals were given a broad-spectrum antibiotic (neomycin); food intake and body mass were monitored. When feeding on creosote resin, the woodrat foregut metagenome was notably enriched in genes associated with the metabolism of aromatic compounds, stress responses, protein metabolism, carbohydrate metabolism, and membrane transport. Woodrats given antibiotics consumed less food and lost more weight compared to woodrats not given antibiotics, but only when the diet contained PSCs. Metagenomic results revealed that dietary toxins strongly alter the functional profile of woodrat gut microbes, which may have impacts on host homeostasis. The antibiotic study represents the first experimental evidence that microbes enhance the consumption of PSCs in wild herbivores. These results suggest that beneficial microbes play a large role in enhancing dietary niche breadth in herbivores by allowing them to consume toxic plants. This may have implications for wild and domesticated herbivores facing rapid changes in plant communities due to changes in global climate or land-use practices.

RNA-seq as a Tool to Understand the Evolution and Development of the Single-Chambered Eye: Transcriptomics of the Long-finned Squid, Doryteuthis (Loligo) pealeii

Cephalopods (Octopus, Squid, Cuttlefish and Nautilus) are a group of highly successful mollusks with advanced cognitive capacity and complex body plans. As the field of evolution and development broadens, these organisms provide an ideal system to examine questions of parallel and convergent evolution of specific organ systems. Our interest in the squid Loligo pealeii is to further understand the evolution and development of complex image-forming eyes across the Metazoa. The subclass Coleoidea, which includes squid, octopus and cuttlefish, share a single-chambered image-forming eye, resembling the vertebrate eye. To begin to dissect the molecular and morphogenetic events that underpin the development of this complex organ and to facilitate molecular and functional analyses, we sequenced the embryonic transcriptome of L. pealeii. These data enabled us to analyze evolutionarily conserved eye-specific transcriptional cascades and provide a reference for RNA-seq experiments in the absence of a sequenced genome. We performed RNA-seq studies of isolated eye and optic lobe tissues from the developing embryo, quantifying changes in gene expression throughout distinct stages of eye morphogenesis. This work builds the foundation of a model to better understand developmental constraint as well as examine how convergent and parallel evolutionary processes impact the formation of complex organs such as the eye.

RNA-seq and cell-specific DNA methylation profiling for comparative and integrative biology: Toward genomic portraits of individual blastomeres and identified neurons

Considering the enormous heterogeneity of cell populations, metagenomics offers single-cell RNA-seq (transcriptome) and unbiased epigenomic analysis of individual cells is essential for biology in general, and for development and neuroscience in particular. Here we present novel approaches that allow fast and cost-efficient transcriptome sequencing from ultra-small amounts of tissue or even from individual cells across phyla. Specifically, the developed protocols not only can perform single-cell transcriptome profiling but also capture nascent RNAs (nRNAs) following a developmental program or experience-dependent plasticity (e.g. following learning and memory consolidation). We implemented and validated these protocols using identified molluscan neurons (Aplysia californica) and developmental stages down to the 1 cell stage of the ctenophore Pleurobrachia bachei. As a result of initial mapping to the reference genomes, we estimated that the majority of the genome is expressed in a given cell, generating on the order of 100,000 unique transcripts (including large and small non-coding RNAs) supporting unique cell phenotypes. Furthermore, these RNAseq protocols can be integrated with DNA methylation from the very same cell and miRNA profiling. Because homologous cells and cell populations can be recognized across classes and phyla, both in early development and in nervous systems, it is now possible to follow dynamic reorganization of the specific cellular genomes in evolution to reveal the molecular bases underlying origins of complex phenotypes and novelties. Integrating this type of resolution to comparative biology has enormous evolutionary implications to deciphering the logic of gene regulation and the full scale integrative activity of genomes across phyla.
8.3 KOMOROSKE, LM*; HASENBEIN, M; LINDBERG, J; CONNOL, RE; FANGUE, NA; UC Davis; lmkomoroske@ucdavis.edu

Understanding climate change impacts on Delta Smelt

The delta smelt (Hypomesus transpacificus) is an endemic fish in the San Francisco Bay-Delta and is an important ecological indicator species. Delta smelt have been rapidly declining in the past 30 years due to a variety of physiological and ecological stresses, and climate change is expected to further impact this species by altering regional temperatures and salinities. Some thermal and salinity studies have investigated whole organism tolerance in adults, but little is known about how tolerance thresholds vary across life stages, sublethal stress thresholds, or their mechanistic drivers. We sought to understand climate change impacts on delta smelt by conducting Critical Thermal Maximum (CTmax) and acute thermal exposure−recovery gene expression experiments in all life stages. Similarly, we assessed salinity tolerance and sublethal stress responses by exposing fish to environmentally relevant salinity increases (mimicking tidal cycles). We found that CTmax differed between life stages (15−16°C acclimation, CTmax larval=29.9°C+/−0.35; adult=26.3°C+/−1.8). For salinity, percent mortality was similar for all treatments at short time periods (0−6hrs), but increased at high salinity levels over longer time periods (at 48 hours: 18ppt =92% vs. 0ppt=47%), suggesting that while fish may be able to cope with short periods of increased salinity, they may not subsist in the long-term. We also linked these tolerance data to gene expression profiles. Climate change may result in temperature and salinity levels under which delta smelt cannot effectively persist physiologically, causing large−scale habitat reduction or loss. Quantifying tolerance and sublethal stress thresholds helps to understand these physiological limits and better predict habitat suitability for delta smelt under various management plans in the Bay−Delta.

10.4 KONCZAL, M. *; KOTEJA, P.; RADWAN, J.; STUGLIK, M.; BABIK, W.; Jagiellonian University in Krakow; mateusz.konczal@uj.edu.pl

Accuracy of pooled RNA−seq

For non−model organisms without reference genome, genome−wide information focusing on functionally relevant variation may be obtained through RNA−seq with de novo assembled reference transcriptome. Sequencing itself has become relatively cheap, but library preparation for many samples remains prohibitively expensive. In such cases pooling appears an attractive, but nontrivial approach. Inter−individual and inter−locus variation in expression level could cause inaccuracy in allele frequency (AF) estimation, the problem which does not affect pooled genome resequencing. To estimate the accuracy of pooled RNA−seq in predicting AF we analyzed liver transcriptomes of 10 bank voles (Myodes glareolus). Each sample was sequenced both as an individually barcoded library and as a part of a pool. The pool consisted of equal amount of total RNA from each vole, combined prior to mRNA selection and library construction. On average 16.8 million reads (100bp PE) were obtained per individual. Reads were mapped on the de novo assembled reference transcriptome. For 35 000 SNPs high quality genotype was available for each vole. These genotypes allowed us to calculate true AF in the sample. AFs estimated from the pool were compared to the true values. High correlation between true frequencies and those estimated from the pool (R²=0.89) was observed. Mean estimation error reached 21% of true value and was independent of expression level, which indicates that accuracy of AF estimation from pooled samples is relatively robust to variation in expression between individuals. However, we observed highly negative correlation between minor AF and calculated error, the problem affecting also genome studies. Our results indicate that the efficiency of pooled RNA−seq may be comparable to pooled genome resequencing.

January 3−7, 2013, San Francisco, CA
28.5 Konow, N*; Von Busse, R; Cheney, JA; Breuer, KS; Swartz, SM; Brown University; nkonow@brown.edu

What is the relationship between pectoralis muscle recruitment intensity and air speed velocity in an un−laden bat?

Aerodynamics theory predicts a U−shaped relationship between flight power and speed: The cost of transport should be lower at intermediate than at low and high speeds, due to constraints imposed by lift and drag. A similar relationship between muscle recruitment intensity and in some cases actual power production, with respect to flight speed has been found in some birds and insects, but not in others. This relationship remains unknown for bats, the only other extant group that has evolved powered flight. We measured recruitment intensity in two regions of the pectoralis muscle in five Sebas short−tailed bats (Carollia perspicillata) flying at 1−7 m/s air speeds in a wind tunnel. The relationship between muscle recruitment intensity (integrated area under the rectified electromyogram) and flight speed was U−shaped in one individual, —shaped in two individuals and invariant in two individuals. Several factors may combine to produce this inconsistent relationship: Compared with birds and insects, bats can modulate their wingbeat kinematics more extensively, in part due to their numerous wing joints. These joints are crossed by muscles that may contribute to the down−stroke, so the bat pectoralis is not necessarily the only source of flight power. Bats also have muscles in their wing membrane that may modulate camber and thus alter aerodynamic power production differentially with speed. Like other flapping flyers, bats have diversified across a vast range of foraging strategies, and use flight modes that range from hovering to fast hawking. Kinematics differences between these diverse flight modes may constrain power production across speeds as well as individuals and species. Funded by AFOSR.

12.6 Kraatz, BP*; Bumacod, N; Wedel, M; Azevedo, B; Western University of Health Sciences; bkraatz@westernu.edu

Evolution, Ecology, and Medicine of the Lagomorph Skull

The lagomorph (rabbits, hares, and pikas) skull exhibits a unique set of characteristics that distinguish it from most other mammals. Hares and rabbits hop, and some species show a level of cursoriality that is unmatched for animals of their size. Previous workers have suggested that hare skull morphology is related to locomotion, but this hypothesis has not been thoroughly tested. We explored the relationship between skull shape and ecology using an 2D morphometric data set that included 144 skulls from 17 living leporids (rabbits and hares). Our analyses showed strong correlation of skull shape and burrowing behavior. We also found that the tilt of the facial skeleton relative to the basicranium correlated with locomotion, with generalized scampering taxa having flatter skulls and hoppers having more facial tilt. This led us to investigate possible modularity within leporid skulls. Our 2D data showed that diastema length was more strongly correlated with overall skull length than was basioccipital length. To explore this further we utilized the RV coefficient to analyze a subset of skulls using 3D geometric morphometric data taken from surface renders from CT scans. These analyses suggest a distinct pattern of modularity between the facial and basioccipital regions in the lagomorph skull. The most recent ancestors of lagomorphs, the mimitontoids (ca 55Ma), exhibit a facial region that is remarkably similar to that of living lagomorphs, but a relatively primitive basicranium. It wasn’t until tens of millions of years later that the basicranium of fossil lagomorphs showed features that were consistent with those of the highly tilted skulls of living lagomorphs.

31.4 Krarov, B.R.*; Khokhlova, I.S.; Ben−Gurion University of the Negev; krarov@bgu.ac.il

Patterns, mechanisms, consequences of gender−biased parasitism in small mammals

We will review patterns, causes and consequences of gender−biased infestation of small mammalian hosts by macroparasites. We start with a description of gender biases in parasite infestation and discuss variation in these patterns among host and parasite taxa. We will also look at temporal and spatial variations in gender−biased parasitism and demonstrate that they can vary seasonally and be mediated by environmental conditions. Then, we will present main hypotheses that examine mechanisms of gender−biased parasitism. One group of these hypotheses focuses on differences between male and female hosts in their probability to be attacked by parasites, while another group links gender−biased parasitism with differences in parasite performance in male versus female hosts. Finally, we discuss possible consequences of male−biased parasitism for individual parasites, their populations and communities.

145.4 Krause, A/J*; Serb, J/M; Iowa State University; ajkrause@iastate.edu

Functional divergence? Comparing opsin expression in extra−ocular tissues and eyes of the scallop (Pectinidae).

Photosensitivity plays a role in vision, entrainment of the circadian clock, and phototaxis, ultimately affecting the life history and fitness of many species. While we often think of the eyes as the primary light−perceiving organ, extra−ocular photosensitivity (EOP) is common in animals and many species maintain photosensitivity despite their eyeless condition. Presumably, the key photoreceptive protein in animals in both ocular and EOP structures is a member of the opsin family, a group of seven transmembrane G−protein coupled receptors, but the relationship between opsins used in these specific photo−sensing systems is largely unexplored. Recently, we isolated two copies of Gq−opsin from eyes of the common bay scallop, Argopecten irradians (Pectinidae). One of the copies has been previously reported in scallops, while the second copy differs by 45% in amino acid sequence. Surprisingly, both copies contain a lysine residue required for chromophore binding and photosensitivity suggesting both proteins are functional. To test the hypothesis that a gene duplication event resulted in tissue−specific functional divergence of scallop opsin, we determined the evolutionary relationship and examined spatial expression patterns of the two A. irrigans Gq−opsin copies. Using in situ hybridization techniques, we determined both copies are expressed in the nerves of mantle tissue as well as ocular tissues. Our results suggest a scallops mirror−type eyes and the EOP in surrounding mantle tissue may be sensitive to similar spectrums of light.
124.3 KRAUSZER, M.; LEIKEN, A.; ELLIOTT, J.K.*; Univ. of Puget Sound, Tacoma; jkelliott@ups.edu
Ontogenetic color variation in the sea star Pisaster ochraceus as an adaptation to avoid predation by gulls
Early life history stages of many species are often camouflaged to reduce detection by visual predators because they are more vulnerable than older/larger individuals. We have studied a variety of ontogenetic stages of the sea star Pisaster ochraceus in Puget Sound, WA. Juveniles are grey/brown, and at a size of approximately 5 cm arm length they change to their characteristic adult color of purple, brown, or orange. Small sea stars (< 7 cm arm length) of P. ochraceus are most abundant in habitats with high structural complexity (e.g. cobble), and are found under rocks or in crevices at low tide. In contrast, large sea stars are often observed out in the open during low tide. We observed gulls foraging under rocks at low tide and feeding on small sea stars, and we hypothesized that the grey/brown coloration of juveniles was an adaptation to reduce detection by foraging gulls. To test this hypothesis we placed different colored clay models (grey, brown, purple, orange) and live sea stars (grey, brown, orange) in the intertidal to determine whether gulls would preferentially prey on certain colors. We also used reflectance spectrometry to compare the brightness of each color morph in relation to their background as a measure of conspicuousness. Orange sea stars were the most conspicuous, and they experienced the highest predation rates. Grey and brown sea stars were the least conspicuous and had the lowest predation rates. Selective predation by gulls on small brightly colored orange sea stars may be a factor causing the purple color morph to be predominant in Puget Sound, whereas low predation rates by gulls in more exposed coastal locations may allow orange color morphs to occur at higher frequencies.

17.9 KRISHNAN, A.*; SANE, S.P.; National Centre for Biological Sciences, TIFR, Bangalore; anandk@ncbs.res.in
Antennal positioning in flying hawk moths
Insects of diverse orders display forward positioning of the antennae at the onset of flight. Because antennal mechanosensory feedback is important for flight control, proper positioning of the antennae may be of critical importance for the acquisition of these innate skills during flight. We investigated the neural mechanisms of antennal positioning in the hawk moth Daphnis nerii. Our results indicate that the mechanosensory Bohms bristles on the antennal scape and pedicel are the primary mediators of positioning of the ipsilateral antenna. Ablation of these mechanosensors results in mis-positioning of the antennae and frequent collisions between the antennae and wings. The antennal motor neurons respond to stimulation of the Bohms bristles at very rapid latencies, suggesting that the underlying sensorimotor connections are probably monosynaptic. Moreover, we found that the antennal muscles of hawk moths also received visual inputs from both ipsilateral and contralateral eyes. However, the response latencies to visual stimuli were longer than those to stimulation of the Bohms bristles. Our results thus suggest that antennal positioning behaviour constitutes a multimodal reflex arc, with the Bohms bristles providing rapid feedback to set the ipsilateral antennal position whereas the visual system functions in slower context-dependent modulation of positions of both antennae. Integration of these multi-sensory inputs may be critical in ensuring that the antennae are properly positioned during rapid flight maneuvers.

66.6 KRIENGWATANA, B.*; AITKEN, S.D.T.; GARCIA, L.; FARRELL, T.M.; MACDOUGALL-SHACKLETON, S.A.; University of Western Ontario, University Western Ontario, London, ON, Canada
Decline in conditions during the juvenile period impair behavioral flexibility, while consistently poor developmental conditions impair spatial memory of zebras
Developmental environments can have long-term effects on learning and cognition. Multiple aspects of cognition may be affected by poor conditions during development if underlying systems are maturing simultaneously. The present study investigates the effect of nutritional stress at different stages of development on behavioral flexibility, spatial memory, and neophobia. Zebra finches were raised in consistently high (HH) or low (LL) food conditions until 65 days post-hatch (DPH), or were switched from high to low conditions (HL) or vice versa (LH) at 35 DPH. Subjects were then tested as adults. An attentional set-shifting task that required subjects to inhibit responding to a previously rewarding cue and shift attention to a previously non-rewarding cue was used to quantify behavioral flexibility. A hippocampus-dependent spatial memory task (Bailey et al. 2009) was used to quantify spatial memory, and willingness to approach a novel object was used to quantify neophobia. Results indicate that HL conditions impaired subjects ability to shift attention and inhibit previously correct responses, while LL conditions impaired subjects performance on the spatial memory task. Although there was no main effect of treatment conditions on neophobia, birds that were more neophobic tended to be more flexible, especially females. These findings provide insight into the differences in windows of vulnerability for development of attentional and hippocampal-dependent processes, as well as the possibility that a decline in environmental quality during the juvenile period may permanently affect dopaminergic systems responsible for attention and inhibitory control.

84.5 KROCHMAL, A.R.*; BAKKEN, G.S.; Washington College, Indiana State University; akrochmal2@washcoll.edu
Temperatures of Trekking Turtles: Estimates by Water-filled Models and Hollow Te Thermometers
Aquatic turtles take to land during oviposition or when seeking out new aquatic habitats. Though such overland treks are central to the biology of aquatic turtles, the physiological strain placed on turtles during such treks remains largely uninvestigated. During treks, turtles encounter environments that are thermally more extreme, more variable, and potentially more stressful than are their aquatic habitats. We tested 3 methods for predicting body temperature (Tb) during treks that might prove useful in management or climate change models. We exploited treks forced by annual drainage of artificial ponds for management purposes in our Maryland study area. Turtles at our site use habitual overland routes, allowing accurate pre-positioning of thermal sensors and thus accurate comparison between the Tb of free-ranging animals and Tb as estimated by an array of temperature sensors. We used and compared several proposed methods (1) anatomically correct, water-filled, electroformed copper turtle models to estimate Tb directly, (2) hollow electroformed copper models and (3) approximate models consisting of sized-matched aluminum baking pans, both of which were used to compute Tb. Additionally, we used both (4) plain and (5) solar-absorbance matched Thermochrons to record temperature at sensor locations. Models were painted to approximate the solar absorptance of turtle shells and were calibrated against both turtle shells and live turtles. Model accuracy and precision will be discussed, and models will be evaluated for their suitability for use in management and climate change modeling.
Do shifts in host use or larval development drive speciation in the sea? A comparative study of herbivorous sea slugs.

Marine biodiversity presents a challenge to current theory of allopatric speciation, given the lack of physical barriers to gene flow and the high dispersal potential of many organisms, either as pelagic adults or as planktonic larvae. Recent studies of invertebrates, fish and marine mammals suggest ecological speciation can proceed in sympathy, but this remains controversial. For specialized consumers or epibionts, disruptive selection on host or habitat choice may drive speciation. Alternatively, life-history shifts from dispersive larvae to short-lived, non-feeding larvae may reduce gene flow among populations, and shrink the scale at which populations diverge in allopatry. Non-dispersive life histories could also act synergistically with selection, together increasing local adaptation to newly colonized niches. Sea slugs in clade Sacoglossa, the most host-specialized marine herbivores, are an excellent system with which to explore how shifts in host or life history alter patterns and rates of speciation. We present a comparative analysis of this group, using a molecular phylogenetic framework of 200 taxa to identify traits that influence the geographic and temporal mode of speciation. Bayesian and maximum likelihood methods of ancestral character state reconstruction and correlated trait evolution will be used to test the evidence for sympatric speciation by host shift, and determine whether clades with frequent host shifts have accelerated rates of evolution or speciation. We will also test the hypothesis that larval type influences rates of (a) molecular evolution, (b) speciation, and (c) gene flow estimated from population genetic data.

Delusions of immunocompetence: song complexity, song consistency and immune trade-offs in song sparrows

In short-lived, migratory songbirds, constitutive innate immunity is an important component of fitness. Females cannot directly assess immune function but condition-dependent ornaments or displays may provide information about the signaler's past or current condition. We investigated the degree to which song complexity and song consistency, thought to reflect condition over different developmental timescales, predict multiple aspects of constitutive innate immunity in 38 male song sparrows. We also investigated correlations among immune measures. Principal components analysis revealed an overall pattern of opposite loading between protective protein (haptoglobin, lysozyme, natural antibody) versus cellular (microbicidal, phagocytosis) components of immunity. Song complexity, a static trait that does not change during adulthood in this species, was associated with relative investment in protective proteins versus cellular activity: males with large repertoires had higher protective protein titres but lower leukocyte activity relative to males with small repertoires. Song consistency, a dynamic trait that varies throughout the life of the individual, did not predict relative investment in proteins versus cellular defences. Song complexity may reflect individual variation in self-maintenance strategies, rather than overall immune functioning per se. Perhaps most important, these findings illustrate the importance of assessing multiple aspects of immunity rather than attempting to infer immunocompetence from a single metric.
Turning up the Heat: Investigating the Physiological Effects of Climate Change on Mammalian Herbivores

Climate change is causing range shifts and population declines in many animal populations, particularly mammalian herbivores. One hypothesis to explain these changes in mammalian herbivores is that plant secondary compounds may be perceived as more toxic due to decreased liver metabolism at warmer ambient temperatures compared to cooler temperatures. The phenomenon of temperature-dependent toxicity (TDT) has been documented in pharmacological studies in laboratory rodents, but has not been extensively explored in wild mammalian herbivores. To test for TDT, we investigated how ambient temperature impacts liver metabolism in the desert woodrat, Neotoma lepida, by using hypnotic state assays. In a cross-over design, wild caught N. lepida (N=26) were housed at two ambient temperatures (warm=29°C, cool=21°C) for either 30 days or 3 hours to capture ecologically relevant situations in the wild (i.e., within season or access to microclimate). After each temperature exposure, animals were given a hypnotic agent (hexobarbital via intraperitoneal injections 100mg/kg), which was used as a proxy for liver function with longer sleep times indicating decreased liver function. The average sleep time of woodrats acclimated to warm temperatures for 30 days was almost 50% longer than cool-acclimated woodrats and almost 30% longer after the 3 hour exposure to warm versus cool temperatures (paired t-tests, p<0.01). These results demonstrate that warmer ambient temperatures adversely affect liver function, even within a short period of time, and may provide a physiological mechanism through which climate change acts on herbivorous mammals.

Assessing Autonomous Reef Monitoring Structures (ARMS) as Biodiversity Monitors

Assessing Autonomous Reef Monitoring Structures (ARMS) as Biodiversity Monitors Akela Kuwahara, Alen Collins, and Chris Meyer Humboldt State University

Assessing Autonomous Reef Monitoring Structures (ARMS) as Biodiversity Monitors due to the complexity of coral reef ecosystems and the multitude of cryptic species, accurate estimates of coral reef biodiversity are difficult. To better understand coral reef biodiversity and how it varies, Autonomous Reef Monitoring Structures (ARMS) were developed to collect comparable samples of reef cryptobiont communities. These units create standardized, habitable structure for both sessile and motile reef organisms, thus allowing statistically rigorous examination of a consistent, diverse subset of cryptobiota across a variety of reef habitats, locales and time. Over 300 ARMS have been deployed at over 40 sites worldwide, but no tests have been performed to measure the variance in community composition within and/or between sites for the sessile biota. In order to test the sensitivity of ARMS to detect change, we measured percent cover of major sessile groups using high-resolution photographs of the ARMS plates after one-year deployments on reefs in the Coral Triangle and French Polynesia. These data were used to test the following: 1. How much variation in major functional groups exists within regions on local scales (i.e. 2m versus 100m)? 2. Can ARMS detect differences in community composition across regional scales (Indonesia versus French Polynesia)? 3. Are communities established on reconditioned ARMS different from those on new ARMS? These tests are critical to determine the potential of ARMS data as a rigorous biodiversity metric. Our results argue for the use of ARMS as standardized monitoring structures and provide insight into the cryptic community on coral reefs. This morphological data can also be compared with metagenomic data derived from the ARMS, allowing us to assess the accuracy of these emerging molecular methods in measuring biodiversity.

Scaling of the Hydrostatic Skeleton in the Earthworm, Lumbricus terrestris

The structural and functional consequences of changes in size or scale have been well studied in animals with rigid skeletons, but relatively little is known about scale effects in animals with hydrostatic skeletons. We used microscopy and histology to examine the scaling of mechanically important morphological features using an ontogenetic size range of the earthworm Lumbricus terrestris from 0.03g~12.89g. Each worm was anesthetized and laid out under a dissecting microscope, and measurements were taken of its elongated body length as well as diameter. The worms were then sacrificed and several segments were removed and embedded in glycol methacrylate plastic. Our results indicate that several functionally important morphological features do not maintain geometric similarity with ontogeny. We found that the cross-sectional area of the longitudinal muscles (which are used to radially expand the worm) scaled as body mass to the ~0.6 power across segments, which is significantly lower than the 0.66 power predicted by isometry. However, the cross-sectional area of the circular muscles (used to axially elongate the worm) scaled as body mass to the ~0.8 power across segments, which is significantly higher what is predicted by isometry. These data suggest that as worms increase in body size, they may produce relatively greater forces during axial elongation but relatively weaker forces during radial expansion than what is expected by scaling with geometric similarity.

Division of labour between adhesion and friction pads in stick insects (Carausius morosus)

Stick insect legs bear two types of attachment pads, tarsal heel pads (euplantulae) and a pre-tarsal toe pad (arolium). In order to investigate whether these pads are specialized for different functions, we measured friction and adhesion of single pads under varying normal and shear force loads, using a custom-built 2D force transducer. Euplantulae were found to generate negligible adhesion (peak values below 15% body weight), but large friction forces exceeding the insect’s body weight. In contrast, peak adhesion of arolia amounted to up to 80% body weight. Adhesive forces significantly increased with the applied shear force, and were independent of the normal pre-load over nearly one order of magnitude. These results suggest that stick insects use their tarsal euplantulae for generating friction forces when no adhesive force is needed (e.g. when walking upright or for legs below the centre of gravity during vertical climbing), and thereby minimize costs associated with detachment of the pads. The distal arolia, in turn, are likely used as true adhesive pads that maintain surface contact during vertical climbing or inverted walking. The shear stress (friction per apparent contact area) of euplantulae (but not of arolia) was dependent on normal load. This dependency may be explained by the specific surface topography of the euplantulae, which are covered by tapered microtrichia. High-magnification light microscopy and reflected-light contrast recordings of the euplantula contact area during force measurements confirmed that their real contact area increased both with normal and shear force via a larger number of microtrichia contacting the surface and/or side contact of individual microtrichia.
134.5 LAHMAN, SE*; MOORE, PA; Bowling Green State Univ.; 
slahman@bgsu.edu
Sexual information in chemical signals: the interaction between odor source and hydrodynamics.
Within an aquatic ecosystem, many organisms rely on chemical signals in order to perform a range of ecological decisions. Understanding the role of chemical signals in the ecology of aquatic organisms requires a thorough understanding of the spatial and temporal distribution of sensory stimuli. For chemo-reception, chemical signal dispersion is intimately tied to fluid mechanics. Alterations in the hydrodynamics of a habitat or in the way that chemical signals are introduced to habitats can have profound effects on sensory information which can subsequently alter the behavior or ecology of organisms using chemical signals. As organisms have a defined threshold for the induction of chemically driven behaviors, variations in the information received will elicit alternate behavioral responses. This study examines the influence of point versus non-point introduction of chemical signals into a simulated flowing freshwater habitat. The fine scale spatial-temporal distribution of chemical signals was measured in situ using an electrochemical detector. Molecule concentration at varying distance and height from the source was quantified using the chemical tracer dopamine coupled with an electrochemical detection system (Epsilon, Bioanalytical Systems). The fine-scale distribution of chemical signals from point and non-point sources showed significant differences in the types of information that are available to organisms. This quantification of chemical signal dispersion patterns and the types of information that are available allows a greater understanding of chemo-reception. Based on these results, organisms should be able adjust their search strategy to differences in information received.

88.5 LAMMERS, A.R.*; DORSEY, E.J.; Cleveland State University, Ohio; a.Lammers13@csuohio.edu
Kinetics of locomotion on arboreal and terrestrial substrates in Siberian chipmunks (Tamias sibiricus)
Traveling on tree branches and twigs is common among mammals, but until recently most studies concentrated on primates. With work carried out on gray short–tailed opossums, rats, and red squirrels (Schmidt & Fischer 2010; Schmidt 2011), it is possible to begin generalizing about differences in arboreal locomotor biomechanics between primates and other mammals. We trained five Siberian chipmunks to run on 2 m long trackways one with a flat surface to simulate an arboreal substrate. We instrumented a cylindrical (2 cm diameter) to simulate a terrestrial surface, and the other cylindrical (2 cm diameter) to simulate an arboreal substrate. We instrumented a portion of each trackway to measure substrate reaction force from the limbs on the animals right side. The force pole was split so that the right side of the cylinder measured force while the left side was un-instrumented. Peak vertical force and vertical impulse were higher in forelimbs than hindlimbs. Peak vertical force was reduced on the arboreal track. These patterns are consistent with other non-primate mammals traveling on arboreal substrates. Furthermore, the reduction in peak vertical force on arboreal supports is consistent across mammals. If reducing branch oscillation is the reason for this behavior, then the adaptation probably occurred early in the mammalian radiation. Forelimbs were net braking and hindlimbs net propulsive; there were no differences in net fore–aft impulses between arboreal and terrestrial trackways. Laterally-directed substrate reaction impulse was higher on the arboreal supports. On the narrow arboreal cylinder, the chipmunks squeeze the branch between right and left hands or feet, providing a stable grip. This is consistent with the other non-primate mammals from which mediolateral forces were measured from individual limbs.

91.4 LAILVAUX, SP*; WILSON, R; KASUMOVIC, MM; 
LANDBERG, T*; WARKENTIN, K; WILINK, B; MOUNT, K; 
Hyla chrysocelis; n=344) and Cope's
Lammers13@csuohio.edu

115.4 LAILVAUX, SP*; WILSON, R; KASUMOVIC, MM; 
University of New Orleans, University of Queensland, University of New South Wales; slailvaux@gmail.com
Sex-specific aging of performance in male and female professional basketball players
The expression of phenotypic traits is often influenced by dynamic resource allocation trade-offs which, when occurring over the course of individual lifespans, may be manifest as trait aging. Although aging has been studied for a variety of traits that are closely tied to reproduction or reproductive effort, the aging of multiple traits related to fitness in other ways are less well understood. We took advantage of almost 30 years of data on human whole–organism performance in the National Basketball Association to examine trends of aging in performance traits related to speed, endurance and accuracy. Given that patterns of aging are known to differ between sexes in other animal species, we also analysed a smaller dataset on players in the Womens National Basketball Association to test for potential sex differences in the aging of comparable traits. Finally, we tested the hypothesis that different aspects of performance trade-off as individuals age. These data suggest that the aging of performance traits used in basketball is generally characterised by senescence in males, whereas females show evidence of terminal investment in performance.

8.5 LANDBERG, T*; WARKENTIN, K; WILINK, B; MOUNT, K; CLOUSE, E; WHITEMAN, H; Murray State University, Boston University of Costa Rica; tobias.landberg@gmail.com
Larval density affects jumping performance development during metamorphosis in two arboreal frogs
Metamorphosis is the rapid shift of an organism between niches. In amphibians, the transition between phenotypes adapted for aquatic larval and terrestrial adult environments is awkward and dangerous. Metamorphs are not well-adapted to life either in water or on land and therefore vulnerable to predation. In two separate outdoor mesocosm experiments in Panama and Kentucky we raised larval Red–Eyed treefrogs (RE; Agalychnis callidryas; n=344) and Cope's Grey tree frogs (CG; Hyla chrysocelis; n=176) under high, medium and low density conditions. To measure the carry-over effects of the larval stage on the development of jumping performance, each individual was placed at the center of a jumping arena marked with concentric circles (1.25cm and 1cm apart for RE and CG respectively) and stimulated to jump by applying gentle manual pressure to their rear ends. We analyzed the average of three jumps per individual and also measured snout–vent, limb (tibia/fibula), and tail lengths, mass, and stage of metamorphosis (Gosner stages). When analyzed separately using ANCOVA, both species showed similarly strong positive effects of snout–vent length and limb length on jumping performance and strong negative effects of tail length. Both species also showed snout–vent length by mass interactions and effects of density that interacted with morphological traits such as tail and limb length. Clear species effects are also apparent. While limited in scope, this simple two–species comparison reveals that during metamorphosis there is a highly dynamic relationship between body size metrics and jumping performance that is modified by the larval environment.

January 3–7, 2013, San Francisco, CA
Are invasive species stressful?
Invasive species represent a substantial threat to native species worldwide. Previous research has focused on population-level impacts on invasive species; however, the sub-lethal effects of invasive species on wild living vertebrates are relatively unknown. We conducted a series of laboratory and field surveys and manipulations to assess the impact of invasive red imported fire ants (Solenopsis invicta) on physiological stress levels (corticosterone, CORT) of native fire lizards (Scleropus undulatus). Field surveys revealed that lizards from sites that had been invaded by fire ants had higher levels of CORT than did those from uninvaded sites. Direct encounters with fire ants caused increased levels of CORT in lizards, suggesting that fire ants may be directly driving the pattern observed in the field. Longer-term exposure to fire ants in field enclosures resulted in lower baseline levels of CORT as compared to controls, however. This may be due to the stress associated with enclosures, in combination with fire ant exposure, pushing lizards into chronic stress and resulting in a breakdown in negative feedback controls of the stress response. These results underscore the challenges of assigning causation to studies of anthropogenically-induced stress, and the importance of considering the length, frequency, and magnitude of exposure to the stressor when examining its consequences.

Effects of scaling on bite force and suction index in the Eastern Hellbender (Cryptobranchus alleganiensis)
In 1950, AV Hill developed a series of predictions on how animal movements should scale with body size. Since this pivotal paper, many studies have been published regarding animal locomotion and scaling, but few have focused on feeding mechanisms and scaling. The hellbender (Cryptobranchus alleganiensis), is a salamander that grows over a large range of body sizes (18−74 cm TL) making it an ideal organism for examining scaling effects. Morphology can be expected to change as an organism grows larger, and because morphology and performance are closely linked, this morphological change can result in a change in feeding ability. C. alleganiensis are primarily aquatic salamanders and utilize both suction feeding and biting behaviors while feeding. We hypothesized that bite force would increase with positive allometry due to a possible dietary shift in diet during ontogeny in which larger Cryptobranchus favor crayfish, which are hard shelled and aggressive when confronted by a predator. Suction potential is hypothesized to scale with negative allometry because it would be advantageous for smaller animals to rely on suction due to consumption of smaller prey items and a lower absolute bite force. Preserved specimens (11.9−34.5 cm SVL) were used to investigate the effects of scaling on suction potential and bite force. Bite force was calculated by use of a 3D static equilibrium model and suction potential was calculated as suction index. Bite force scaled with positive allometry allowing the animals to bite relatively harder with increasing body size, yet suction index showed no effect of body size.

Evolution of parental care in Endomyarian sea anemones
In benthic, primarily sessile animals like sea anemones (Cnidaria: Actiniaria), the retention of developing offspring (brooding) can significantly impact the potential for dispersal and speciation when compared with a strategy of producing free-swimming larvae. Brooding internally is a pan-latitudeal phenomenon among anemones, but external brooding is restricted to cold-temperate and polar regions. The genus Epiactis contains twelve species that brood, nine of which do so externally and include representatives from the arctic and Antarctic. The life history and reproductive details of brooding species are tested by mitochondrial and nuclear DNA sequences. The relationships implied by the current classification of these diverse species are tested by mitochondrial and nuclear DNA sequences. The results inform our understanding of the evolution of brooding strategies within Endomyarian sea anemones.

Reproductive Timing and Connectivity in the Octocoral Pseudopterogorgia elisabethae
Reproductive synchrony is essential for species that cast gametes into the water column. While synchrony is necessary the basis for the day and time of day in which spawning occurs is less clear. Proximal mechanisms based on the intensity and spectral quality of light and endogenous clocks have been identified in some systems and the predictability of those cues may be the basis of selection for that timing. However, discussions of the timing of reproduction most commonly focus on factors such as production of gametes, successful fertilization, and dispersal and survival of the resultant larvae. The Caribbean octocoral Pseudopterogorgia elisabethae is a surface brooder which in The Bahamas spawns on a weak lunar cycle centered around the new moon in November and December. The larvae are negatively buoyant. A coupled bio-physical model, the Connectivity Modeling System, was used to simulate patterns of dispersal and larval retention during spawning months in The Bahamas from 2005-2008. The model was used to compare the hypothetical patterns of recruitment and dispersal that would occur with spawning across the entire lunar month. The timing of release across the lunar month affected neither overall settlement nor dispersal. Gonochoric species must exhibit some degree of synchrony in their spawning, but the basis for the timing of those events is not apparent. Bio-physical models provide a valuable tool in exploring the consequences of that timing on successful recruitment.
65.4 LATTIN, C. R.; ROMERO, L. M.; Tufts University; christine.lattin@tufts.edu

Seasonal variation in intracellular glucocorticoid receptor binding in the immune tissues of a wild bird
Glucocorticoids such as corticosterone (CORT) help wild animals regulate their metabolism and cope with environmental stressors, but they can also have immunosuppressive effects. Nelson and others have proposed that animals should have evolved mechanisms to increase immune function in reaction to seasonally-recurrent stressors that might otherwise compromise immunocompetence. We hypothesized that this could occur in part by seasonally downregulating immune tissue sensitivity to CORT by reducing concentration of CORT receptors. We captured wild house sparrows (Passer domesticus) in Massachusetts during 6 different life history stages: molt, early and late winter, pre-egg-laying, breeding and late breeding (n = 12 for each period). Mineralocorticoid receptors (MR) and glucocorticoid receptors (GR) were quantified in spleen and skin using radioligand binding assays, and spleen mass was also assessed. Spleen mass was greater in the late breeding period compared to both winter periods. MR binding in spleen was lower in late breeding compared to pre-laying. There were no seasonal patterns in GR binding in spleen, although overall, female sparrows showed greater GR binding than males. The spleen’s increased size and decreased sensitivity to CORT during the late breeding period could be related to the large influx of fledglings carrying potential pathogens into the house sparrow population at this time of year, or some other predictable life history event. There were no seasonal changes in MR or GR binding in back or belly skin. There is evidence of local downregulating immune tissue sensitivity to CORT by reducing concentration of CORT receptors. We captured wild house sparrows (Passer domesticus) in Massachusetts during 6 different life history stages: molt, early and late winter, pre-egg-laying, breeding and late breeding (n = 12 for each period). Mineralocorticoid receptors (MR) and glucocorticoid receptors (GR) were quantified in spleen and skin using radioligand binding assays, and spleen mass was also assessed. Spleen mass was greater in the late breeding period compared to both winter periods. MR binding in spleen was lower in late breeding compared to pre-laying. There were no seasonal patterns in GR binding in spleen, although overall, female sparrows showed greater GR binding than males. The spleen’s increased size and decreased sensitivity to CORT during the late breeding period could be related to the large influx of fledglings carrying potential pathogens into the house sparrow population at this time of year, or some other predictable life history event. There were no seasonal changes in MR or GR binding in back or belly skin. There is evidence of local production of glucocorticoids in mammalian skin, so skin receptors could be regulated locally. In any case, these results show that glucocorticoid receptors may be seasonally regulated in a tissue-specific manner.
Differential energy allocation for protein synthesis is genetically determined during marine larval development

Many studies have demonstrated that physiological processes change in response to environmental perturbations. Less is known, however, about the genetic bases that might establish physiological potential for adaptation. Genetically–determined variation in metabolic efficiency will likely impact the energetic scope for stress responses. The energetic requirement of protein synthesis is a major component of metabolism and has been reported to have a fixed cost in specific stages of animal development. We measured the cost of protein synthesis in larvae of a bivalve (Crassostrea gigas). Phenotypic contrasts in metabolic allocation to protein synthesis were studied at different temperatures and for different genotypes using crosses of pedigreed families. In wild–type “control” larvae, approximately 60% of available metabolic energy was allocated to protein synthesis. This metabolic allocation varied in contrasting phenotypes. In slower–growing larvae, up to 80% of metabolic rate was allocated to protein synthesis. In faster–growing larvae, this value was 2–fold lower, decreasing to ~40% of metabolic rate. The effect of environmental variation on metabolic allocation to protein synthesis was studied. Variation in temperature differentially changed rates (Q10) of respiration relative to protein synthesis. This differential response resulted in a lower percent of metabolic rate being used in respiration. Phenotypic variation in temperature allocation has implications for understanding the role of genotype–dependent responses to changing environmental conditions.

A two–element Hill–type model to predict muscle forces

Muscle models are commonly used to quantify and interpret musculoskeletal function. However, most previous models have assumed homogenous muscle types throughout the muscle with only a single contractile element, and validation of these models has been limited to in situ experiments that do not represent the muscles dynamic behavior in vivo. The purposes of this study were to develop and test a two–element Hill–type muscle model with independently activated slow and fast fibre contractile elements. The model was evaluated under in situ and in vivo conditions by comparing the predicted forces to directly measured forces. We recorded electromyography (EMG), tendon force, and sonomicrometry (fascicle length) data in the lateral and medial gastrocnemii of six goats during 1) in situ nerve stimulation experiments (goats walked, trotted, and galloped on a treadmill). Activation states of different motor units were quantified via wavelet analysis of the EMG data and tuned transfer functions. By comparing the coefficients of determination between the predicted and measured forces, we found that the two–element model predicted muscle forces with up to 7.6% and 8.2% greater accuracy than several commonly used, one–element models for the in situ and in vivo conditions, respectively. Root mean square errors were up to 21% lower for the two–element model than for the one–element models tested. This study offers a novel Hill–type muscle model, validated against in vivo forces, that can independently activate slow and fast contractile elements. This model has the potential to improve studies of locomotor tasks where recruitment patterns of different motor unit types differ. (NIH R01 AR055648)
Collision–based analysis of human walking versus running with and without additional vertical loading

Collision–based analysis quantifies geometrically and energetically the interaction between the center of mass (CoM) and the environment. This approach is applied here for the first time to bipedal locomotion. The force–velocity angle is the deviation from perpendicular of the angle between the instantaneous velocity and force vectors. If these vectors were to remain perpendicular throughout a cycle of locomotion, the force–velocity angle would be zero and the mechanical cost of transport would also be zero. Furthermore, the actual collision given by the instantaneous force–velocity angle can be expressed as a fraction of the potential collision given by the sum of instantaneous force and instantaneous velocity angles. This collision fraction would be zero in the previous idealized example, whereas a compliant spring–like inverted pendulum (SLIP) would produce a collision fraction of unity. During walking, the force–velocity angle was 0.08 radians on average throughout the stride. Collision fraction was 0.50 during walking, hence the dynamics of walking afforded on average a 50% reduction of the potential mechanical cost. During running, the force–velocity angle was 0.29 radians ~ 260% greater than that of walking. Consequently, collision fraction was 0.83 during running compared with 0.50 during walking and the dynamics of running reduced the potential mechanical cost by only 17%. We also simulated hyper–gravity by applying a constant downward vertical force equal to 35% body weight through a climbing harness. Despite a significant reduction in force due to this manipulation, the force–velocity angle and mechanical cost of transport remained statistically similar. Collision fractions show striking similarities between bipedal and quadrupedal walking as well as bipedal running and quadrupedal trotting.

Direct aerodynamic force measurements in avian flight support active upstroke hypothesis

Birds dynamically change the shape of their wing during the stroke, resulting in dramatic differences in wing shape between the up– and down–stroke. The wing is partially folded during the upstroke, which suggests that the upstroke of birds might not actively contribute to aerodynamic force production. This hypothesis is supported by the significant mass difference between the large pectorals muscle that powers the down–stroke and the much smaller supracoracoideus that drives the upstroke. Previous workers used indirect or incomplete techniques to measure the total force generated by bird wings ranging from muscle force, airflow, wing surface pressure, to detailed kinematics measurements coupled with bird mass–distribution models to derive net force through second derivatives. I will present a new validated and verified technique that measures aerodynamic force directly time–resolved. It does not require exposing animals to laser light, surgery or sacrificing animals to obtain mass distribution – and is more precisely verified and validated compared to previously published methods. Results obtained for 5 slowly flying lovebirds (Agapornis roseicollis) show that the upstroke of birds is surprisingly active during slow hovering flight. The method is scalable and can be applied to all flying animals from birds and bats to insects. Other potential applications could include swimming.

RNA–Seq uncovers extensive differential expression of metabolic genes in symbiotic versus aposymbiotic cnidarians

Aiptasia pallida, a small sea anemone that hosts dinoflagellates similar or identical to those found in reef–building corals, is being developed as a model system for study of the underlying molecular and cell biology of cnidian–dinoflagellate symbiosis. As a step to that end, we have sequenced and assembled the transcriptome of both aposymbiotic (dinoflagellate–free) and symbiotic Aiptasia using the Illumina sequencing platform. We have also developed a support vector machine learning algorithm to identify the organism of origin for each transcript, which was 97% accuracy on our test sets. A comparison of transcript levels revealed extensive differences between aposymbiotic and symbiotic animals, with many changes in the levels of transcripts encoding transporters and metabolic enzymes. We identified 38 classes of transporters that are differentially regulated, as well as transcripts from pathways involved fatty acid metabolism, sulfur–containing amino acid synthesis, and carbon–nitrogen metabolism.

Collision–based analysis of human walking versus running with and without additional vertical loading

Collision–based analysis quantifies geometrically and energetically the interaction between the center of mass (CoM) and the environment. This approach is applied here for the first time to bipedal locomotion. The force–velocity angle is the deviation from perpendicular of the angle between the instantaneous velocity and force vectors. If these vectors were to remain perpendicular throughout a cycle of locomotion, the force–velocity angle would be zero and the mechanical cost of transport would also be zero. Furthermore, the actual collision given by the instantaneous force–velocity angle can be expressed as a fraction of the potential collision given by the sum of instantaneous force and instantaneous velocity angles. This collision fraction would be zero in the previous idealized example, whereas a compliant spring–like inverted pendulum (SLIP) would produce a collision fraction of unity. During walking, the force–velocity angle was 0.08 radians on average throughout the stride. Collision fraction was 0.50 during walking, hence the dynamics of walking afforded on average a 50% reduction of the potential mechanical cost. During running, the force–velocity angle was 0.29 radians ~ 260% greater than that of walking. Consequently, collision fraction was 0.83 during running compared with 0.50 during walking and the dynamics of running reduced the potential mechanical cost by only 17%. We also simulated hyper–gravity by applying a constant downward vertical force equal to 35% body weight through a climbing harness. Despite a significant reduction in force due to this manipulation, the force–velocity angle and mechanical cost of transport remained statistically similar. Collision fractions show striking similarities between bipedal and quadrupedal walking as well as bipedal running and quadrupedal trotting.

Direct aerodynamic force measurements in avian flight support active upstroke hypothesis

Birds dynamically change the shape of their wing during the stroke, resulting in dramatic differences in wing shape between the up– and down–stroke. The wing is partially folded during the upstroke, which suggests that the upstroke of birds might not actively contribute to aerodynamic force production. This hypothesis is supported by the significant mass difference between the large pectorals muscle that powers the down–stroke and the much smaller supracoracoideus that drives the upstroke. Previous workers used indirect or incomplete techniques to measure the total force generated by bird wings ranging from muscle force, airflow, wing surface pressure, to detailed kinematics measurements coupled with bird mass–distribution models to derive net force through second derivatives. I will present a new validated and verified technique that measures aerodynamic force directly time–resolved. It does not require exposing animals to laser light, surgery or sacrificing animals to obtain mass distribution – and is more precisely verified and validated compared to previously published methods. Results obtained for 5 slowly flying lovebirds (Agapornis roseicollis) show that the upstroke of birds is surprisingly active during slow hovering flight. The method is scalable and can be applied to all flying animals from birds and bats to insects. Other potential applications could include swimming.

RNA–Seq uncovers extensive differential expression of metabolic genes in symbiotic versus aposymbiotic cnidarians

Aiptasia pallida, a small sea anemone that hosts dinoflagellates similar or identical to those found in reef–building corals, is being developed as a model system for study of the underlying molecular and cell biology of cnidian–dinoflagellate symbiosis. As a step to that end, we have sequenced and assembled the transcriptome of both aposymbiotic (dinoflagellate–free) and symbiotic Aiptasia using the Illumina sequencing platform. We have also developed a support vector machine learning algorithm to identify the organism of origin for each transcript, which was 97% accuracy on our test sets. A comparison of transcript levels revealed extensive differences between aposymbiotic and symbiotic animals, with many changes in the levels of transcripts encoding transporters and metabolic enzymes. We identified 38 classes of transporters that are differentially regulated, as well as transcripts from pathways involved fatty acid metabolism, sulfur–containing amino acid synthesis, and carbon–nitrogen metabolism.
105.3 LESSIOS, N.*; RUTOWSKI, RL; COHEN, JH; Arizona State University, University of Delaware; nicolas.lessios@asu.edu Visual ecology of two ephemeral pool crustaceans: phototaxis and light–orientation behavior of Triops (Branchiopoda: Notostraca) and Streptocephalus (Branchiopoda: Anostraca) Triops and Streptocephalus are branchiopod crustaceans that are often found within the same ephemeral habitat. Many species are mainly benthic foragers but also swim to the air–surface boundary in hypoxic conditions. They have two sessile compound eyes, as well as four median oecelli (naupliar eyes). Streptocephalus swim within the water column and are mainly suspension feeders. They have two stalked compound eyes and three median ocelli. Both lay desiccation–resistant eggs that also require light to resume development. This study aimed to characterize the light environment, phototactic response and dorsal light–orientation of Triops and Streptocephalus from the same pools (filled by monsoon rains in SE Arizona, USA). Irradiance measurements were taken over a depth gradient, and over time. Phototactic responses were observed within an acrylic chamber in the horizontal plane using a 500W Tungsten projector with interference filters to limit stimulus light to narrow bandwidths. Action spectra and phototaxis thresholds were obtained from ovisac–bearing adults for species of each genus, taken from the field and lab–reared. A distinct dorsal light reflex was observed by testing orientation in an acrylic chamber that simulates natural angular light distribution near the surface of an ephemeral pool. Statocysts have not been reported in branchiopod crustaceans, suggesting that light is a primary means of vertical orientation. Irradiance measurements were red–shifted with increasing depth, suggesting that vertical orientation could have a wavelength–specific component. Understanding the adaptive significance of eyes in Triops, Streptocephalus and other non–malacostracan crustaceans will help to infer transitions in eye evolution, and will illustrate the diversity of extant insect–crustacean sensory systems.

13.7 LEVESQUE, D.L.*; LOVEGROVE, B.G.; University of KwaZulu–Natal; danieell.levesque@gmail.com Reproduction and the evolution of endothermy–Increased homeothermy in reproductively active female Greater hedgehog tenrecs (Setifer setosus) There is increasing evidence that the level of homeothermy observed in most modern endotherms was derived from an ancestral heterothermic state. One of the hypotheses for why this occurred is that homeothermy allows for greater energetic output during reproduction (gestation and lactation) which has direct benefits to fitness. We tested this hypothesis by recording free–ranging body temperatures as well as resting metabolic rate over a range of ambient temperatures in both reproductive and non–reproductive Greater hedgehog tenrecs (Setifer setosus, Tenrecidae), a physiologically primitive mammal from Madagascar. During pregnancy and lactation there was an increase in metabolic rate and body temperature, accompanied by a decrease in body temperature variability. This indicates that homeothermy accompanies reproduction, and that benefits to parental care may have contributed to the evolution of endothermy in mammals.

SICB 2013 Annual Meeting Abstracts
January 3–7, 2013, San Francisco, CA
Models of population dynamics have been used to infer the impacts of climate change on the distributions of species. The predictions of these models depend greatly on parameters that characterize the phenotype and the environment. Throughout the range of _S. undulatus_*, behavioral thermoregulation buffers environmental extremes that would otherwise decrease performance. Under climate change, the frequency and magnitude of these extremes may increase while vegetation that provides shade may decrease. Moreover, competition during thermoregulation may entail costs that will reduce energy gain. When competing for space, individuals may be excluded from preferred thermal patches. By contrast, when competing for food, individuals may obtain less energy in preferred thermal patches. We used an individual–based model to study the outcomes of competition for shade and food in current and project climates. We also studied how changes in vegetation would affect the life-history and geographic range of _S. undulatus_. In the model, juveniles competed for food while adults competed for food and space. Introducing costs of competition while reducing vegetation enhances a lizard’s vulnerability to environmental extremes. Improving the realism behind individual–based thermoregulation models may increase our understanding of the complex interactions between climate, animals and vegetation cover.

Vestigial structures and rudiments provide windows into the evolutionary history of animals. Common examples are the transient limb buds or atavistic pelvic girdles found in tetrapods that have undergone limb loss. Vestiges of internal organs have received far less attention, and they have the potential to reveal how organ loss can occur in highly pleiotropic genetic networks and within tightly integrated organ systems. One example of organ loss is the loss of lungs in plethodontid salamanders (Caudata: Plethodontidae). We have discovered several atavistic features of lungless salamanders during both organogenesis and adulthood. Plethodontid embryos form a transient lung rudiment and express lung–specific transcripts in the absence of lungs. From one perspective, presence of the transient rudiment in embryos suggests conservation of inductive interactions that govern lung formation. In contrast, unanticipated expression patterns of lung–specific transcripts in lungless adults may be an example of evolutionary novelty. In light of our results, we reexamine the idea, proposed first in 1900, that the pharynx may play a significant respiratory role in lungless salamanders. By studying atavistic features of internal organs we have uncovered unexpected conservation of lung developmental–genetic programs following lung loss, as well as a novel expression pattern of a gene that may play important functional roles.
Rapid locomotion of a small lizard on sand requires fluid–like ground reaction forces

The desert–dwelling generalist zebra–tailed lizard (Callisaurus draconoides, ~10 cm, ~10 g) uses its large, elongate hind feet to rapidly run (~10 body length/s) on a diversity of substrates ranging from solid rocks to loose sand. In a previous study (Li et al., 2012; J. Exp. Biol.), visible light high speed video showed that during each step on granular media (sand), the lizards hind feet slapped on the surface at touchdown and penetrated into the substrate during stance. To explain the observed center–of–mass dynamics, the ground reaction force was assumed to be dominated by speed–independent frictional drag, and it was hypothesized that during stance the hind feet rotate subsurface in the vertical plane to generate lift. Here we use x–ray high speed video to obtain the lizards subsurface foot kinematics during running on granular media and confirm the hypothesized foot rotation. However, using granular impact force measurements, a recently developed tardodynamics of granular media, and the observed foot kinematics, we find that the combined impact force during initial foot touchdown and speed–independent frictional drag force during foot rotation only account for part of the required lift to support locomotion. This suggests that the rapid foot rotation further allows the lizard to utilize inertial forces from the local acceleration of the substrate (particles), analogous to the basilisk lizard which runs on the surface of water using hydrodynamic forces. Further evidence of inertial–force–dominated propulsion has been found in small lizard–sized robots (~10 cm, ~20 g) running on granular media (Qian et al., 2012, Robotics: Science & Systems).

Coordination between inertial and impulsive mechanisms during rapid turns in lizards.

Animals induce aerial reorientation by swinging appendages or bending torsos. Inertial torques also play a role during terrestrial locomotion by changing ground reaction forces. To examine the role of back bending and tail swinging during rapid terrestrial turns in lizards (Agama agama), we developed a six–link, planar, rigid–body dynamics model. Informed by the morphometrics of lizards, our model enabled estimation of total angular momentum about the animals center of mass (COM) from high–speed video kinematics. We derived the model to represent the expression for angular momentum about the COM of a chain of rigid bodies for an arbitrary number of segments. By writing angular momentum in terms of shape coordinates, we decomposed body velocity into two components revealing the extent to which shape change and impulsive force each contribute towards turning the body. During escape responses, lizards started from a standstill, executed a rapid turn and then ran away from the stimulus. Escape turns typically began with curling and pivoting about the hind legs, followed by an acceleration through the second stride in a maneuver analogous to a C–start in fish. Turns averaged 112° ± 86% of the turn was completed within the first stride. Our model predicts that 57% of the rotation during the first stride can be attributed to inertial torques due to curling. Systematically reducing the number of segments in the zero angular momentum model revealed that over 70% of the shape change induced rotation was due to the tail, with the remaining fraction due to back bending. During the second stride, angular velocity from impulsive ground contact countered the tendency towards backwards rotation when the tail uncurled as the animal transitioned to steady running.

Epigenetic variation: a mechanism to overcome reduced diversity in novel environments?

Many introduced populations experience reduced genetic diversity in their new areas, and how sparrow (Passer domesticus) in Kenya (one of the most recent vertebrate introductions) are no exception. Microsatellite data indicate that Kenyan house sparrows are less genetically diverse than other house sparrow populations, with higher relatedness and lower heterozygocity than expected by chance; further, data also suggest that the pattern of spread within Kenya has resulted in little to no admixture in some areas, while others are considerably admixed. Despite reduced genetic diversity, other research from our lab shows that behavioral, physiological, and immune differences exist among Kenya house sparrows dependent on time since colonization. Epigenetic mechanisms, such as methylation, sometimes inherited across generations, can control gene expression; epigenetic changes can be stable (determined either through inheritance or during early life) or labile within an individuals lifetime permitting enhanced responsiveness to the environment. We propose that in a novel or changing environment, more labile epigenetic marks might provide the variation necessary to facilitate short term adaptation in populations constrained by low genetic diversity. Here, we document high epigenetic variation (measured using MS–AFLP techniques) among Kenyan house sparrows in a group of cities with little or no genetic admixture. Our results suggest that DNA methylation might allow an enhanced response to new environments when genetic variation is limited, allowing individuals to rapidly adjust to novel habitats as their range expands.
1.10 LIGHTON, J*; BROWNELL, P; Sable Systems International, Oregon State University; Lighton@sablesys.com

Sticking necks out: A novel sesamoid bone in crocidurine shrews

Why do scorpions have low metabolic rates – if in fact they do? We undertook a rigorous study of scorpion metabolic rates, and found that their metabolic rates are in fact much lower than those of conventional arthropods such as insects and spiders. By analysis of covariance we found that their metabolic rates were only 25% of the expected values. The logical question to ask is why? If we consider that a scorpion, relative to other arthropods, requires only one quarter of the energy needed for basic metabolism, it follows that the remaining energy available to it can be channeled into somatic growth. It is our contention that this explains another widely debated area of scorpion biology: cannibalism. Because of their high trophic efficiency, scorpions can convert food into biomass extremely efficiently. Consequently their unusually high population densities result in high interaction rates. This leads in turn to cannibalism, it is additionally our contention that in effect, adult scorpions are using their young as extrasomatic energy storage reservoirs, further facilitated by the likelihood that juvenile scorpions occupy a predator niche distinct from that of adults. This is all a grotesque (to humans) side effect of their extreme metabolic efficiency. Ken Nagy has data on scorpion field metabolic rates, as yet unpublished, that I hope to analyze to add further light on this deliciously Gothic phenomenon.

4.2 LILLIE, MA*; PISCITELLI, MA; GOSLINE, JM; SHADWICK, RE; University of British Columbia; lille@zoology.ubc.ca

Structure and Mechanics of Fin Whale Arteries

The mechanical properties of mammalian arteries are linked to their function and generally reflect the loads they experience in vivo. Fin whales have a collagen rich and unusually incompliant thoracic aorta. We hypothesized that it might represent a mechanism to deal with changing transmural arterial pressures, which may vary if thoracic pressure differs from ambient. To test this hypothesis we examined the morphology and in vitro mechanical properties of a range of fin whale arteries exposed to both positive and negative transmural pressures. Arteries were tested under inflation for the pressure−stretch response and under deflation to determine the negative pressure required to cause buckling and collapse. We found abundant adventitial and perivascular collagen in all arteries. With the exception of the subclavian artery, the collagen became taut at very low pressures, stiffening the arteries circumferentially, allowing little compliance at low strains and stretches of only 10% at physiological pressures. Circumferential stiffness increased non-linearly with stretch. Under a negative transmural pressure some arteries collapsed readily while others did not, depending on their wall−thickness−to−radius ratio and on the stretch−dependent modulus. Wall bending was resisted by adventitial collagen, indicating a possible advantage of its recruitment at low stretches. However, adaptations to resist collapse under negative pressures and render diameter independent of pressure are of value only in a system where transmural arterial pressures vary. Whether these arterial properties provide evidence that transmural pressures do vary has yet to be established.

148.3 LIN, Y.F.*; LU, T.W.; DUMONT, E.R.; LEE, L.L.; University of Massachusetts, Amherst, National Taiwan University; yifen@bio.umass.edu

Sticking necks out: A novel sesamoid bone in crocidurine shrews

Sesamoid bones develop in tendons or other connective tissues that are subject to stress and are thought to function to diminish friction, distribute loads and aid muscle excursion. However, the effect of sesamoid bones on performance is rarely tested experimentally. In this study, we combined anatomical, behavioral and biomechanical analysis to examine the function of a newly−found sesamoid bone in axial skeleton of shrews. This novel sesamoid bone is embedded in the nuchal ligament over the 2nd thoracic vertebra (T2) in Crocidura shantungensis, C. tanakae, C. rapax, Suncus murinus, Scutisorex somereni (subfamily Crocidurinae) but not in Episoriculus fumidus, Chodsigoa sodalis, Anuorosorex yamashinai, and Blarina brevicauda (subfamily Soricinae). The T2 sesamoid bone supports the origin of splenius muscle, which attaches to the skull and controls head movement. Postural and behavioral analysis demonstrated that the necks of C. shantungensis and C. tanakae are significantly more flexible (p = 0.015), and they stick necks out more frequently (55 times/hour) during routine activities than does E. fumidus (16 times/hour). We modeled the mechanical advantage of splenius during postures used by the three species, and found that mechanical advantage was more than twice as high in Crocidura spp. We also modeled the mechanical advantage of splenius in Crocidura with and without the sesamoid bone, and found that the presence of the sesamoid bone greatly enhances mechanical advantage (p < 0.001). To our knowledge, this is the first sesamoid bone reported from the axial skeleton and we have demonstrated its function in neck extension among crocidurine shrews.

Problem and solution: Multiplexing distorts metabolic data

When measuring the metabolic rates of multiple animals, it is common practice to sample excreta air from each cage or chamber, and direct these air samples to a single gas analyzer chain. These samples are analyzed in succession (or multiplexed), interleaved with periodic analysis of incumbent air composition in order to compensate for analyzer drift and fluctuations in incumbent gas concentrations. Each such analysis takes a finite time, and must be completed before the next sample is analyzed. Thus an appreciable time the cycle time of the system will elapse between successive measurements of a given animal. The actual metabolic signal from each animal is therefore composed of a series metabolic snapshots which are separated by the cycle time of the system. This approach has the advantage of requiring only a single gas analyzer chain, and thus lowering costs. However, it suffers from two major disadvantages. First, rapidly changing metabolic signals may be missed, or, even worse, distorted by aliasing effects. Second, the nature of the sampled data depends critically on the moment at which the sampling cycle is initiated. Because the effect of starting time cannot be predicted because its effects lie along the path of times arrow, the results of any multiplexing system include a strong stochastic component, especially where the metabolic data are variable. As a result, resting energy expenditure (REE) is generally overestimated and activity EE (AEE) is underestimated. Using a Promethion multiple−animal, continuous (non−multiplexed) metabolic phenotyping system, we model a variety of multiplexed systems using continuous data from 16 mice, demonstrating and quantifying the serious errors that result from multiplexing.
107.1 LINDBERG, D.R.*; ERLANDSON, J.M.; GRAHAM, M.; BYRNES, J.; Univ. of California, Berkeley; University of Oregon, Moss Landing Marine Laboratories, University of Massachusetts, Boston; drl@berkeley.edu
Assembly and Anthropogenic Alterations in Kelp Forest Ecosystems: Historical Perspectives from Deep Time
We examine the assembly and anthropogenic alterations in 20 kelp forest ecosystems comprised of 15 kelps, and 18 key predators and 22 key herbivores. Our analyses found age and assembly differences between kelp forests in the northern and southern hemispheres. In the northern hemisphere predators are oldest in the lower latitudes. Herbivores are the youngest lineages typically originating after the kelp in the northern hemisphere. The sea otter is the youngest component in North Pacific kelp forests. In the southern hemisphere most herbivores and predators are substantially older than the kelp; the herbivores are the oldest lineages and have low latitude ancestry. Kelp forests in the North Atlantic show patterns similar to the North Pacific; most likely due to the role of recent migration of numerous kelp forest taxa from the North Pacific into the Atlantic. In addition to assembly differences, humans have differentially affected kelp forests. Some of the earliest evidence for intensive marine harvesting by humans is in kelp forest ecosystems, and human impacts on shellfish, apex predators, and other marine fauna affects trophic cascades as well as size class structure of key interacting taxa. These data and analyses from paleontological, geological, archaeological, and historical sources all demonstrate that coastal ecosystems are highly dynamic, and understanding the modern structure of these ecosystems requires deep paleontological and biogeographic perspectives that shed light on their assembly, as well as the long human history of interference and alteration of these systems.

93.2 LINQUIST, AG*; BURNETT, JB; HATLE, JD; University of North Florida; alicia@linquist.net
The effects of inhibited reproduction by ovariectomy or vitellogenin RNAi on the longevity of grasshoppers (Romalea microptera).
Reduced reproduction has been shown to increase lifespan in many animals, yet the mechanisms behind this trade-off are mostly unknown. A previous study has shown that in the lubber grasshopper, Romalea microptera, ovariectomized (OVX) individuals have a 30% increase in lifespan relative to controls (Sham). In a separate study, an increase in fat body mass and a halting of ovarian growth were seen upon reduction of vitellogenin transcript via RNAi (VgRNAi). The protein vitellogenin is a precursor to vitellin, which constitutes 90% of egg protein. These data suggest that VgRNAi may increase lifespan through the trade-off between reproduction and longevity. We used two injection control groups for the VgRNAi treatment, namely buffer injection or injection with RNAi against a 90kDa hexamerin storage protein (Hex90RNAi). In this study we have combined these manipulations to test lifespans upon: OVX & VgRNAi, OVX & Hex90RNAi, OVX & Buffer, Sham & VgRNAi, Sham & Hex90RNAi, and Sham & Buffer. By combining these treatments we wish to determine if they use separate mechanisms in lifespan extension. To date, 40 of the 151 individuals have died; OVX & Buffer, and OVX & VgRNAi individuals are currently showing the highest survival rates at 77% and 84% respectively, while OVX & Hex90RNAi and Sham & Hex90RNAi individuals exhibit the lowest survival rates at 68% and 56%. Consistent with previous data, OVX groups are showing a reduction in feeding rates (all P < 0.03). However, all other treatment groups show no differences among feeding rates. Survivorship and feeding rates will be discussed in terms of whether or not reduced feeding is consistently associated with life-extension via reduced reproduction. Funding provided by NIH 2R15AG028512-02A1 to JDH.

50.1 LINS, L.S.F.*; HO, S.Y.W.; WILSON, G.D.F.; I.O. N.; University of Sydney/Australian Museum, University of Sydney, Australian Museum; luana.lins@sydney.edu.au
Evidence for Permo-Triassic colonization of the deep sea by isopods
The deep sea is one of the largest ecosystems on Earth and is home to a highly diverse fauna, with polychaetes, molluscs, and peracarid crustaceans as dominant groups. A number of studies have proposed that this fauna did not survive the anoxic events that occurred during the Mesozoic Era. Accordingly, the modern fauna is thought to be relatively young, perhaps having colonized the deep sea after the Eocene/Oligocene boundary. To test this hypothesis, we performed phylogenetic analyses of nuclear ribosomal 18S and 28S and mitochondrial COI and 16S sequences from isopod crustaceans. Using a molecular clock calibrated with multiple isopod fossils, we estimated the timing of deep-sea colonization events by isopods. Our results show that some groups have an ancient origin in the deep sea, with the earliest estimated dates spanning 232–314 Myr ago. Therefore, anoxic events at the Permian-Triassic boundary and during the Mesozoic did not cause the extinction of all the deep-sea fauna; some species may have gone extinct while others survived and proliferated. The monophyly of the munnsapid radiation within the isopods suggests that the ancestors of this group evolved in the deep sea and did not move to shallow-water refugea during anoxic events.

S7–1.3 LIWANG, A.*; CHANG, Y.-G.; TSENG, R. D.; University of California, Merced; aliwang@ucmerced.edu
Rhythmic Ring-Ring Stacking Drives the Circadian Oscillator Clockwise
The oscillator of the circadian clock of cyanobacteria is composed of three proteins, KaiA, KaiB, and KaiC, which together generate a self-sustained circadian rhythm of phosphorylation of KaiC. The mechanism driving this oscillator, however, has remained elusive. We show that stacking interactions between the CI and CII rings of KaiC drive transitions from the phosphorylation-specific KaiC–KaiA interaction to the dephosphorylation-specific KaiC–KaiB interaction. We have identified the KaiB–binding site, which is on the CI domain. This site is hidden when CI domains are associated as a hexameric ring. We have shown that CI and CII rings exposes the KaiB–binding site. We have studied the role of a new regulatory protein, SaaA also binds to CI and competes with KaiB for binding, ring stacking probably regulates clock output. We demonstrate that ADP can expose the KaiB–binding site in the absence of ring stacking, providing an explanation for how it can reset the clock.
Coping with stress: the cellular maintenance of embryonic development

It is widely known that thermally variable environments adversely affect the physiologies of ectothermic organisms. However, it is a widely held tenet in the field of developmental biology that embryos are canalized to develop normally despite environmental perturbation. Are embryos actually vulnerable to thermal stress, and what structures and developmental processes are most vulnerable? Here we investigate the effects of heat stress on embryos of *Drosophila melanogaster* by measuring whole-organism survival, the cellular structures that mediate this stress, and the mechanisms that may buffer this stress during development. We find that exposure of early stage embryos to temperatures as low as 28°C causes a significant decrease in survival to adulthood. We also find that some genotypes are more tolerant to heat stress than others, suggesting that heat tolerance in embryos has a genetic basis. We discuss our progress using confocal fluorescence microscopy to assess the effects of heat stress on cellular structures that coordinate early development.

Leptin Function in Zebrafish

One of the most striking anatomical features of both cold adapted and cold acclimated fishes is their extreme adiposity, with lipid comprising up to 60% of the dry mass of Antarctic fishes. We are investigating the hormone leptin as an approach to understanding both the how and why of lipid accumulation in fish from cold environments. In mammals, leptin influences appetite, metabolic rate, bone growth and immune function. Because leptin has not been cloned in polar fishes, we used a genome-enabled model fish, the zebrafish (*Danio rerio*), to manipulate leptin expression in developing embryos. Reduced leptin expression (via morpholino oligonucleotides) results in poor yolk absorption, reduced sensory structures (eyes and ears), reduced otoliths, impaired cardiac function, and significantly reduced metabolic rate. A majority of these effects can be rescued with recombinant zebrafish leptin. Identical or similar effects were seen when we reduced expression of leptins in embryonic development in *Drosophila* melanogaster. We hypothesize that leptin signaling is disrupted in Antarctic fishes, leading to both lipid accumulation and reduced skeleton mineralization. Supported by NIH 1R15DK079282-01A1 to RLL, QL, and BB.

Synergistic Effects of Crude Oil and Corexit Dispersant on a Sponge Holobiont System

Following the worst oil spill in US history, Macondo crude oil from the Deepwater Horizon spill and Corexit 9500 dispersant were applied in experimental dosing of the common reef sponge, *Cinachyrella alloclada*, found in both the GOM and many Caribbean reefs. Physiological monitoring included baseline descriptions of a) tissue ultrastructure by electron microscopy, b) profiling the sponge microbiome and c) preliminary RNA-sequencing of the host transcriptome. SEM revealed novel (embryo-like) structures. Under closed aquaculture conditions, *C. alloclada* individuals (n > 75) were exposed to sublethal amounts of oil or 10:1 oil/Corexit mixtures for 1, 24 and 48 hours. Unexpectedly, microbial communities of the same sponge host diverge into two distinct 16S rRNA clades after PCA analysis. Additionally, over 8000 sponge transcriptome sequences were identified; with oil and/or Corexit dosed samples having increased expression of protein transport and breakdown, cytochrome P450, and DNA repair responses. Predicted metabolite turnover demonstrated differential metabolism of sulfur-containing and phenolic compounds.
Physiological conditioning hormesis improves post-irradiation organismal and sexual performance

Oxidative stress can be a strong mediator of organismal life history because oxidative stress damage extends from merely affecting survival and longevity into mating and reproduction. The organism must carefully balance their oxidative status with reproduction and performance in order to properly allocate limited resources. We previously showed that physiological conditioning hormesis can lower oxidative damage and improve organismal performance in fruit flies. When a hormetic treatment was applied to these flies early in life, it led to improved longevity and sexual performance later in life.

Here we investigated whether these hormetic effects were present in a moth species, *Cactoblastis cactorum*, which already has a short adult lifespan. These cactus moths must carefully allocate their resources between defense and reproduction as they do not have functional mouthparts as adults and therefore are unable to replenish spent nutrients. We hypothesized that an hour of anoxic conditioning will reduce post-irradiation oxidative damage and lead to an improvement in organismal performance. We found improvements in several metrics of organismal performance including longevity and flight. Male mating was also improved as the anoxia-irradiated males mated with unirradiated females more frequently in subsequent days than their normoxia-irradiated counterparts. The effects of anoxic conditioning hormone on longevity were restricted to males; however, irradiation extended female longevity due to sterility. Currently we are conducting field trials to monitor hormesis-based moth performance in a release-recapture experiment in our field site in central Florida.
91.1 LOWERY, M.S.*; KAUFMANN, R.; GRAY, S.; BOUDRIAS, M.; TALLEY, D.; University of San Diego; slowery@san diego.edu

Sustaining Science: Authentic Oceanographic Field Experience at the Core of Multiple Science Courses

For over a decade, students at the University of San Diego have participated in a 24 hour oceanographic cruise aboard the R/V Robert Gordon Sproul, a research vessel of the Scripps Institution of Oceanography. Using professional marine sampling gear, students collect data at sea and engage in a long-term multidisciplinary study of nearshore sites through inquiry–based learning. Multi-week analysis of hydrographic parameters including CTD depth profiles and water chemistry, sediments collected with grabs and multicorers, and plankton tows continues throughout the semester and is integrated into biological and geological oceanography courses. Students write several reports in the format appropriate for submission to a scientific journal or a poster presentation at a conference. Major studies among these courses include the following: variability in mineralogy, grain size distributions, and organic matter content; variation in the living (stained) and sub–fossil benthic foraminifera community; variation in plankton with distance from shore, hydrographic parameters, and time of day; variation in benthic macrofauna with sediment characteristics, oxygen concentration, and overlying plankton communities. Increasingly, students from additional courses such as analytical chemistry participate in the cruise, enhancing the scope of the project and underscoring the importance of collaboration in modern science. In fact, many students participate in the cruise in multiple years, gaining deeper insight from a different analytical focus on samples from the same sites. Emphasis on integration of physical and biological parameters provides a unique opportunity for students to make connections among disciplines and gain experience in executing field studies.

116.10 LUDEMAN, D.A.*; REIDENBACH, M.A.; LEYS, S.P.; University of Alberta, University of Virginia; sleys@ulb herta.ca

Testing passive flow and oxygen consumption in three temperate demosponges

Sponges are suspension feeders that process up to 900x their body volume in water daily, and extract bacteria with up to 98% efficiency. Because of their small incumbent openings and larger excurrent vents, sponges have long been considered to take advantage of passive flow to reduce the cost of pumping for filtration. But it is unclear whether all sponges a) need to use passive flow, and b) are able to use passive flow. Deep–water glass sponges live in nutrient–poor waters, and are found mainly in areas of constant high ambient flow. The cost of pumping (resistance through their filtration system) for glass sponges has been found to be nearly 30% of their metabolism, and the expense of pumping is reduced by taking advantage of current induced flow. Demosponges have much finer canal systems which should provide higher resistance than in glass sponges. We predict that passive flow does not occur in these sponges, but instead their food–rich temperate waters provide enough energy to sustain maintenance and growth despite the high cost of pumping. To determine this we studied excurrent filtration rates and oxygen consumption during ambient flows of 0–18cm/s in three temperate demosponges using particle imaging velocimetry, profiling acoustic Doppler velocimeters, and an oxygen optode. We found that excurrent velocities varied among the three demosponges, but none increased with increasing ambient flow. Oxygen drawdown was similar for all three sponges (0.1–0.4 mg/mL) and also did not increase with increased ambient flow, meaning no additional energy was expended to pump during increased ambient flow. Morphometric analysis of the aquiferous system will be used to model whether increased ambient currents can induce excurrent flows.

86.5 LYONS, S.M.*; BEAULIEU, M.; Sockman, K.W.; University of North Carolina, Chapel Hill; lyonsms@live.unc.edu

Differentiation and development of steroid–producing cells during ovarian differentiation in tilapia

Sex hormones produced from steroid–producing cells (SPCs) play important role in sexual phenomena such as sex differentiation, gonadal development, maturation, sexual behaviour etc. Differentiation and development of steroid–producing cells and folliculogenesis during ovarian differentiation in Nile tilapia Oreochromis niloticus were ultrastructurally and immunohistochemically. SPCs with ultrastructural features were first observed in the area near the blood vessels in the gonads of fish at 20–25 day after hatching (dah) around the time of ovarian differentiation. Ultrastructural results showed that differentiation and development of SPCs from undifferentiated to differentiated occurred in the area near blood vessels, indicating that it would be the original site of SPCs. The process of folliculogenesis was ultrastructurally observed. SPCs enclosed by fibroblastic cells invaded the interstitial areas among oocytes and some reached the surfaces of oocytes. The upper portions of these elongations opened and began to enclose the outer surfaces of developed oocytes to become thecal layer. Later, newly migrated SPCs reach the thecal layer to become thecal cells. These results indicate that steroid–producing thecal cells originate from the SPCs in the area near blood vessels. After thecal layer formation, an immunopositive reaction against P450 arom, but not against P450ccc or 3–HSD ABs, appeared first in the granulosa cells enclosing the vitellogenic oocytes at 100 dah. At this time, estrogen production in serum levels rapidly increased. At 7080 dah, IPCs invaded the interstitices among oocytes at the perinucleolar stage from the area near the blood vessels. IPCs increased in number in the interstitices among the previtellogenic oocytes, and some began to enclose the outer thecal layer of the previtellogenic oocytes at 90 dah. Thus, folliculogenesis could be essential for active production of estrogen in the ovary.

63.5 M.N., M; Univ. of the Ryukyus; masaru@lab.u−ryukyu.ac.jp

Recent song experience alters the threshold for female mate choice

The costs of mate choice can be high, and therefore females should adjust their threshold for choice according to the prevalence of high–quality males. In many songbird species, vocal signals advertise male quality. Because of a constraint of frequency bandwidth on syllable–production rate, trill performance (the capacity to produce high–bandwidth syllables at a rapid rate) is important role in sexual phenomena such as sex differentiation, gonadal development, maturation, sexual behaviour etc. Differentiation and development of steroid–producing cells and folliculogenesis during ovarian differentiation in Nile tilapia Oreochromis niloticus were ultrastructurally and immunohistochemically. SPCs with ultrastructural features were first observed in the area near the blood vessels in the gonads of fish at 20–25 day after hatching (dah) around the time of ovarian differentiation. Ultrastructural results showed that differentiation and development of SPCs from undifferentiated to differentiated occurred in the area near blood vessels, indicating that it would be the original site of SPCs. The process of folliculogenesis was ultrastructurally observed. SPCs enclosed by fibroblastic cells invaded the interstitial areas among oocytes and some reached the surfaces of oocytes. The upper portions of these elongations opened and began to enclose the outer surfaces of developed oocytes to become thecal layer. Later, newly migrated SPCs reach the thecal layer to become thecal cells. These results indicate that steroid–producing thecal cells originate from the SPCs in the area near blood vessels. After thecal layer formation, an immunopositive reaction against P450 arom, but not against P450ccc or 3–HSD ABs, appeared first in the granulosa cells enclosing the vitellogenic oocytes at 100 dah. At this time, estrogen production in serum levels rapidly increased. At 7080 dah, IPCs invaded the interstitices among oocytes at the perinucleolar stage from the area near the blood vessels. IPCs increased in number in the interstitices among the previtellogenic oocytes, and some began to enclose the outer thecal layer of the previtellogenic oocytes at 90 dah. Thus, folliculogen–esis could be essential for active production of estrogen in the ovary.

86.5 LYONS, S.M.*; BEAULIEU, M.; Sockman, K.W.; University of North Carolina, Chapel Hill; lyonsms@live.unc.edu

Recent song experience alters the threshold for female mate choice

The costs of mate choice can be high, and therefore females should adjust their threshold for choice according to the prevalence of high–quality males. In many songbird species, vocal signals advertise male quality. Because of a constraint of frequency bandwidth on syllable–production rate, trill performance (the capacity to produce high–bandwidth syllables at a rapid rate) is thought to provide females with information about male quality. Using Lincoln’s sparrows (Melospiza lincolnii), we manipulated the perceived availability of high–quality mates by exposing one group of females to songs with experimentally reduced trill performance and another to the same songs but with experimentally elevated trill performance. Initially, females in the high–performance group spent more time next to playback speakers than females in the low–performance group, demonstrating a preference based on trill performance previously shown for this species. This difference between groups disappeared by day six of song exposure as females habituated. We then exposed all females to a novel song with trills of intermediate performance. Females accustomed to low–performance trills spent more time near the playback speaker than females accustomed to high–performance trills. In a second round, we switched the females’ treatment assignments and consequently reversed individual females’ preferences for a new novel song of intermediate trill performance. These findings indicate that females have highly flexible song–choice criteria and adjust their standards for choosing a novel song based on the quality of songs they have most recently experienced. This would seem adaptive in species in which the prevalence of high–quality males fluctuates.
100.5 MACKEY, T.L.*; JAYNE, B.C.; University of Cincinnati, Ohio; mackey.93@gmail.com

Meal size affects the speed and modes of arboreal locomotion of the brown tree snake, Boiga irregularis

Snakes commonly consume large prey and move in diverse environments including trees. Unlike many terrestrial animals, snakes in trees commonly need to move on variable slopes and to balance on narrow, cylindrically shaped branches. Hence, we expected the arboreal locomotor performance of snakes to decrease substantially after consuming large meals that increased their weight and altered their distribution of mass. To test for this likely cost of consuming a large meal, we determined the maximal speed and mode of locomotion for 15 individuals of a highly arboreal snake species, Boiga irregularis, when they were unfed and within 48 hours of eating one or two mice, each of which averaged ~12% of the snakes mass. The snakes crawled on cylindrical surfaces 24 mm in diameter, with and without pegs and with the long axis oriented horizontally or inclined 45 degrees. On all surfaces with pegs the snakes performed lateral undulation, and their maximum speed decreased significantly with increased meal size. When moving up the inclined cylinders without pegs, all snakes used concertina locomotion, and the maximum speeds after eating two mice were significantly slower than those of the other two treatments. On the horizontal cylinders without pegs, 87% of the unfed snakes had continuous sliding contact while performing lateral undulation, whereas after eating two mice 80% of the snakes periodically stopped and gripped the cylinder while performing concertina locomotion at speeds that were not significantly different from those of the unfed snakes. Thus, although large meals were often detrimental to speed, the behavioral response of switching the mode of locomotion (concertina) prevented slipping and long-axis rolling which commonly occur on smooth cylindrical surfaces.

122.5 MACNEIL, K.E.A.*; PATEL, D; TAYLOR, V; BISHOP, C.D.; BURKE, R.D.; St. Francis–Xavier Univ., Antigonish, Nova Scotia, Univ. of Victoria, Victoria, B.C.; cbishop@sfu.ca

The canonical echinoid apical organ evolved from within the euechinoids: evidence from the cidaroid Eucidaris tribuloides

Descriptions of the structure and development of larval nervous systems of all five classes of echinoderms have recently been reported. Among these taxa, several differences in neural development and neuroanatomy support the hypothesis that echioid larvae are the most derived. The cidaroids, a major clade of echinoids, are considered to have several primitive features that more closely represent the common ancestor to all extant echinoids. To test whether cidaroid larvae also present features that are ancestral to the echinooids, and to clarify the timing and nature of changes from a dipleurula–like condition to the echinopluteus condition we have investigated the development and anatomy of the larval nervous system of Eucidaris tribuloides. Using markers for neurons (SynB, serotonin), ciliary band (Hnf6), oral ectoderm (Chd) and anterior ectoderm (Nk2.1), we describe the development and organization of the larval nervous system of E. tribuloides more closely resembles that of non–echinoid larvae. We also used LiCl and 1–azakenpaullone (GSK–3² inhibitors) and ZnSO4 (an animalizing agent) to test for the presence of known echinoid anterior–posterior axial signaling mechanisms. Collectively these neuroanatomical and experimental data have allowed us to conclude that the evolution of the canonical sea urchin apical organ was derived within the euechinoids about 250 million years ago.

123.4 MACLEAN, H J*; HIGGINS, J K; KINGSLOVER, J G; BUCKLEY, L B; University of North Carolina Chapel Hill; heidi.maclean@gmail.com

Responses to climate change: morphology and behavior, in Rocky Mountain Colias species

Colias butterflies have long been a model system for understanding thermoregulatory behavior and local adaptation to climate. What are the behavioral, ecological and evolutionary responses of Colias to recent climate changes in the Rocky Mountains? Colias use behavioral postures to maintain body temperatures required for flight (30–40ºC) and to avoid overheating, and adapt to local climate conditions via differences in melanin on the ventral hind wings and the thickness of thoracic setae (fur). Our recent reciprocal transplants with high–elevation Colias meadii and lower–elevation Colias eriphyle show that butterflies from higher elevations with darker wings and thicker setae tend to initiate morning flight sooner regardless of location. Moreover, the high–elevation phenotype experiences more frequent overheating and consequences thereof.

45.6 MADLIGER, C.L.*; LOVE, O.P.; University of Windsor, Ontario; madliger@uwindsor.ca

Fitness consequences of individual variation in stress hormone levels: why repeatability and plasticity of physiological traits matter

Physiological measures can provide insight into how organisms respond mechanistically to changes in their environment. Baseline stress hormones (glucocorticoids–GCs) have garnered considerable attention due to their essential role in the maintenance of energetic balance. However, to understand the evolutionary implications of individual variation in GCs and interpret concentrations as population–level indicators of environmental change, GCs must display two characteristics: i) high repeatability (consistency); ii) a predictable relationship with fitness. Results pertaining to both have been markedly mixed and investigations often lack a consideration of ecological or demographic contexts. We investigated the repeatability of baseline GCs in a free–living population of tree swallows (Tachycineta bicolor) within and across breeding seasons. In addition, we incorporated a feather–clipping manipulation to examine the influence of changing energetic cost (i.e., environmental quality). We find high repeatability within, but not across, years. However, our results indicate that this high within–season repeatability is dependent on age and energetic constraints, providing evidence for individually–specific plasticity in the response to environmental fluctuations. We further investigate whether plasticity in GCs represents a better predictor of fitness than static measures of the trait. Our results call to attention the importance of considering the contexts of environmental quality and age when examining repeatability, caution the interpretation of individual baseline GC levels as population–level indicators of environmental disturbance, and indicate that an investigation of plasticity can provide insight into the evolutionary consequences of variation in physiological traits.
Recently molecular phylogenetic analyses of the Asteroida have produced comprehensive and well-resolved trees for the Porciopulatacea and the Valvatacea, two of the most taxonomically diverse and ecologically important groups of asteroids. Although our work is broadly concerned with higher level phylogeny, we have focused on projects across a diversity of scales and herein we present highlights from our work that emphasize interests relevant to asteroid taxonomy on the west coast of North America. Analysis of the Asteridae shows it is composed of multiple clades corresponding to specific geographic/climatic regions. The boreal clade suggests endemism for asterids occurring on the west coast of N. America and adjoining regions, including familiar genera such as Pisaster and Leptasterias. Pycnopodia and the deep-sea Rathbunaster were supported as sister taxa which presents at least 2 different hypotheses of relationship. The goniatiderid Hippasteria includes 15 nominal species and is widely distributed in cold-water settings throughout the Atlantic, Pacific and southern Indian Ocean. In order to assess relationships and genetic structure, we sampled populations from throughout the world. Partial sequences for a mitochondrial gene (COI) and a nuclear gene (ATPS) were obtained for approximately 150 specimens. Our results showed little ongoing genetic exchange between trans-Arctic populations. Only 1 of 31 COI haplotypes and 4 of 16 ATPS haplotypes were shared among two or more ocean regions (N. Pacific, S. Pacific and N. Atlantic) despite sampling between 50–100 sequences per region. The widespread H. phrygiana identified from Atlantic, New Zealand, and Kerguelen Island populations and H. spinosa from the N. Pacific were all supported as one widely distributed global lineage, which has recently diversified.

While producing the highest power output of any vertebrate hummingbirds must also precisely modulate muscle activity to vary wingbeat kinematics and modulate lift production. However, wingbeat kinematics can vary in different ways depending on whether increased lift requirements are the result of lifting greater mass or hovering in lower density air mixtures. It is possible that differences in drag on wings due to variation in air density and viscosity may affect wingbeat kinematics that result from given muscle activation profiles. We evaluated whether wingbeat kinematics varied in response to increased lift requirements differently in hypodense hollux gas mixtures compared to when birds were hovering while lifting small weights and whether any differences were solely a function of muscle activation patterning. To do this, we simultaneously recorded wingbeat kinematics and electromyograms (EMGs) from the pectorals and supracoracoideus (responsible for the downstroke and upstroke, respectively) in ruby-throated hummingbirds (Archilochus colubris). As expected, increased lift was achieved through increases in stroke amplitude during both treatments. However, wingbeat frequency increased only during air density reduction trials. Overall relative EMG intensity was the best predictor of wingbeat frequency, stroke amplitude, and power output, while the relationship of kinematic features to spike number and EMG amplitude was less consistent. The relationship between EMG intensity and kinematics was quite similar between treatment types, suggesting wingbeat frequency did not change solely as a result of decreased drag on the wings. Despite the relative symmetry of the hovering downstroke and upstroke, the timing of activation and number of spikes per EMG burst were consistently different in the supracoracoideus compared to the pectoralis, likely reflecting differences in muscle morphology.

How seahorses hang on to their life
Tail prehension is a common, although poorly studied behavior among seahorses. We investigate this behavior in the potbellied seahorse, Hippocampus abdominalis, and the longsnout seahorse, H. reidi. Although both species are more distantly related and have significantly higher number of tail segments (45–48) than H. reidi (33–37). We hypothesize that the tail of H. abdominalis would be more flexible than the shorter tail of H. reidi. We compared 3D grasping kinematics on a 1 cm horizontal perch. In H. reidi the whole tail is involved in grasping with an increased range of motion towards the tip. In contrast, in H. abdominalis the most proximal third of the tail is not involved in grasping. Still, other kinematic variables are similar for the two species. In addition, both species show lateral bending during tail curling, an unexpected finding that might be important for modulation of grasping in substrates with different orientations, such as corals and seagrasses. Different artificial holdfasts were also tested in a preference study in H. abdominalis. Seahorses selected for vertical oriented, cylindrical and smooth holdfasts. However, color (sand vs. green) and holdfast diameter (1 and 1.5 cm) were neutrally selected for. Preference for vertical holdfasts is likely a result of the relative abundance of similarly oriented substrates in the wild, and thus selection for lateral bending may have played a role in prehensile tail evolution in seahorses. Pot-bellied seahorses also selected negatively for rough and blade like structures, which is likely explained by increased contact area in smooth, cylindrical surfaces which should facilitate attachment. Negative selection for rough structures seems to indicate that friction mechanisms are not predominant, while selection for higher contact area suggests reliance on wet adhesion and muscular grasping.

67.5 MAHLER, D. L.*; INGRAM, T.; REVELL, L. J.; LOSOS, J. B.; Univ. of California, Davis, Harvard Univ., U. Mass., Boston; lmahler@ucdavis.edu
Testing for exceptional among-island convergence in Greater Antillean Anolis: introduction and application of a novel comparative method
Replicated adaptive radiations suggest that diversification may be strongly deterministic, even over macroevolutionary timescales. However, species-rich clades are expected to produce many convergent species by chance alone, such that the convergence we observe among selected species pairs in replicated radiations may be nothing more than a by-product of extensive diversification. To date, there have been few studies of clade-wide convergence, and these have tended to examine only those species that are most obviously similar. It thus remains to be determined whether the similarity of these clades is due to deterministic adaptive convergence. To test this hypothesis, we investigated patterns of trait evolution in Greater Antillean Anolis lizards, a group famous for among-island convergence. We developed an Ornstein-Uhlenbeck method for detecting convergence of lineages to the same peaks on a shared macroevolutionary landscape, without requiring prior hypotheses about which lineages may have converged. This allows us to test for convergence in faunas with some non-convergent species, which must be ignored by alternative methods. Applying this method to island anoles, we found exceptional clade-wide convergence among islands, supporting the hypothesis that evolutionary radiation has determinedly produced similar outcomes in Anolis. Although not every species of Greater Antillean anole has a phenotypic match from another island, most do, and among-island convergence greatly exceeds expectations from evolutionary null models. Our results demonstrate that historical contingencies are insufficient to preclude the emergence of deterministic macroevolutionary patterns during diversification.

43.6 MAHLINGAM, S.; WELCH, KC*; University of Toronto, University of Toronto Scarborough; kmwelch@utoronto.ca
Neuromuscular modulation of kinematic performance in hovering hummingbirds
While producing the highest power output of any vertebrate hummingbirds must also precisely modulate muscle activity to vary wingbeat kinematics and modulate lift production. However, wingbeat kinematics can vary in different ways depending on whether increased lift requirements are the result of lifting greater mass or hovering in lower density air mixtures. It is possible that differences in drag on wings due to variation in air density and viscosity may affect wingbeat kinematics that result from given muscle activation profiles. We evaluated whether wingbeat kinematics varied in response to increased lift requirements differently in hypodense hollux gas mixtures compared to when birds were hovering while lifting small weights and whether any differences were solely a function of muscle activation patterning. To do this, we simultaneously recorded wingbeat kinematics and electromyograms (EMGs) from the pectorals and supracoracoideus (responsible for the downstroke and upstroke, respectively) in ruby-throated hummingbirds (Archilochus colubris). As expected, increased lift was achieved through increases in stroke amplitude during both treatments. However, wingbeat frequency increased only during air density reduction trials. Overall relative EMG intensity was the best predictor of wingbeat frequency, stroke amplitude, and power output, while the relationship of kinematic features to spike number and EMG amplitude was less consistent. The relationship between EMG intensity and kinematics was quite similar between treatment types, suggesting wingbeat frequency did not change solely as a result of decreased drag on the wings. Despite the relative symmetry of the hovering downstroke and upstroke, the timing of activation and number of spikes per EMG burst were consistently different in the supracoracoideus compared to the pectoralis, likely reflecting differences in muscle morphology.

47.4 MAIJA, A.*; COUTO, A.; ADRIAENS, D.; Ghent University, Belgium; anabelamia@gmail.com
How seahorses hang on to their life
Tail prehension is a common, although poorly studied behavior among seahorses. We investigate this behavior in the potbellied seahorse, Hippocampus abdominalis, and the longsnout seahorse, H. reidi. Although both species are more distantly related and have significantly higher number of tail segments (45–48) than H. reidi (33–37). We hypothesize that the tail of H. abdominalis would be more flexible than the shorter tail of H. reidi. We compared 3D grasping kinematics on a 1 cm horizontal perch. In H. reidi the whole tail is involved in grasping with an increased range of motion towards the tip. In contrast, in H. abdominalis the most proximal third of the tail is not involved in grasping. Still, other kinematic variables are similar for the two species. In addition, both species show lateral bending during tail curling, an unexpected finding that might be important for modulation of grasping in substrates with different orientations, such as corals and seagrasses. Different artificial holdfasts were also tested in a preference study in H. abdominalis. Seahorses selected for vertical oriented, cylindrical and smooth holdfasts. However, color (sand vs. green) and holdfast diameter (1 and 1.5 cm) were neutrally selected for. Preference for vertical holdfasts is likely a result of the relative abundance of similarly oriented substrates in the wild, and thus selection for lateral bending may have played a role in prehensile tail evolution in seahorses. Pot-bellied seahorses also selected negatively for rough and blade like structures, which is likely explained by increased contact area in smooth, cylindrical surfaces which should facilitate attachment. Negative selection for rough structures seems to indicate that friction mechanisms are not predominant, while selection for higher contact area suggests reliance on wet adhesion and muscular grasping.
Developmental physiology: Predicting "Winners and Losers" to environmental change

Physiological variance is clearly evident in the biological responses of conspecifics to changing environmental conditions. This variance cannot fully be attributed to experimental error—some of the variance likely represents underlying, genetically determined variation in physiology and therefore a potential basis for an evolutionary adaptive response to environmental change. Understanding how developmental stages function under various scenarios of environmental change will require a merging of physiological (phenotypic), genetic, and environmental information—i.e., Phenotype = Genotype + Environment + Genotype–by–Environment Interaction. Variance in components on the right hand side of this equation could give rise to adaptive phenotypes of "Winners" regarding tolerance to environmental change. Of particular importance is the genotype–by–environment component, which heretofore has received less attention in marine developmental biology but bridges genetics and physiology to provide new insights into adaptive mechanisms. We have studied genotype–by–environment interactions in larval stages of the Pacific oyster Crassostrea gigas. This species has genetic and genomic resources that are unparalleled for most marine animals and permit cross-generational experiments because of the availability of purebred lines. Contrasting larval phenotypes have been used to study the physiological, biochemical, and environmental gene–expression bases of potential "Winners and Losers." Such experimental approaches offer the potential of improving predictions through a mechanistic understanding of the physiological and genetic bases of biological adaptation to changing environmental conditions.

The Effects of Climate Change on the Immunocompetence of the Caribbean Sea Fan Coral

Effects of climate change have been shown to negatively affect a multitude of organisms causing increases in disease prevalence, morbidity, and ultimately changes to the biodiversity and structure of ecosystems. This is especially true for coral reefs. We hypothesize that the effects of climate change, such as elevated sea surface temperatures are compromising the immunity of corals leading to disease outbreaks. In this study, we examined the immunocompetence of the Caribbean Sea fan coral, Gorgonia ventralina under natural and experimental temperature stress. Naturally stressed sea fans were collected during an abnormally warm year (2010) where temperatures remained elevated (>29°C) for 12 weeks or longer. To examine short term thermal stress, sea fans were also exposed to elevated temperatures in the lab for a period of 18 days. Immune responses were quantified using a suite of biochemical assays examining antioxidant, antimicrobial, protease inhibitor and melanization activity of crude protein extracts. Both experiments exhibited significant decreases in the various measures of immunity with the natural temperature stress having the most dramatic effect. Considering the increase in disease prevalence of corals, the data suggest that elevated sea surface temperatures are affecting the immunocompetence in corals that may lead to disease susceptibility. With the current trends of climate change, where temperatures are expected to continue increasing, incidences of coral disease and mortality rates are likely to continue increasing. It is imperative to continue to look at effects of climate change on corals in order to develop mitigation and management tools for coral reef conservation.
Differentiating slip perturbation recoveries from falls in bipedally–running lizards.

In nature, animals often encounter unsteady or unpredictable surfaces that they must counteract to maintain locomotor stability. Yet, the recovery mechanisms aiding restabilization remain under studied. The goal of this study was to describe the recovery kinematics that lead to successful slip recoveries compared to falls in the bipedally–running frilled lizard (Chlamydosaurus kingii). Lizards were run along a 2.5 m trackway and filmed with a six–camera auto tracking system (Motion Analysis Corp). Each lizard was run on a full–traction surface, as well as one in which we embedded an obscured low–friction surface. Trials were divided into three groups for analysis: steady–state unperturbed, successful recoveries, and falls. When lizards successfully recovered from a slip, perturbation compensation occurred rapidly and locomotor kinematics returned to unperturbed, steady–state values within one stride. Successful recoveries differ from falls by the proportion of ground contact time (duty factor), absolute slip surface contact time, and total displacement of the perturbed foot. In all perturbed trials, stride frequency increased relative to steady–state running, independent of the outcome. When lizards fell, the duty factor of the unperturbed foot (0.50 ± 0.058 SD) was significantly greater than that during steady–state (0.43 ± 0.10) or recovery (0.34 ± 0.19) trials. However, the duty factor of the perturbed foot was greater during falls (0.41 ± 0.12) than recoveries (0.32 ± 0.07) but no different than steady–state trials. Total translation distance of the perturbed foot appears to be an important factor determining perturbation outcome as falls coincided with the perturbed foot slipping significantly further (56.89 ± 4.82 mm) and for longer (0.067 ± 0.026 s) than in recovery trials (38.55 ± 16.48 mm; 0.053 ± 0.010 s).

Understanding the morphological characteristics of an organism opens the possibility of making future morphofunctional and systematic studies. The aim of the present study is to define the general morphology of the foot–leg mechanical unit of the lizard Anolis antonii (Boulenger, 1908) (Squamata, Polychrotidae). Understanding the morphological characteristics of an organism opens the possibility of making future morphofunctional and systematic studies. The aim of the present study is to define the general morphology of the foot–leg mechanical unit of the lizard Anolis antonii (Boulenger, 1908). This was done by the observation of the leg and foot muscles with a stereoscope, their description by dissecting them, their identification, and their comparison with the available literature. We identify foot and leg muscles as well as the ones belonging to the foot–leg mechanical unit, and describe two new muscles which we name: m. extensor digitorum brevis profundus IV and m. extensor digitorum brevis profundus IV–V. Our observations and comparisons indicate several differences between the descriptions of the literature and the ones suggested in the present paper. This new information may have great potential systematic value, since it can be considered as characters for future cladistic studies to assess whether they are autapomorphies or apomorphies, and may serve as a starting point in biomechanic studies.

Interspecific brood parasitism in birds negatively affects parental fitness by reducing current reproductive success, but its impact on future reproduction has been rarely tested. Glucocorticoid stress hormones often mediate the trade–off between current and future reproduction by mobilizing resources towards parental care or self–maintenance. To determine if brood parasitism alters the trade–off between current and future reproduction, we measured parental care behavior and glucocorticoid levels in nestlings in the Neotropical host–parasite system of the striped cuckoo (Tapera naevia excellens) and the rufous and white wren (Thryophillus rufalus) during three reproductive stages: incubation, nestling, and fledgling. We found that foster parents of cuckoo chicks had significantly higher levels of stress–induced, but not baseline, corticosterone during the post–fledgling stage. Higher maximal levels of stress–induced corticosterone were associated with an increase in parental care. Foster parents delayed re–nesting due to prolonged care of a cuckoo chick and were less likely to return to nest the year following a parasitism event. Together, these results suggest that foster parents express higher parental investment in cuckoo chicks than their own chicks, mediated by corticosterone, and that parasitism reduces opportunity for future reproduction.
13.11 MARSHALL, H.M.*; BRILL, R.; BUSHNELL, P.; SKOMAL, G.; BERNAL, D.; University of Massachusetts Dartmouth, Virginia Institute of Marine Science/NOAA, Indiana University South Bend, Massachusetts Division of Marine Fisheries; hmarshall@umassd.edu

Comparison of fishing-induced stress response and post-release mortality between sandbar (Carcharhinus plumbeus) and dusky (Carcharhinus obscurus) sharks

In recent years, exploitation of many shark species has incited management organizations to revise commercial fisheries management plans (FMPs) with the hopes of conserving shark populations. Specifically in the western Atlantic, amendments to the Consolidated Highly Migratory Species FMP demand the post-capture release of several coastal species, including the sandbar (Carcharhinus plumbeus) and dusky (C. obscurus) sharks (Family Carcharhinidae). Although these FMPs are designed to conserve populations, they result in an increased number of sandbar and dusky sharks being released after capture. Research on fishing-related stress indicates that the survival of released fish after capture is not well understood. This study investigates stress response in sandbar and dusky sharks after longline capture, and subsequent post-release mortality. Pop-up Satellite Archival Tags were used to determine post-release survival of sharks after capture on longline gear, and blood stress parameters (electrolytes and metabolites) were collected from each fish. Post-release mortality appears to occur more often, after shorter capture times, in the dusky versus the sandbar shark. In addition, at-vessel mortality occurs after ~3 hours on the longline in the dusky shark. Regression analysis reveals a significant (p<0.05) correlation of increasing levels of sodium, potassium, glucose, and lactate with soak time in the dusky shark. Regression analysis reveals a significant (p<0.05) correlation of increasing levels of sodium, potassium, glucose, and lactate with soak time in the dusky shark. However, the regression analysis suggests that this correlation is not present in the sandbar shark. Post-release mortality appears to occur more often, after shorter capture times, in the dusky versus the sandbar shark. In addition, at-vessel mortality occurs after ~3 hours on the longline in the dusky shark. Regression analysis reveals a significant (p<0.05) correlation of increasing levels of sodium, potassium, glucose, and lactate with soak time in the dusky shark. Regression analysis reveals a significant (p<0.05) correlation of increasing levels of sodium, potassium, glucose, and lactate with soak time in the dusky shark. However, the regression analysis suggests that this correlation is not present in the sandbar shark. Post-release mortality appears to occur more often, after shorter capture times, in the dusky versus the sandbar shark. In addition, at-vessel mortality occurs after ~3 hours on the longline in the dusky shark. Regression analysis reveals a significant (p<0.05) correlation of increasing levels of sodium, potassium, glucose, and lactate with soak time in the dusky shark. Regression analysis reveals a significant (p<0.05) correlation of increasing levels of sodium, potassium, glucose, and lactate with soak time in the dusky shark. However, the regression analysis suggests that this correlation is not present in the sandbar shark. Post-release mortality appears to occur more often, after shorter capture times, in the dusky versus the sandbar shark. In addition, at-vessel mortality occurs after ~3 hours on the longline in the dusky shark. Regression analysis reveals a significant (p<0.05) correlation of increasing levels of sodium, potassium, glucose, and lactate with soak time in the dusky shark. Regression analysis reveals a significant (p<0.05) correlation of increasing levels of sodium, potassium, glucose, and lactate with soak time in the dusky shark. However, the regression analysis suggests that this correlation is not present in the sandbar shark.

104.4 MARSHALL, K.E.*; THOMAS, R.H.; ROXIN, A.; CHEN, E.K.Y.; BROWN, J.C.L.; GILLIES, E.R.; SINCLAIR, B.J.; University of Western Ontario, University of Toronto; kmmarsh@uwo.ca

The goldenrod gall flys liquid little secret: 3-acetyl-1,2-diacyl-sn-glycerols are associated with natural survival of intracellular freezing in Eurosta solidaginis

The fat body cells of the goldenrod gall fly Eurosta solidaginis have the unusual ability to naturally withstand intracellular ice formation (IIF). To date, no unique compounds associated with natural IIF survival have been identified for any animal. Here we show that E. solidaginis seasonally synthesizes an unusual class of neutral lipid, 3-acetyl-1,2-diacyl-sn-glycerols (acTAGs). acTAGs are accumulated in preparation for winter and at their peak concentration comprise over 36% of the insects neutral lipid pool while long-chain TAGs (IcTAGs) comprise only 17% percent (by molarity). The acTAGs have a low melting point (~17 °C), and are therefore expected to remain liquid at temperatures where the cells freeze. These acTAGs are not found in other cold tolerant insects, and are not present in the Solidago spp. host or other members of the gall community. In addition, the amount of acTAGs increases when repeatedly frozen, and when added to saline, acTAGs lower the melting point of the resulting emulsion. We suggest these properties are consistent with a role as a candidate molecule for IIF survival.

S3–1.5 MARTIN, K.L.*; MORAVEK, C.L.; CARTER, A.L.; Pepperdine Univ., Pepperdine Univ., Charleston Southern Univ.; kmartin@pepperdine.edu

Brave New Propagules: Terrestrial Embryos of Aquatic Fish

Species within many lineages of teleost fishes reproduce terrestrially, despite lacking the key evolutionary innovation of the amniotic egg. In contrast with shelled eggs of reptiles and birds, the anamniotic eggs that contains an embryo of a fish or amphibian is typically much smaller and enclosed in relatively simple membranes. Anamniotic embryo incubation duration is usually brief and hatchlings arrive as larvae rather than juveniles. Advantages of terrestrial incubation include the increased availability of warmer temperatures and higher oxygen levels that may speed development, while disadvantages include the increased availability of warmer temperatures and higher oxygen levels that may speed development, while disadvantages include desiccation, exposure to novel predators and pathogens, and the risk of hatching into a hostile habitat. In most species of teleosts maternal investment for a fish embryo in a terrestrial environment is challenging, and most teleost examples occur in the marine intertidal zone, with its predictable ebbing and flooding of seawater. Examples of terrestrial breeding freshwater teleosts and their habitats will be provided for contrast and comparison with examples of terrestrial incubation among amphibian taxa. The selection pressures leading to successful nesting and early development out of water for fish and amphibians may provide numerous alternate routes to vertebrate land invasion, even if only for the early portion of the life cycle.

1.6 MARTIN, K.L.; Pepperdine Univ.; kmartin@pepperdine.edu

Seas of Sand, From Desert to Beach: Sand as a Nesting Habitat for Fish, Turtles, and Tortoises

Deserts and beaches are both characterized by sandy substrates, abundant sunshine, minimal fresh water, and desiccating terrestrial conditions. Surface substrates in these highly variable habitats experience rapid diurnal changes in temperatures, a propensity for wind transport, and a dearth of attached plants. In spite of the harsh physical conditions, beaches and deserts both support diverse forms of vertebrate life at all stages of growth and development. In these highly variable ecosystems, nesting within or beneath the surface of the substrate of beach or desert sand may provide the embryos with protection, thermal stability, and other potentially beneficial conditions. However, survival is constrained by temperature-driven sex determination, and threats such as vulnerability to predators, desiccation, pathogens, and the potential for flooding and oxygen deficit. Some ecological advantages and consequences of egg burial in beaches and desert sand will be compared for example species of marine fish, sea turtles, and desert tortoises.
14.5 MARTIN, CH*; WAINWRIGHT, PC; University of California, Davis; chmartin@ucdavis.edu

Multiple fitness peaks on the adaptive landscape drive the evolution of novel ecological niches within a recent sympatric adaptive radiation of Cyprinodon pupfishes

Multiple fitness peaks corresponding to ecological opportunities are thought to be the major force driving niche diversification during adaptive radiation. Here we measured a large portion of the adaptive landscape within a 10,000–year-old radiation of Cyprinodon pupfishes endemic to San Salvador Island, Bahamas from the growth and survival of 1,865 F2 hybrids placed in field enclosures in two lakes. We found that hybrid phenotypes corresponding to the abundant generalist species sit atop an isolated fitness peak separated by a valley from a higher fitness peak corresponding to the hard-shelled prey specialist species. We confirmed experimentally the presence of multiple fitness peaks in sympatry driven by increased competition in high-density field enclosures, strongly supporting the early burst model of adaptive radiation. Furthermore, this striking multi-peak landscape explains both the rarity of trophic specialists across the Caribbean due to stabilizing selection on generalist founding populations and the rapid increase in morphological diversification rates of specialists due to the higher fitness of the specialist peak.

107.4 MARTIN, RA*; LANGERHANS, RB; NIMBioS, North Carolina State Univ.; ryanandrewmartin@gmail.com

Piscivorous fish in a fishless environment: phenotypic differentiation of bigmouth sleepers in Bahamas blue holes

Ecology's role in driving predictable differentiation between populations is a central topic in evolutionary ecology. Based on a priori knowledge of theory and natural history, just how predictable are organisms responses during times of ecological change? Here, we use the model system of inland blue holes in the Bahamas to test the predictability of dietary, demographic, and phenotypic differentiation following the invasion of an otherwise fishless environment by a piscivorous fish, the bigmouth sleeper (Gobiomorus dormitor). In its ancestral environment of coastal streams and lakes, the bigmouth sleeper is a benthic, ambush predator, feeding primarily on fish and large invertebrates. On Andros Island, The Bahamas, bigmouth sleepers have colonized numerous land-locked blue holes. These isolated blue holes harbor depauperate fish communities, with bigmouth sleeper often co-occurring with only one other fish species, the small, livebearing Bahamas mosquitofish (Gambusia holbrooki). However, bigmouth sleepers inhabit two isolated blue holes in which no other fish species are present. Without any potential fish prey (other than cannibalism), how has their diet diverged? And has this shift in ecological environment driven changes in population and phenotypic characters, such as density, habitat use, size structure, sex ratio, feeding performance, and locomotor and trophic morphology? We first use existing ecological and biomechanical knowledge to build a set of predictions for ecological differentiation, and test them using comparative and experimental approaches. We find that bigmouth sleepers have diverged in many ways between populations with and without potential fish prey, mostly (but not always) in manners consistent with our predictions.

127.2 MARTIN, P; Humboldt University, Berlin;
Peer.Martin@alumni.hu-berlin.de

The relevance of parthenogenesis to the role of Marmorkrebs as a model organism and potential invader

Animals as model organisms are indispensable tools for life sciences and thus a series of species have been firmly established in research for this purpose. Nevertheless, genetic differences between individuals often bias the results and therefore genetically identical organisms are more and more in demand as laboratory objects. Here, the use of asexual organisms would provide an opportunity. However, parthenogenetic animals are relatively rare, in particular those that combine a high reproduction rate and a complex organization. In addition, not all forms of parthenogenesis lead to genetically identical progeny. In the amictic mode, for example, meiosis occurs and diplody is then restored by fusion between two of the resulting haploid nuclei. Thus, the genetic composition of automatically produced progeny is not absolutely identical because of recombination by crossing over during the reduction division. In contrast, Marmorkrebs propagate apomictically, i.e. meiosis is completely suppressed. The progeny develop directly from unreduced oocytes and therefore all offspring are true clones of their mother. In addition, Marmorkrebs are very robust and have a high reproductive rate and so they are very suitable as experimental animals for a number of questions. However, the advantages of apomixis for its use as a model organism are counter-balanced by the fact that this reproduction mode also makes Marmorkrebs an effective invader. Due to the parthenogenesis only a single individual is able to found a new population. Furthermore, the apomixes protects the clones from the effects of low population size such as bottlenecks, inbreeding depression and genetic drift and this enables the Marmorkrebs to also conquer areas which provide less favourable living conditions.

SS5-2.2 MARUSKA, K.P.*; FERNALD, R.D.; Baton Rouge, Stanford Univ, CA; kmaruska@lsu.edu

Social regulation of male reproductive plasticity in an African cichlid fish

Social interactions and position in a dominance hierarchy can have profound effects on reproductive behavior and physiology, requiring animals to constantly integrate environmental information with their internal physiological state. How is salient information from an animals dynamic social environment transformed into adaptive behavioral, physiological, and molecular–level changes? The African cichlid fish Astatotilapia burtoni is an ideally–suited model to examine socially–controlled reproductive plasticity because activity of the male reproductive axis is linked to social status. Males form hierarchies where a small percentage of brightly colored dominant individuals have an active reproductive axis, defend territories, and spawn with females, while the remaining males are subordinate, drably colored, do not hold a territory, and have a suppressed reproductive axis with minimal spawning opportunities. These social phenotypes are plastic and reversible, meaning that individual males may switch between dominant and subordinate status multiple times within a lifetime. Here we review the rapid and remarkable plasticity that occurs along the reproductive axis when males change status, a transition that has important fitness implications. Transformations occur in the brain, pituitary, bloodstream, and testes over short time scales, which are evident in overt behavioral modifications as well as physiological, cellular, and molecular level changes that impact reproductive capacity. These widespread changes triggered by a switch in rank highlight the significance of external social information in shaping internal physiology, and emphasize the importance of the vertebrate reproductive system as a substrate for phenotypic plasticity to promote survival and fitness in a dynamic social and physical environment.

January 3–7, 2013, San Francisco, CA
Sidewing snakes on sand

Desert snakes such as the sidewinder rattlesnake *Crotalus cerastes* propel themselves over sand using sidewinding, a mode of locomotion relying upon traveling waves. While the kinematics of sidewinding on hard ground have previously been studied, movement on more natural substrates such as granular media remain poorly understood. In this experimental study, we collected animals near Yuma, Arizona, and in the laboratory we use 3-D high speed video to characterize the motion of sidewinders (N=4, mass=110 ± 53 grams) as they move on a granular bed composed of natural desert sand. We used a tiltable air-fluidized bed trackway to challenge the animals on different compactions and inclination angles of the granular media. We find that speed decreases with increasing inclination angle while wave frequency remains constant at 0.57 ± 0.01 Hz. Moreover, body speed also increases with increasing body length. We evaluate the ability of an elliptical helix model [Hatton & Choset, 2010] to describe the sidewinders’ body configurations.

**Patterns of cell cycle arrest during formation of the nematode uterine–vulval connection**

During development, transcription factors program the differentiation of discrete cell types. The adoption of a differentiated fate is often accompanied by cell cycle arrest. Many of these differentiated cells are then required to execute morphogenetic behaviors. Data suggests that the complex cell biological behaviors that occur during morphogenesis (e.g., EMT and convergent extension) also require a prolonged cell cycle arrest. We are examining the transcriptional control of cell cycle arrest during nematode larval development. The anchor cell (AC), a specialized gonadal cell, invades through the underlying basement membranes (BM) to connect the developing uterine and vulval tissues. After initiating the breach, the AC is no longer required to expand the BM gap. Instead, the BM breach is widened through BM sliding and is stabilized by the innermost secondary fated vulval precursor cell, vulD. We are dissecting AC invasion and vulval morphogenesis in *C. elegans* and related nematode species as a model to understand how morphogenetic mechanisms evolve. We performed a tissue-specific RNAi screen targeting ~700 *C. elegans* transcription factors, identifying the TLX ortholog NHR−67 as a new regulator of invasion. Strikingly, loss of NHR−67 results in multiple mitotic ACs that fail to invade. Prevention of cell cycle progression in NHR−67-depleted animals rescues the invasion defect, demonstrating that cell cycle arrest is required for invasion. This requirement for cell cycle arrest may also hold true during BM stabilization. Similar to *C. elegans*, in all other nematode species we have examined, the BM appears stabilized over the post-mitotic vulD cell. Together our molecular, cell biological, developmental and evolutionary studies indicate a requirement for the precise transcriptional control of a genetic program that links cell cycle arrest to both BM invasion and stabilization.

**Gene expression signatures of local adaptation in reef−building corals**

The role of algal symbionts (*Symbiodinium* sp.) in adaptation of corals to local environmental conditions is well established, but little is known about the complement of mechanisms employed by the coral host. We present two experiments involving RNA-seq profiling of host gene expression in corals originating from different thermal environments. In the first experiment (*Porites astreoides*, Florida Keys), corals from inshore and offshore reefs were kept in common garden conditions involving long-term heat stress for 6 weeks. In the second experiment (*Acropora millepora*, Great Barrier Reef), corals were reciprocally transplanted between their native locations separated by about 1000 kilometers along the length of GBR, for 6 months. Two particularly interesting themes emerge from the functional analysis of hundreds of genes that were differentially regulated with respect to the site of origin or, in the second experiment, the site of outplanting. There is an effect on genes processing carbonate and bicarbonate ions and putatively involved in calcification. In addition, many genes involved in lipid transport and metabolism become regulated. It is tempting to speculate that these findings have implications for the evolution of larval form. A recent study of the red drum (*Sciaenops ocellatus*) has revealed a surprising amount of undescribed species—level diversity in a region where nemerteans are thought to be well characterized. We found many species new to science, and while some are commercially important crab species, we also identified hoplonemerteans that have long-lived pelagic larvae that feed and grow in the plankton, which is likely to have consequences for larval dispersal and population connectivity.
147.1 MAYORGA, O.*; YIP, V; MAZOUCHOVA, N; GOLDMAN, DI; SPAGNA, JC; William Paterson University, Georgia Institute of Technology, Georgia Tech; daniel.goldman@physics.gatech.edu

Running performance and gait kinematics of a sand–adapted arachnid, Galeodes granti

Solifuges (camel spiders; Arachnida: Solifugae) typically live in desert environments and run quickly on sandy substrates. To test the hypothesis that Solifugae are well–adapted to running on sand, we compared the running performance of the solifuge Galeodes granti, to three cockroaches: B. discoidalis and immature B. discoidalis, which are tropical, and A. investitum, a desert species. We then analyzed the solifugae gait characteristics and compared them to those of spiders and scorpions. The animals were placed on a platform covered with a uniform layer of 0.3 mm diameter glass particles, similar to natural sand, ~1 cm deep. The platform was adjusted to four angles (0, 5, 10, 15, 20 degrees) and locomotion bouts were recorded using a high–speed camera. Comparisons of slopes of speed vs. angle showed that with increases in angle, solifugae performance was maintained, while the other species slowed (ANOVA, p < 0.05). Each solifugae video (n=3 individuals, mean mass 1.7g, 34 total runs) was analyzed to measure periods of ground contact and swing phase for each leg across two step–cycles. These indicated that the solifugae used their 6 rear legs in alternating sets of three, analogous to the insect alternating tripod gait. Average speed was 12 cm/sec, stride frequency was approximately 3 strides/sec, duty factor was 0.86, and tripod synchrony factor was 0.62. Regression analysis revealed a significant relationship (p < 0.01) between speed and frequency, but not between speed and duty factor, or speed and stride length. The gait patterns of solifugae are more similar to those of spiders than to comparably–sized spiders, which may reflect adaptation to their shared sandy habitats.

67.5 MAZOUCHOVA, N.; UMBANHOWAR, P.B.; GOLDMAN, D.I.*; Temple Univ., Northwestern Univ., Georgia Tech; daniel.goldman@physics.gatech.edu

Principles of flipper use during walking on flowing ground

Animals, like lobe–finned fishes, likely first walked on wet sand and mud. In the evolutionary transition from aquatic to terrestrial locomotion, the rheology of limb interaction changed from slipping through fluid to pushing against materials that can be fluid or solid. Locomotor strategies thus changed as bodies and appendages shifted from generating thrust during swimming to generating both lift (to maintain posture and reduce ground contact) and thrust (to propel the body). However, as little is known of the biomechanics of walking/crawling on soft substrates, detailed hypotheses for how limbs and control strategies adapted to these substrates are lacking. To discover principles of flipper/fins based terrestrial locomotion, we study a sea turtle–inspired robot, FlipperBot (FBot), during quasi–static movement on dry granular media. FBot implements a symmetric gait using two, servo–motor driven front limbs with flat–plate flippers and either freely rotating or fixed wrist joints. For a range of gaits, FBot moves with constant step length. For gaits with sufficiently shallow flipper penetration or sufficiently large stroke, step length decreases with successive steps resulting in failure after a few steps. The biologically inspired free wrist is less prone to failure than the fixed wrist, largely because it does not yield material and can thus maintain FBot's base above the surface. Failure occurs when FBot interacts with ground disturbed during previous steps; measurements reveal that flipper forces decrease as step length decreases. When step length is constant, models provide insight into how disturbed ground leads to locomotor failure. We hypothesize that the evolution of limb morphology (like a flexible wrist) and control strategies in terrestrial locomotors was influenced by flowing substrate rheology.

67.6 MAZOUCHOVA, N.*; WILSHIN, S; HSIEH, T; Temple University, Royal Veterinary College; nicole.mazouchova@temple.edu

The aquatic–terrestrial transition of freshwater turtles from a dynamical systems perspective

A multitude of complex environments are found on our planet and are inhabited by a variety of animal species exhibiting diverse forms of adaptation. Animals that must locomote across the land–water interface range from mammals, to birds, to reptiles or fish. Studies have focused on movement on unfamiliar terrain but fewer analyze the locomotor requirements when transitioning from one environment to another, such as at the land–water interface. We are interested in a dynamical system analysis of locomotor abilities of freshwater turtles when transitioning from swimming to walking. Freshwater turtles frequently utilize freshwater streams and ponds to hunt for food and emerge onto the shores to bask in the sun. We hypothesize that transitions may be asymmetrical with gaits being specialized for escape and others for prey pursuit. The animals are kept in a freshwater tank outfitted with a dry–land dock and equipped with a high–speed video camera to film their behavior and kinematics during transitions between land and water. A simple dynamical systems model is fitted to the kinematics of the flipper motions during the aquatic/terrestrial transitions to explore patterns of gait changes between these two environments. The model captures the variability in the phase of the flippers and any phase locking of the transition onset. We will examine how the structure of the gait transitions affects performance of the turtles.

S7–1.1 MÜLLER, W.E.G. *; WANG, X.H. ; University Medical Center, Mainz, GERMANY; daniel.goldman@physics.gatech.edu

Metazoan circadian rhythm: an universal “Zeitgeber” existing from sponges to humans

In higher metazoans, the 24 h periodicity in the environment contributed to the evolution of the molecular circadian clock. We studied the circadian clock circuit in the lowest metazoans, the sponges. First, we identified in the demosponge Saberites domuncula the enzyme luciferase which generates photons. Then very likely, the photos generated by luciferase are transmitted via the biosilica glass skeleton of the sponges and are finally harvested by cryptochrome, acting as photosensor. Therefore, we propose that this photoreception/phototransduction circuit functions as a nerve–cell like signal transmitting system. This could be certified by the fact that S. domuncula reacts to different light wavelengths with a differential gene expression of the transcription factor SOX. Recently, we succeeded to demonstrate that the sponges nocturnin is a light/dark controlled clock gene and shows a poly(A) specific 3' exoribonuclease activity. qPCR analyses revealed that primmorphs, 3D cell aggregates, after transferred from light to dark, show a 10–fold increased expression of nocturnin gene. In contrast, the expression level of glycogenin decreases in the dark by 3– to 4–fold. Finally it is concluded that sponges are provided with the molecular circadian clock protein nocturnin which is highly expressed in the dark and controls in the dark the stability of a key metabolic enzyme, glycogenin. References: Müller et al. (2009) Cell Mol Life Sci 66: 537. * Müller et al. (2010) FEBS J 277: 1182. * Wiens et al. (2010) J Cell Biochem 111:1377–1389. * Wang et al. Soft Matter; in press.
Planktrophic larvae of marine invertebrates develop and grow by utilizing energy and materials from a combination of maternally-supplied endogenous egg reserves and exogenous food. Egg size varies considerably among planktrophic species, and egg size is thought to evolve in the context of food availability; large eggs will be favored if food for larvae is scarce, and small eggs will be favored if food is abundant. Evolutionary changes in egg size can also affect maternal fitness by altering the balance between per-offspring maternal investment and fecundity. To test the hypothesis that egg size alters the effect of food availability on larval growth and development, we reared larvae of three closely related species of Echinometra that differ in egg size and egg energetic content at three different food levels. We found that overall, at a given food level, larvae of species with larger eggs developed more rapidly than larvae of species with smaller eggs; larvae reared at higher food levels also grew more rapidly than those fed less. We also found a significant interaction between egg size and food level for larval size and developmental rate: food level had a greater effect on species with smaller eggs than those with larger eggs. These data support the prediction that larger eggs act as a nutritional and energetic buffer against the unpredictability of food in the plankton, and that smaller eggs may enhance maternal fitness in high-food environments.

Immune costs of the physiological stress response are affected by cross-generational exposure to stress

An organism's ability to respond to stressors is integral to its survival and reproductive fitness, and is increasingly important in light of immune gene changes. An animal's physiological response to stress is generally adaptive. For example, the production of glucocorticoid hormones, including corticosterone (CORT), can trigger survival-enhancing behavior. However, chronic stress, such as that elicited by frequent encounters with predators, can divert energy from other important processes, such as immune function. Additionally, it is possible that the costs of chronic stress differ between populations that have evolved in high- versus low-stress environments. We investigated the tradeoff between stress and immune function in male Eastern fence lizards (Sceloporus undulatus) in both high- and low-stress sites. This difference in field stress (measured as baseline CORT levels) is associated with the long-term presence or absence of predatory invasive fire ants (Solenopsis invicta). We experimentally manipulated CORT levels by applying exogenous CORT, or a control vehicle, to lizards daily for 23 days, and then measured two immune parameters (complement bacterial lysis and antibody hemagglutination). Immune function of lizards from low-stress sites appears to be fairly robust to stress. However, lizards from high-stress sites had a stress-sensitive immune response, and the nature of this response varied between the two immune measures. This suggests that cross-generational exposure to stressors can affect tradeoffs between the physiological response to a stressor and other nutrient-demanding processes, such as immune function.

63.1 MCCORMICK, S.D.; USGS. Conte Anadromous Fish Res Ctr; mccormick@umext.umass.edu Downstream: the hormonal control of smolt development in salmon

The parr-smolt transformation is a series of behavioral, morphological and physiological changes that are adaptive for downstream migration and seawater entry. The Bern lab conducted some of the earliest work on the hormonal control of smolting, particularly with regard to the development of seawater tolerance. Growth hormone, insulin-like growth factor I, cortisol and thyroid hormones increase during smolt development, whereas prolactin decreases. There are important interactions among these endocrine axes that control the timing and magnitude of smolt development. The recent identification of salinity-specific isoforms of the ion transporting enzyme Na/K-ATPase has helped identify cellular changes in the gill that promote salt secretory capacity and their hormonal control. Areas of future research include the hypothalamic control of smolting and the identity of mechanisms contributing to interaction of endocrine axes during this pan-hyperendocrine developmental event.

117.4 MCCORMICK, G.L.*; LANGKILDE, T.; Pennsylvania State University; gmb173@psu.edu

Direct measurement of starvation-induced shifts in endogenous fuel oxidation in mice

Fasting animals typically switch from one metabolic substrate to another in the order of carbohydrates, lipids, and then proteins. The timing of these physiological transitions are traditionally estimated using indirect measures of substrate oxidation including, changes in respiratory exchange ratios (RER), blood metabolites, or enzyme activity. Here I describe how different nutrient pools in the body can be chronically 13C labeled and how fasting-induced physiological shifts in substrate oxidation can be directly quantified using 13CO2-breath testing. Weaning mice were raised to adulthood on diets supplemented with one of three artificially enriched isotope labels (i.e., 13C-1-1-D-glucose, 13C-1-1-D-leucine, 13C-1-palmitic acid, or 13C-glucose mice occurred between 8h-18h, during the transition of Phase I to Phase II. By 6h endogenous lipid oxidation increased from 6% of the energy budget to over half of the energy used by mice. The amount of energy derived from protein oxidation dropped sharply during the first 10h (i.e., protein sparing) and eventually reached a point where protein oxidation accounted for as little as 9% of the energy expenditure. By the end of the 72-hour experiment protein oxidation accounted for at least 24% of the total energy expenditure. This experiment supports the idea that direct measurements of substrate oxidation complement traditional, indirect approaches to studying fasting physiology.
**14.4 MCCULLOUGH, E.L.*; TOBALSKE, B.W.; EMLEN, D.J.; mcgee@ucdavis.edu**

**Long and strong? Mechanical limits to maximum weapon size in a giant rhinoceros beetle**

In the Japanese horned beetle (*Trypoxylus dichotomus*), males have a long, branched head horn that they use to compete for access to females. These horns can reach exaggerated proportions of up to two-thirds the length of the beetles body. Sexual selection theory predicts male ornaments and weapons will evolve until the fitness costs outweigh the reproductive benefits of further trait exaggeration. Interestingly, the giant horns of *T. dichotomus* do not incur substantial fitness costs, so it is unlikely that weapon size is limited by a cost–benefit equilibrium. However, males often damage and sometimes break their horns during intense male–male combats, suggesting that maximum horn size is set by mechanical constraints on horn strength. We tested this hypothesis by measuring the safety factors of horns across the full range of horn sizes. Horn safety factors were calculated as the ratio between the force required to break a beetles horn and the force a beetle would have to generate to dislodge a typical size–matched rival. In support of our hypothesis, we found that horn safety factors decreased as horn length increased. Large horns are therefore more likely to break and perform poorly in combat. We suggest that mechanical constraints have played an important role in shaping the evolution of the beetles elaborate horn morphologies.

**15.1 MCENTEE, JP*; PENALBA, J; BOWIE, RCK; University of California, Berkeley; jaymcentee@yahoo.com**

**Singing out from sky islands: sunbird song evolution across the Eastern Afrotomante**

Song evolution is thought to be important to the diversification of extant birds, because songs are functionally critical in social interactions such as mate choice and are thought to diverge rapidly among isolated populations. The sky island distribution of the Eastern Double−collared Sunbird (EDCS) species group (*Nectarinia* sp.) allows examination of song divergence among spatially isolated populations at varying degrees of evolutionary relatedness. In this study, we examine the trajectory of song evolution among these populations; phenotypic differences were assessed at levels ranging from within–species to among–species divergences. Previous authors have reasoned that song in–song−learning species should be especially subject to rapid divergence in allopatry, regardless of ecological differences or divergence in other traits. Multi−locus molecular phylogenies indicate that six to eight distinct EDCS lineages have evolved, and moreover that several individual EDCS populations have existed in isolation long enough for reciprocal monophyly in mtDNA to develop. Our study indicates that, while major shifts in song phenotype have occurred coincident with molecular divergence, spatial isolation alone does not appear sufficient for substantial song divergence to accrue. Conservatism in learned song phenotypes despite the opportunity for divergence in isolation suggests the possibility that social selection can promote not only directional change but also stasis.

**12.1 MCGEE, MD*; BORSTEIN, SR; WAINWRIGHT, PC; University of California Davis, California State University Sacramento; mcgee@ucdavis.edu**

**Origin and loss of cichlid craniofacial diversity**

Cichlid fishes are famous for their exceptional diversity, particularly in craniofacial morphology. Despite remarkable phenotypic diversity in locations like the East African Rift Valley, it is not currently known which lineages produced the extremes of cichlid phenotypic diversity, or how extinction events have altered patterns of morphospace occupation in cichlids. We generated a dataset of lateral head images of one species from each of the two hundred and twenty three genera of cichlids. We then estimated the rate of relative tail length evolution for each lizard family. The results suggest uneven rates of tail length evolution across lizards, with several sister–families exhibiting very different rates (e.g. *Pygopodidae* – high rate, *Gekkonidae*, low rate).

**74.1 MCELROYE, EP*; BERGMANN, PJ; College of Charleston, Clark University; mcelroye@cofc.edu**

**The evolution of tail size, tail autotomy, and locomotor performance in lizards**

The effect of tail autotomy on locomotor performance has been studied in a number of lizard species. These studies show that tail autotomy can have a positive, a negative, or no effect on locomotor performance with a variety of mechanisms proposed to explain these findings. This study will test the hypothesis that tail size is correlated with the magnitude of change in performance after tail autotomy. To test this hypothesis, we compiled published records of the effect of tail autotomy on sprint speed in lizards. Based on these data, we measured relative tail length and volume using museum specimens. There is tremendous variation in relative tail size and the impact of autotomy on performance which inhibits the ability to detect patterns within the data. However, when the outlying species are down−weighted prior to regression analysis, we find a positive relationship between tail size and performance change after autotomy. Lizards with larger tails exhibit a larger change in performance after tail loss. Phylogenetically−informed analyses indicate that relative tail length and volume and the magnitude of change in sprint speed after autotomy have co−evolved. These findings suggest that future studies of tail autotomy and locomotor performance might be most productive if they focus on clades with large variation in tail size. To help identify such clades, we compiled all published records of relative tail length combined with a published lizard supertree, which yielded a final data set of 365 species. We then estimated the rate of relative tail length evolution for each lizard family. The results suggest uneven rates of tail length evolution across lizards, with several sister–families exhibiting very different rates (e.g. *Pygopodidae* – high rate, *Gekkonidae*, low rate).
**21.3** MCGINTY, E.S.*; MCMAHON, R.F.; MYDLARZ, L.D.; McWHORTER, T.J.*; SCHONDUBE, J.E.; NICOLSON, S.W.; Thamnophis sirtalis

MCGLOTHLIN, J. W.*; FELDMAN, C. R.; BRODIE III, E. D.; Pfrender, M. E.; Brodie III, E. D.; Virginia Tech, University of Nevada, Reno, Utah State University, University of Notre Dame, University of Virginia; joelmcg@vt.edu

Evolutionary history of tetrodotoxin−resistant sodium channels in snakes

The garter snake Thamnophis sirtalis and its prey, the toxic newt Taricha granulosa, appear to be engaged in a coevolutionary arms race in western North America, with snakes evolving ever greater resistance to increasing levels of tetrodotoxin (TTX) in newts. On a molecular level, resistance in garter snakes derives from amino acid substitutions in voltage−gated sodium channels (Nav1.x, a family of 9 proteins found in excitable tissue), that prevent TTX from binding and thus blocking ion flow. Populations of western Th. sirtalis that vary in resistance vary in the genotype of skeletal muscle sodium channels (Nav1.4), indicating an ongoing arms−race at that locus. We have recently discovered parallel evolution of signatures of resistance in two other channels, Nav1.6 and Nav1.7, which are found primarily in peripheral nerves. Here, we trace the evolutionary history of these genes in Thamnophis snakes and their relatives. Our results suggest that resistant nerves predate resistant muscles, perhaps predisposing garter snakes and their relatives to escalating coevolutionary arms races with toxic prey.

---

**6.4** MCGOWAN, C.P.*; SHINE, C.; University of Idaho; cpmcgowan@uidaho.edu

Incline hopping by kangaroo rats: Is there a division of labor?

Muscle−tendon specializations associated with specific modes of locomotion are often linked to trade−offs in function. In wallabies, the short, pinnate muscle fibers and long, thin ankle extensor tendons are well suited for elastic energy and return. However, they have a limited capacity to generate net mechanical work and control joint position. Because of this, there is a division of labor within the hind limb when performing tasks that require work to be done against the environment such hopping up an incline. Kangaroo rats share a similar hind limb morphology with wallabies, expect their ankle extensor tendons are relatively thicker and are thus better suited for generating work and controlling joint position. The goal of this study was to determine if a division of labor between proximal and distal muscles also exists during incline hopping by kangaroo rats, or if relatively thicker tendons enable all joints to contribute equally to raising the body’s center of mass. To test this, we collected data from desert kangaroo rats (D. deserti) as they hopped up a track inclined to 10, 15, 20 and 25 degrees. High speed video and ground reaction force data were combined in an inverse dynamics analysis to calculate the mechanical power and net work developed at each joint. Our results show that the net mechanical work done by the ankle is largely independent of slope, whereas the work done on the hip and knee both increase significantly. At the highest slope, 44% of the positive mechanical work was developed by the hip, compared to 35% for the knee and 20% by the ankle. Therefore, similar to wallabies, muscles acting at the proximal joints are primarily responsible for modulating mechanical power output during incline hopping. However, the ankle extensors do contribute, suggesting that there is not a similar division of labor.

---

**98.1** MCWHORTER, T.J.*; SCHONDUBE, J.E.; NICOLSON, S.W.; PINSHOW, B.; FLEMING, P.A.; MARTíNEZ DEL RIO, C.; University of Adelaide, Universidad Nacional Autónoma de México, University of Pretoria, Ben−Gurion University of the Negev, Murdoch University, University of Wyoming; todd.mcwhorter@adelaide.edu.au

Convergence in digestive capacity in nectar−feeding birds

Across five continents, nectarivorous birds show striking similarities in their physiological and morphological attributes and foraging strategies. We tested whether different nectar−specialist avian taxa are convergent in characteristics of their digestive physiology and gastrointestinal morphology. Specifically, we compared the digestive traits of eight nectarivorous passerine species from the families Meliphagidae (Australasian honeyeaters) and Nectariniidae (Old World sunbirds) with published data for hummingbirds (Trochilidae) and other passerine species that are considered diet−generalists. We examined the capacity to digest three food substrates: sucrose (via the activity of the enzyme sucrase−isomaltase), maltose (via maltase−glucoamylase activity, an indirect measure of capacity to digest starch) and protein (via aminopeptidase−N activity), and also compared intestinal nominal surface area. Intestinal surface area and maltase activity were similar across species. Aminopeptidase activity was lower in hummingbirds than in passerines. Nectar−specialist passerines had lower capacity to digest sucrose (a common nectar sugar) than hummingbirds, but higher sucrase activity than diet−generalist passerines. Using a chemical reactor model of digestive function we found that the ability of nectar−specialist passerines to assimilate energy from sucrose solutions falls between that of hummingbirds and diet−generalist passerines. The ability of passerines that specialize in feeding on nectar to hydrolyse sucrose therefore appears to be convergent with that of hummingbirds.
The stress of stopping over: oxidative stress associated with long-duration flights and its implications for the ecology of migrants at stopover sites.

Birds during migration use primarily fats to fuel their long-duration flights and this high rate of fat metabolism during exercise substantially increases the bird's oxidative stress. We tested the following series of related hypotheses: (a) free-living birds at migration stopover sites select fruits based on antioxidant content; (b) dietary protein consumption in urticolic birds is positively related to circulating antioxidant levels; and (c) exercise training such as flight causes upregulation of liver antioxidant enzymes. We report evidence from field and captive studies that support all three hypotheses. Thus, birds actively select antioxidant-rich fruits during autumn migration and upregulate their endogenous antioxidant capacity during migration, and this protects them from the potentially damaging effects of oxidative stress caused by long-distance fasting flight. Supported by NSF (IOS–0748349), USDA (RIAES–538748), and Canadian Foundation for Innovation (AFAR).

Importance of the calcareous eggshell to normal skeletal development in the American alligator

During development, oviparous reptiles rely on both yolk and eggshell calcium stores for skeletal growth of the embryo. By hatching time, squamates and chelonians deplete the yolk almost completely of calcium. In contrast, embryonic archosaurs (crocodilians and birds) sequester calcium from the heavily mineralized eggshell and store it in yolk, so that the yolk sac can serve as a mobile calcium source in hatchlings. We studied the relative importance of eggshell calcium to normal development and growth of the American alligator (Alligator mississippiensis). At approximately three weeks after egg laying, the calcareous eggshell layer of the experimental eggs was completely peeled by hand, while clutch-matched control eggs were sham-handled but not altered. All eggs were incubated at 30°C and 100% humidity, and embryos were sampled at regular intervals until hatching. At first, there was no discernible difference in embryo growth. As incubation progressed, however, experimental embryos grew more slowly than sham embryos. At hatching, experimental embryos were 36% smaller than their yolk siblings, whereas their yolk sacs were 3-4x larger. Despite being diminutive, experimental hatchlings were active and apparently healthy. Our results suggest that eggshell calcium is important for embryonic growth in alligator, but sufficient calcium reserves are found in the yolk. Shell-less embryos are capable of survival until and after hatching. We posit that evolution of heavily mineralized eggshells of archosaurs may have been driven by factors other than the need for calcium mobilization during embryonic skeletal development.
Hox Gene Evolution in North American Suckers (Cypriniformes: Catostomidae), a Tetraploid Family of Fishes

Most eukaryotic organisms are diploid, containing two sets of chromosomes, one from each parent. However, having more than two sets of chromosomes, a condition known as polyploidy, is prominent in some taxa such as vascular plants. Members of Catostomidae, a fifty million–year–old monophyletic family comprising sucker fishes, have four sets of chromosomes. This condition, known as tetraploidy, presents interesting questions in regard to the fate of the duplicated genome. In particular, Hox genes in a diploid organism are normally highly conserved due to their role in orientation and morphology of organisms. The duplication of Hox genes in Catostomidae may lead to a higher rate of mutation. This is due to the presence of the extra copy which would mask a normally detrimental effect. This study tests the hypotheses that 1) fourteen Hox clusters will be present in Catostomidae rather than the seven clusters found in most teleost fishes; 2) some Hox genes within the clusters will not be conserved but silenced through the formation of stop codons; 3) Hox genes that are silenced will show a phylogenetic pattern across the catostomids; and 4) the species of catostomids with more derived traits will have more changes to their Hox genes. To test this, thirteen degenerate primer sets were used to target and isolate specific regions of Hox genes. Subsequent amplification through PCR, cloning of plasmid DNA, and sequencing of the clones were performed on a diversity of species across the catostomid phylogeny. Preliminary results will be presented.

Hyla femoralis

Both female preference and male competition shape the evolution of acoustic sexual signals. In the complex acoustic environment of anuran breeding aggregations, signalers are challenged to transmit signals that receivers must recognize and then respond to appropriately. Often signal traits are classified as static or dynamic based on the amount of within–individual variation. Static traits have little variation, while dynamic traits can vary drastically within a single calling bout. For North American hylids, fine–scale temporal patterns are generally static. In several species, females show a strong preference for a narrow range of variation; therefore, the static nature of certain temporal traits is presumed to be crucial for mate choice. The advertisement signal of Hyla femoralis is characterized by a highly unusual, irregular series of pulses. Our research is the first to explicitly investigate pulse period irregularity in this group of hylids and may reveal new recognition mechanisms in females of this species, in which females attend to subpulse structure. Our results show that competition among males as well as female preference for fast and regular pulse rates may enhance signal detection in noisy choruses.

Signal plasticity and mate recognition in the pine woods treefrog, Hyla femoralis

S7–1.6 MERRITT, D J*; MAYNARD, AJ; The University of Queensland, Australia; d.merritt@uq.edu.au

Synchronization of circadian bioluminescence as a group–foraging strategy in cave glowworms

Flies of the genus Arachnocampa are sit–and–lure predators that use bioluminescence to attract flying prey to their silk webs. Some species are most common in rainforest habitat and in others their habitat includes both caves and rainforest. We have studied the circadian regulation of bioluminescence in two species; one found in subtropical rainforest with no known cave populations, the other found in temperate rainforest with large populations in limestone caves. The rainforest species is typical of most nocturnal animals in that individuals are entrained by the light:dark cycle to be active at night. In this case, their propensity to bioluminesce is greatest at night. The dual–habitat species shows the opposite entrainment response; its bioluminescence propensity rhythm is entrained by light:dark exposure to peak during the day. Nevertheless, in L:D environments, individuals dont bioluminesce during the day because ambient light inhibits their bioluminescence (negative masking), pushing bioluminescence into the dark period. This unusual and unexpected phenomenon could be related to their association with caves. Entrainment of the bioluminescence rhythm to the photophase causes colonies of larvae in the dark zone to synchronise to each other, creating a daily sinusoidal rhythm of bioluminescence intensity in the many thousands of individuals making up a colony. This synchronisation could provide a group–foraging advantage, allowing the colony to glow most brightly when the prey are most likely to be active.

S7–2.3 MEUTI, Megan E.*; DENLINGER, David L.; The Ohio State University; meuti.1@osu.edu

The Role of Circadian Clock Genes in the Overwintering Diapause of the Northern House Mosquito, Culex pipiens

Diapause is an arrested state of development that allows insects and other arthropods to survive adverse seasonal conditions, such as limited food availability and lower temperatures that are associated with winter. Temperate insects enter diapause in response to the short days of late summer and early fall. However the molecular mechanisms by which insects measure day length is unknown. Several researchers have hypothesized that the circadian clock, which provides insects with information on the time of day, might also be involved in measuring day length. To determine whether the circadian clock is involved in initiating the overwintering diapause of the Northern House Mosquito, Culex pipiens, we used RNA interference to knock down several core circadian clock genes (period, timeless, Cryptochrome2 and Cycle). We confirmed RNA knock down using qPCR, and assessed the diapause status of RNAi–treated females by measuring the length of their egg follicles (large follicles = non–diapause; small follicles = diapause). We found that knocking down the clock gene Cycle, a positive regulator of the circadian clock, had no effect on diapause initiation. However when negative regulators of the circadian clock (period, timeless and Cryptochrome2) were knocked down, female mosquitoes that had been reared under diapause inducing conditions failed to enter diapause. Our results suggest that a functioning circadian clock is essential for initiating the overwintering diapause of these mosquitoes.
MIDDLEBROOKS, ML*; BELL, SS; CURTIS, NE; PIERCE, Zootoca vivipara urosaurus@gmail.com and the upside down jellyfish

MIDDLETON, KM*; COATS, BR; University of Missouri, MILLER, L. A.; University of North Carolina, Chapel Hill; can maintain photosynthetic activity for 3 to 4 months Tripedalia cystophora, a kleptoplastic sacoglossan endemic to the Florida Keys. mlmiddle@mail.usf.edu. In fact, in some Elysia E. clarki that is opportunities.

performance differences that correspond with habitat and thermal These results suggest that variation in dorsal pattern affects on the treadmill, which mimics their escape behavior in the wild. females from closed habitats reversed more frequently when running and stop more frequently when running than linear females. Linear individuals predominated at high elevation, humid sites reticulated females occurred in open habitats at low elevation sites, habitats at different altitudes and differed in structure. More locomotor performance and escape behavior for 18 populations of escape behavior and locomotor performance. We measured Tb has performance consequences and hence affects individual and ultimately population dynamics. Few studies have examined the interaction between habitat structure, dorsal pattern, escape behavior and locomotor performance. We measured lcomotor performance and escape behavior for 18 populations of common lizards during 2007 and 2008. The populations occupied habitats at different altitudes and differed in structure. More reticulated females occurred in open habitats at low elevation sites, but linear individuals predominated at high elevation, humid sites with higher vegetation cover. Endurance and maximum velocity was greater in linear than reticulate females, but only during 2008, a cool, wet year. Escape behavior covaried with morphotype and habitat. Reticulated females from open, disturbed habitats tended to reverse and stop more frequently when running than linear females. Linear females from closed habitats reversed more frequently when running on the treadmill, which mimics their escape behavior in the wild. These results suggest that variation in dorsal pattern affects performance differences that correspond with habitat and thermal opportunities.

124.2 MILES, D.B; Ohio University; urosaurus@gmail.com Covariation of dorsal pattern, locomotor performance and escape behavior As temperatures rise and habitats become less favorable, species may shift their distributions, adapt to the new environments, or go extinct. However, phenotypic plasticity is likely to be an immediate response for coping with climate change. We have documented fluctuation in dorsal melanin patterns in the common lizard Zootoca vivipara that is consistent with variation in June temperatures. Individuals exhibit two dorsal patterns, reticulated and linear, with the latter morph having higher amounts of melanin. Variation in dorsal melanin should affect thermoregulatory behavior and covary with habitat structure (openness), and local climatic conditions (e.g., elevation), which may affect basking behavior and field active Tb. Variation in Tb has performance consequences and hence affects individual fitness and ultimately population dynamics. Few studies have examined the interaction between habitat structure, dorsal pattern, escape behavior and locomotor performance. We measured locomotor performance and escape behavior for 18 populations of common lizards during 2007 and 2008. The populations occupied habitats at different altitudes and differed in structure. More reticulated females occurred in open habitats at low elevation sites, but linear individuals predominated at high elevation, humid sites with higher vegetation cover. Endurance and maximum velocity was greater in linear than reticulate females, but only during 2008, a cool, wet year. Escape behavior covaried with morphotype and habitat. Reticulated females from open, disturbed habitats tended to reverse and stop more frequently when running than linear females. Linear females from closed habitats reversed more frequently when running on the treadmill, which mimics their escape behavior in the wild. These results suggest that variation in dorsal pattern affects performance differences that correspond with habitat and thermal opportunities.

81.3 MILLER, L. A.; University of North Carolina, Chapel Hill; lam9@unc.edu Fluid dynamics of forward swimming and turning in jellyfish Jellyfish propel themselves through the water through periodic contractions of their elastic bells. Some jellyfish, such as the box jellyfish Tripedalia cystophora and the upside down jellyfish Cassiopea xamachana, can perform turns via asymmetric contractions of the bell and by generating asymmetries in the outflow opening of the bell. The fluid dynamics of jellyfish forward propulsion and turning is explored here using the immersed boundary method. The 2D and 3D Navier–Stokes equations are coupled to the motion of a simplified jellyfish represented by an elastic boundary. An adaptive and parallelized version of the immersed boundary method (IBAMR) is used to resolve the detailed structure of the vortex wake. The asymmetric contraction and structure of the jellyfish generates asymmetries in the starting and stopping vortices. This creates a diagonal jet and net torque acting on the jellyfish. This effect will be explored over a range of Reynolds numbers and contraction kinematics.

SICB 2013 Annual Meeting Abstracts

60.5 MIDDLEBROOKS, ML*; BELL, SS; CURTIS, NE; PIERCE, SK; Univ. of South Florida; mbmiddle@mail.usf.edu Molecular analysis demonstrates that proximity is a poor indicator of food source for a photosynthetic herbivore. The diet of many herbivore species has been determined, often incorrectly, by their proximity to potential food plants. Many species of herbivorous, sacoglossan sea slugs, can acquire energy through photosynthesis by intracellular chloroplasts sequestered from their algal food. This additional source of energy might allow these slugs to inhabit areas devoid of food sources for as long as they are photosynthetically capable. We tested this hypothesis on Elysia clarki, a kleptoplastic sacoglossan endemic to the Florida Keys. Elysia clarki can maintain photosynthetic activity for 3 to 4 months without feeding and even synthesizes chlorophyll and other plastid related compounds to sustain the symbiotic chloroplasts. Using a combination of field surveys and DNA sequencing to identify the sequestered chloroplasts, we found that proximity to food sources was a very poor indicator of the diet of E. clarki. In fact, in some cases, slugs had been feeding on algae not detected in the field surveys. These findings support the idea that photosynthetic herbivores may be able to survive in areas lacking food sources for prolonged periods of time. (Supported by an anonymous patron).
107.5 MITCHELL, J.S.; The University of Chicago; mitchelljs@uchicago.edu

Ecomorphology in Modern and Fossil Birds

The origin of the staggering ecological diversity of modern birds remains unresolved. A major limitation to studying the evolution of avian ecology has been the difficulty of determining the timing and overall rate of key ecological divergences in the avian tree of life. Here, I present results combining a recent molecular phylogeny with an extensive database of ecological characters (habitat, diet, foraging mode) and a very large morphological database (>1100 specimens, representing 451 genera in 138 families). Phylogenetic canonical correlations analysis of ecology and morphology yielded 3 statistically significant axes with Pearson's r of 0.6, 0.48 and 0.4 each. The first axis mainly describes the distinction between large-bodied, ground foraging birds and small-bodied, aerially foraging birds. The second axis describes the distinction between aquatic and terrestrial foragers, and the third the separates leg locomotors (e.g., ostriches and loons) versus wing locomotors (e.g., hummingbirds and penguins). I also examined how disparity was partitioned along the avian tree and found substantial departures from Brownian motion expectations early and near the middle of the tree, with disparity on the higher end of the Brownian prediction for almost every node. This suggests that major breaks in ecomorphological evolution may have happened early in the avian tree, and that many of the major groups have retained ecological distinction from one another for an extended period of time.

25.6 MITCHELL, T.S.; MACIEL, J.; JANZEN, F.J.; Iowa State University; timmitch@iastate.edu

Sex-ratio selection influences nesting behavior in a reptile with environmental sex determination

Evolutionary theory predicts that dioecious species should produce an even primary sex ratio, which will be maintained by frequency-dependent selection. Organisms with environmental sex determination, however, are vulnerable to experiencing sex-ratio skews, because environmental conditions vary through space and time. For reptiles with temperature-dependent sex determination (TSD), nest-site choice is a behavioral maternal effect that may respond to sex-ratio selection, as mothers can adjust offspring sex ratios by choosing nest sites that will have particular thermal properties. This theoretical prediction has generated decades of empirical research, yet researchers have not provided convincing evidence that sex-ratio selection influences nesting behaviors. Here we provide experimental evidence that sex-ratio selection is an important component of nest-site choice in a reptile with TSD. We compare painted turtle (Chrysemys picta) neonates from eggs incubated and hibernated in maternally selected nest sites to those in randomly-selected nest sites and observe no difference in hatching success or overwinter survival, but detect a profound difference in offspring sex ratios. As predicted by theory, our results suggest that sex-ratio selection has shaped maternal nesting behavior in ways likely to enhance maternal fitness by producing a balanced primary sex ratio.

82.4 MITTELMAN, B.; GLAZER, I.; WEIL, S.; GAFNI, O.; KHALAILA, I.; TOM, M.; DAVIDOV, G.; ZARIVACH, R.; SAGI, A.; Ben Gurion University of the Negev, Israel Oceanographic and Limnological Research, Ben Gurion University of the Negev; mittedbiny@post.bgu.ac.il

Novel chitin binding proteins with suggested role in organization of a cuticular exoskeleton in a terrestrial crayfish.

Arthropod cuticles are multifunctional structures exhibiting a diverse set of mechanical properties. This diversity is partially attributed to interactions between a chitinous organic matrix and a plethora of proteins. Among these is a protein family containing three Chitin binding type 2 domains (ChitBD2), covering almost their entire length, found in cuticles across the arthropod phylum, and presumed to play a role in the organization of the chitinous matrix. Gastroliths are cuticular structures formed by the crayfish Cherax quadricarinatus during premolt, as transient calcium deposits. However, unlike the exoskeleton, gastroliths are relatively homogenous in composition, making them excellent research candidates for cuticular assembly. Two novel, strong chitin-binding proteins containing three ChitBD2 domains, were identified from C. quadricarinatus gastroliths. Their transcripts were fully sequenced based on RNA from the gastrolith-forming epithelium, and designated C. quadricarinatus gastrolith protein 30 and 35 (Cq-GAP30 and Cq-GAP35, respectively). 454-sequencing of C. quadricarinatus cuticular transcripts revealed additional expressed sequences from the same family. Furthermore, we recombinantly expressed both proteins, demonstrated their chitin-binding ability, and used them for production of polyclonal antibodies to examine the protein distribution pattern within the gastrolith matrix. Our study is aimed towards a better understanding of how chitin and proteins interact in arthropod cuticular structures.

112.5 MLLOT, N.J.; MORRISON, J.; LEAMY, M.; TOVEY, C.A.; HU, D.L.; Georgia Tech, Atlanta; njmlot@gmail.com

Assembly and disassembly of fire ant bivouacs

Fire ants are capable of linking together to form bivouacs, which serve as temporary shelter when alternatives cannot be found. While the presence of army and fire ant bivouacs has long been known, much remains to be learned about the factors that limit the shape and speed of construction. In this combined experimental, theoretical, and computational study, we use time-lapse video to investigate the construction of fire ant bivouacs that are built against a teflon supporting wall. By roughening the wall, we can control the maximum adhesion and shear force applied by the ant’s foot. In turn, we find that the wall properties affect the height and shape of the constructed bivouac. We present a model that rationalizes bivouac shape based on ant adhesion force and the internal distribution of force by the ants. Next, we consider the bivouac disassembly process whereby ants evacuate and disassemble the bivouac and move into a nearby home. We present an agent-based simulation, founded on experimental measurements of ant trajectories, that predicts the rate of disassembly. We pay particular attention to traffic jams and resulting ant clumps that slow the rate of disassembly when ant numbers are sufficiently high.
145.2 MOONEY, T.A.*; LI, S.; KETTEN, D.R.; WANG, K.; WANG, D.; Biology Department, Woods Hole Oceanographic Institution, Hawaii Institute of Marine Biology, University of Hawaii, Institute of Hydrobiology, The Chinese Academy of Sciences: amooney@whoi.edu

**Hearing of the Yangtze finless porpoise: Form and function in an unrepresentative species**

While it is broadly accepted that odontocetes receive sound through tissues near the lower jaw, there are important species differences in the tissue shapes potentially related to what it hears. This paper addresses the hearing of a divergent cetacean species, the Yangtze finless porpoise (*Neophocaena phocaenoides*). Hearing was measured using auditory evoked potentials. Clicks and low-, mid-, and high-frequency (8, 54, 120 kHz) tones were presented through adapted jawphone transducers at nine locations on the body. Thresholds were related to underlying anatomy determined from CT and MR images. Results showed acoustic fat regions coincident with lowest thresholds (best hearing) at locations adjacent to the auditory bullae. Response latencies were shortest from this region, and MR images. Results showed acoustic fat regions coincident with lowest thresholds (best hearing) at locations adjacent to the auditory bullae. Response latencies were shortest from this region, indicating subtle preferential sound pathways. Mean thresholds did not vary significantly along a line from the rostrum to the ear (11.6 dB). This is quite different from the bottlenose dolphin and beluga, in which 30–40 dB threshold differences were found across their heads. Greater stimulus levels produced higher amplitudes and faster auditory responses suggesting sound pathways influence hearing in multiple ways. Yet, finless porpoises have relatively less shading of sounds compared to some odontocetes, implying they hear well from many directions. These distinctions indicate sound reception differences among odontocetes which likely influence vital bio–acoustic behaviors of these sound specialists, and supports caution when attempting to generalize from limited auditory data across cetacean species.

14.3 MOREHOUSE, N.*; BARTOCH, CM; LUNA, EN; ROBERTS, NS; SALEH, NW; University of Pittsburgh; nim@pitt.edu

**Food, Nuptial Gifts and Vaginae Dentatae: Phenotypic Plasticity and Sexual Conflict in a Gift–Giving Butterfly**

Considerable recent effort has been devoted to understanding the role of conflict and cooperation in sexual interactions. Gift–giving insects such as crickets and katydids have proven tractable systems for exploring these issues, with recent research emphasizing nuptial gifts as a source of conflict. In the Lepidoptera, males often transfer large nutrient–rich packages called spermatophores internally to females during mating. In contrast to work in other systems, researchers have typically characterized these nuptial gifts as cooperative contributions of mutual benefit to both partners. Male spermatophores provide essential nutrients that increase female lifespan and reproductive output. In turn, males benefit by delaying female remating and thus increasing their paternity share. However, males of many butterfly species, in an attempt to monopolize female reproductive output, package their spermatophores in hard outer shells. Females have, in response, evolved toothed structures in their reproductive tracts called sigilla, which serve to chew their way through the outer spermatophore coating to access the nutrients within. As a preliminary step in understanding the co–evolutionary dynamics in this system, we explored the environmental and genetic determinants of male spermatophore quality and female sigilla morphology in the gift–giving butterfly *Pieris rapae* using a split–brood experiment where siblings were reared on artificial diets of varying protein content. We report both high heritability and phenotypic plasticity in both traits. We discuss these results in the context of sexual conflict and co–evolutionary dynamics.
Differential Transport Across the Surf Zone of Reflective and Dissipative Shores as a Determinant of Larval Supply

We determined whether differences in water exchange across the surf zone on dissipative and reflective shores regulates larval supply to intertidal populations. We surveyed zooplankton daily for one month relative to physical conditions inside and outside the surf zone at a dissipative and reflective beach near Monterey, California. Larvae of some species completed development nearshore while larvae of other species migrated offshore and back. Concentrations of zooplankton were much greater outside than inside the surf zone at the reflective beach, indicating that the surf zone may block onshore transport. Barnacle cyprids were an exception, suggesting that ontogenetic changes in larval behavior may facilitate penetration of the surf zone. In contrast, zooplankters were 1 to 2 orders of magnitude more concentrated inside the surf zone of the dissipative beach. Settlement of barnacles on rocks at both beaches was low, and settlement of sand crabs, Emerita analoga, was abundant only on the dissipative beach. Different hydrodynamics of surf zones at dissipative and reflective beaches together with larval behavior may play a major role in regulating larval supply along the West Coast.

Sexual dimorphism in the Gray Wolf (Canis lupus): specialization for male–male competition or for male provisioning?

Sexual selection theory predicts that male mammals will be more specialized for physical competition than females. Specialization for aggression, however, may result in functional conflicts with locomotor demands. Characters associated with locomotor economy include long, gracile limbs that reduce the cost of transport by increasing stride length and decreasing the energy required to swing the limbs. In contrast, specialization for aggression appears to result in stout bones and large distal muscles with high mechanical advantage that increase force available to strike or manipulate opponents. Gray wolves (Canis lupus) are highly cursorial animals, traveling immense distances to locate and run down prey. Gray wolves also aggressively defend territory through direct competition and kill much larger, highly dangerous prey species. Because both sexes actively participate in these activities, a low level of musculo–skeletal sexual dimorphism is expected. However, males often lead in aggressive encounters with conspecifics and, for a period during the mating season, must kill prey without the assistance of the dominant female to provision her and their young. Thus, male wolves may exhibit a higher degree of morphological adaptation associated with aggressive activities. To assess sexual dimorphism in three distinct subspecies of gray wolves, a series of skeletal metrics were taken from fresh cadavers and museum specimens. All measures were size–corrected and analyzed to detect relative differences in size and shape. Males were found to have broader skulls, more robust limb bones, and higher muscle mechanical advantages than females, suggesting that males are more highly specialized for physical aggression. However, results for each subspecies differed substantially, likely reflecting differences in selective pressures on pursuit versus handling capabilities based on prey size.

Molecular phylogenies support homoplasies of multiple morphological characters within the taxonomy of Heteroscleromorpha (Porifera: Demospongiae)

The most recent attempt to produce a stable classification of sponges was based solely on morphological characters (Systema Porifera Hooper & van Soest, 2002) and incorporated the cladistic analyses of van Soest et al., 1987 & 1990; de Weerdt, 1989 and Hooper, 1990 & 1991. The current study uses sequence data from 18S rDNA; 28S rDNA and CO1 barcoding fragment combined with morphology to justify the resurrection of Axinellida Levi, 1973. The abandonment of Axinellida and the establishment of Halichondrida sensu lato to contain Halichondriidae, Axinellidae, Heteroxeidae and a new family Dictyoneuridae was based on the hypothesis that it was more parsimonious to assume that an axially condensed skeleton evolved independently in four separate lineages than to assume that asters (star shaped spicules); acanthostyles (club–shaped spicules with spines) and sigmata (C–shaped spicules) each evolved more than once (van Soest et al., 1990). Our resulting molecular trees are congruent and contrast with the morphology based trees of van Soest et al., 1990. The recent phylogeny of sponges (Heteroscleromorpha) and establishment of Halichondrida sensu lato is congruent with the ‘axially condensed skeleton’ hypothesis of van Soest et al., 1990. The current study shows that axially condensed skeletons, asters, acanthostyles and sigmata are all homoplasious or alternatively that some may be ancestral but lost in certain lineages. We use the molecular trees presented here as a basis for re–interpreting the morphological characters within Heteroscleromorpha.
513 MORSE, MPATR; Univ. of Washington, Friday Harbor Labs; mmorse@u.washington.edu
Edward S. Morse 1838–1925. History of scholarly exchanges in marine zoology between US and Japan

Japan and the United States share a distinguished scientist who had a remarkable history with Japan 150 years ago. Edward Sylvester Morse (1838 – 1925) received his understanding of natural history at Harvard University in the laboratory of Professor Louis Agassiz, the founder of the Harvard Museum of Comparative Zoology. Morse is a member of the U.S. National Academy of Sciences and holds four honorary doctorates, from Bowdoin College (1871), Harvard University (1892), Yale University (1918) and Tufts University (1922). Early in his career, in 1877 he visited Japan to collect brachiopods and shortly after his arrival, was invited to be the first Professor of Zoology in Japan and develop natural history and zoological studies at the University of Tokyo. During his time in Japan Professor Morse created the first marine laboratory at Enoshima, established scientific studies on the evolution of the Brachiopoda, and brought the studies of evolution and zoology to Japanese students and into the Japanese science classrooms. He also discovered the ancient shell Mounds of Omori and dug a collection of ancient Japanese pottery still on display at the University of Tokyo. Later at the Peabody Museum in Salem Massachusetts Morse wrote an account of Japan Day by Day, wrote an account with precise illustrations of the Japanese Homes and Their Surroundings, and researched the ancient Japanese pottery formulating a catalog that has also been translated into Japanese. Morse curated two collections of the ancient and modern pottery, one in Japan and one in the Boston Museum of Fine Arts. Professor Morse was president of the American Association for the Advancement of Science (AAAS). Scholarly exchanges between the US and Japan will be reviewed and the importance of Morse discussed.

643 MOUNTCASTLE, AM*; COMBES, SA; Harvard University; mountcastle@fas.harvard.edu
When wings collide: how collisions cause wing wear in bees and wasps

Many flying insects suffer periodic wing damage and exhibit a cumulative loss of wing area over their lifespan. Wing area loss reduces aerodynamic force production, load carrying capacity and flight maneuverability, and thus can have important fitness consequences for an individual and colony. In bumblebees, loss of wing area is associated with an increased rate of mortality, and wing wear has been linked to frequency of wing collisions with vegetation during foraging activity. However, little is known about how insect wings dynamically respond to collisions during flapping flight, the factors that contribute to wing damage during collisions, and the rate at which damage occurs. Here we explore how rapid collisions with a rigid surface cause wing damage in bees and wasps. Using a high-speed motor, we spin wings at their natural flapping velocity and force them to repeatedly collide with a surface obstacle in their path. We investigate how wings dynamically bend during collisions, and quantify wing wear over time. Our results show that rapid collisions can eventually cause significant wing damage, although wing morphology may reflect adaptive mechanisms that help reduce the damaging effects of collisions.

72 MOUCHKA, M E*; LEHNERT, E M; BURRIESC, M S; SCHWARZ, J; PRINGLE, J R ; Cornell University, Stanford University, Stanford University, Stanford University, Vassar College; mep74@cornell.edu
Identification of symbiotic–specific genes reveals a role for host immunity in a cnidarian–dinoflagellate mutualism

Many cnidarians harbor intracellular photosynthetic dinoflagellates in a mutualistic relationship. While some facets of this mutualism have been relatively well studied, we know very little about the cellular and molecular mechanisms that underlie the establishment and maintenance of cnidarian–dinoflagellate symbioses. The stability of this relationship presumably involves a complex interplay between the symbiont and the host immune system. To gain a better understanding of the role of host immunity in mutualistic interactions, we used RNA−Seq to characterize differential gene expression between symbiotic and aposymbiotic anemones. Data from two distinct RNA−Seq experiments were combined to identify a robust set of 1,163 differentially expressed genes. 812 genes were up−regulated in symbiotic anemones, while 351 were down−regulated, with the majority of these genes having functions in metabolism and transport. A subset of differentially expressed genes function in immune−related processes, including inflammation, wound healing, regulation of the JNK cascade, complement activation, and apoptosis. Genes of interest from these categories (based on log2 fold expression) include scavenger receptor B1 (infinitely up−regulated), TNF receptor superfamily member 27 (5.9), and mammalian−binding lectin serine peptidase 1 (−1.6). Our results suggest a role for the host immune system in the maintenance of the symbiotic relationship. In addition, we have generated a list of candidate genes whose function in the onset, regulation, and breakdown of the symbiotic state can be investigated in further detail. Our results offer new insights into genes that play a role in symbiotic homeostasis and will leverage a better understanding of cnidarian–dinoflagellate interactions.

7.2 M.Moustakas, V.H.; Zimm, R.; Cebra-Thomas, J.; Seppälä, N.K.; Kallonen, A.; Mitchell, K.L.; Hämäläinen, K.; Salazar-Ciudad, I.; Jernvall, J.; Gilbert, S.F.; Institute of Biotechnology, University of Helsinki, Biology Department, Millersville University, Department of Physics, University of Helsinki, Biology Department, Swarthmore College, Department of Biology, Universitat Autònoma de Barcelona; Jacqueline.Moustakas@helsinki.fi
The origin and loss of periodic patterning in the turtle shell

Testudines (turtles and their relatives) originated in the Triassic Period and became one of the most successful groups of tetrapods, radiating into terrestrial, semiaquatic, and marine environments on all continents. The developmental mechanisms responsible for the formation of the turtle shell remain one of the great mysteries in evolutionary biology. The keratinous scutes of the turtle shell are novel epidermal structures, the patterns of which are diagnostic of different taxa. These scutes become the modular elements of turtle shell epidermal growth. We show that scutes develop from an earlier array of patterned placodal signaling centers and that these placodal signaling centers are absent from a soft−shelled turtle species in which scutes were lost evolutionarily. Furthermore, inhibiting Shh and BMP signaling experimentally results in losses in the role of these signaling centers and scutes. We propose that these signaling centers are formed by the reaction–diffusion dynamics of activator–inhibitor systems and show that both natural and abnormal variation can be modeled by changes in growth and timing. We propose that these signaling centers represent developmental modules responsible for the evolution of scutes in turtles and that the regulation of these centers have allowed for the diversification of the turtle shell.
**Comparing Aerodynamic Efficiency in Birds and Bats Suggests Better Flight Performance in Birds**

Has the independent evolution of powered flight in birds and bats, with the apparent convergence in size, shape and flight style, resulted in the same overall flight performance? Or do they differ due to morphological peculiarities, such as feathers and membranous wings? We test whether these scenarios fit to two measures of aerodynamic flight efficiency in two passerine bird species and two New World leaf-nosed bat species. Using time-resolved particle image velocimetry measurements of the wake of the animals flying in a wind tunnel, we derived the span efficiency, a metric for the efficiency of generating lift, and the lift-to-drag ratio, a metric for the mechanical energetic flight efficiency. We show that the birds significantly outperform the bats in both metrics, and that the difference in performance is primarily caused by differences in body shape and wing upstroke function. The bats have less streamlined bodies than the birds, partly due to the presence of protruding ears used for echolocation in bats. During the upstroke, birds retract their wings and spread the wing feathers making the wing aerodynamically inactive, while the bats have a more complex upstroke motion where the membranous wing generates thrust and negative lift. Our findings suggest that, despite millions of years of evolution, bats may have not reached the same flight performance levels as birds, and that this could be due to conflicting selection pressures for echolocation and flight in bats. The results may help explain ecological differences between birds and bats, such as why bats typically fly faster, migrate more frequently and migrate longer distances than bats.

**Optomotor flight control of hawkmoths in the context of their flight dynamics.**

The sensorimotor systems involved in controlling an insect's flight are tightly coupled with its flight dynamics. The properties of the flight control system must therefore be interpreted in the context of the insects flight dynamics in order for the functional properties of the system as a whole to be understood. The properties of the flight control system of hawkmoths *Manduca sexta* were investigated using a virtual reality flight simulator to measure the flight forces produced by tethered moths in response to wide-field, oscillating visual stimuli. For a given axis of visual rotation, the moths' response proved to be linear over a range of stimulus frequencies in respect of both homogeneity and superposition. This is particularly interesting given the highly non-linear properties of the neuronal elements of these sensorimotor pathways. Visual stimuli were also presented with six different axes of rotation, in order to present combinations of roll, pitch and yaw stimuli and to explore the limits of the linearity of the flight control system. Examining the moths' responses to these combined stimuli in the context of their flight dynamics showed that the measured responses were strongly tuned to the insects' flight dynamics.
Low hydrogen peroxide production in mitochondria of the long-lived Arctica islandica: underlying mechanisms of increased longevity

The inverse correlation between lifespan and mitochondrial ROS production rate observed in vertebrates represents a major pillar of the oxidative stress theory of aging. Bivalve molluscs are routinely exposed to environmental constraints such as microbial H₂S, anoxia/oxygenation and temperature variations that would normally elicit oxidative stress in mammals. Hence, they represent an interesting taxon to challenge the existence of this correlation in remote phyla. We compared the mitochondrial H₂O₂ production rates between the longest-lived metazoan, the bivalve Arctica islandica (maximum reported longevity = 507 years) and two taxonomically related short-lived species of comparable size. We also compared the oxygen consumption of intact mitochondria and the enzymatic activity of different complexes of the electron transport system. Mitochondria of A. islandica produced significantly less H₂O₂ than those of the two short-lived species in different conditions of mitochondrial respiration which includes forward, reverse, and convergent electron flow. A reduced complex I content in A.I. may provide a partial explanation for the results during reverse electron flow. However, a lower electron flux control, leading to lower degree of electronic reduction of complex I and II, as well as a lower activity of complex II in A.I. may yield another explanation for the results obtained during forward and convergent electron flow, respectively. Overall, our study suggests that the relationship between ROS production rate and longevity may be generalized among metazoans and the adaptive mechanisms to achieve it may be remarkably conserved.

The Homology of Feathers and Scales: Using New High-throughput Methods to Address a Classic Question

Feathers are an important anatomical innovation that evolved in the ancestors of birds and facilitated the evolution of flight, greater thermoregulation, and other facets of modern avian life. However, the molecular basis for the evolution of feathers is poorly understood, and the homology of feathers to other skin derivatives, especially scales, remains contentious. Here, we take a new approach to answering these questions by comparing transcriptomes from different stages of developing feathers, different avian and reptilian scales, and claws. We performed mRNA-sequencing on different stages of skin development collected from two distantly related birds, Chicken (Gallus gallus) and Emu (Dromaius novaehollandiae), and from American Alligator (Alligator mississippiensis), a member of the extant clade most closely related to birds. Comparison of these transcriptomes allows us to investigate the homology of feathers and scales at different developmental stages. Further, they allow us to identify candidate regulatory molecules, including transcription factors and members of signaling pathways, which underlie feather novelty. Finally, to complement our transcriptome data, we used immunohistochemistry to compare patterns of expression and subcellular localization of the transcription cofactor β-catenin, the earliest known molecule expressed in feathers. Our preliminary evidence suggests that β-catenin is also present in early developing avian scales and alligator scales, suggesting these skin appendages use similar molecular pathways at the beginning of their development. Together, our data presents a new and comprehensive look at the homology of feathers and scales and the molecular basis of feather novelty.

Genetic and hormonal regulation of gonadal development and sexual plasticity in fish

Among the vertebrates, teleost fishes display the greatest diversity of sexual phenotypes, thus providing an excellent model to study molecular mechanisms of sex determination, sexual differentiation and sexual plasticity. We identified dmy as the sex-determining gene of the medaka (Oryzias latipes). Recently, we developed a gene-specific transgenic RNA interference (RNAi) technology for the analysis of loss-of-function phenotypes that develop over long periods of time, and used it to knock down the dmy gene in genetically male (XY) fish. Knockdown of dmy strongly downregulated the expression of only other male-associated genes, and upregulated the expression of female-associated genes in XY gonads during the early stages of sexual differentiation. We previously showed that a sharp decrease in estrogen production triggers female to male sex reversal in an adult sex-changing fish, the saddle–back wrasse (Thalassoma duperrey). Therefore, in this study, we used aromatase inhibitors (AIs) to block the conversion of androgens to estrogens and examined whether lack of estrogen can reverse the gonadal morphology in two adult, sexually-mature gonochoristic species, medaka and Nile tilapia (Oreochromis niloticus). Interestingly, we found that AIs were effective in blocking estrogen production and induced a complete sex reversal from females to males in both medaka and tilapia. Further, AIs were sufficient to induce not only the testicular structure, but also the phenotypic transformation including sexual behavior. Our data, for the first time in any vertebrates, has shown that sexual plasticity is preserved even in adulthood.
1.1 NAGY, KA; University of California, Los Angeles; kennagy@biology.ucla.edu

Reproductive and Neuroendocrine Projections on Becoming a Physiological Ecologist

The most important events on my path to becoming a physiological ecologist were: 1) recognizing that I was unusually strongly interested in wild animals and how they survive each day in nature, 2) learning that having such an obsession was OK and that there was a place for people like me, and 3) getting praise, encouragement and help from my teachers as an undergraduate and beginning graduate student. Those supporters included Bill Mayhew, Frank Vasek, Gene Cota-Robles, Carlton Bovell, Rudy Raibal and especially Vaughan Shoemaker, all at UC Riverside, Bill Dawson at Univ. of Michigan, Lon McClanahan at Cal State Fullerton, and George Bart Bartholomew at UCLA. All I did was ask them question about their lectures and research, and in response, they went out of their way to encourage me. I am extremely grateful for their validation of my odd fascination, their facilitation of my academic progress, and their confidence in me. Later, when I became a teacher of undergraduates and a mentor of graduate students, post-docs, and anyone else who got close enough, I simply tried to pass on what was so enthusiastically given to me. For the new person who is unusually curious and interested in how wild animals work, I suggest that you put yourself in the company of physiological ecologists, listen to them, and ask them thoughtful questions. Allow yourself to be driven by your curiosity, and by the excitement that comes from getting a satisfying (Ah-hah) answer. Your teachers and colleagues will probably be delighted to encourage and aid your progress towards becoming a physiological ecologist. And later, your professional help will be much needed as Earth’s climate and ecology continue to change, forcing wild animals to face new challenges to survival and reproduction.

3.4 NATER, O.H.A.; DILLON, M.E.; Univ. of Wyoming, Laramie; onater@uwyo.edu

Thermal time: a tool for predicting climate-induced shifts in native bee phenology

Climate change can decouple the relationship between insect pollinators and their host plants by differentially shifting their phenologies (abundances over time), raising fear of a potential pollinator crisis. For many insects, spring emergence is directly dependent on temperature, but we lack data on the relationship between climate and phenologies of most pollinators. Here we present a novel thermal time approach to estimate climate change–induced shifts in the spring emergence of four locally abundant native bee taxa (Agapostemon angelicus/texanus, Lasioglossum Dialictus spp., Lasioglossum trizonatum and Halictus rubicundus) in southeast Wyoming. We used 2011 bee abundance data to estimate degree days necessary for 50% population emergence. These degree-day estimates accurately predicted 2012 emergences to within ten days. Since 1975, annual mean, minimum, and maximum temperatures in the area have increased by 1.3, 2.7, and 1.3 °C respectively. Based on 2011 degree–day estimates and assuming no evolution, we estimate springtime phenology of native bees to have advanced by roughly two weeks over the same period. While this approach is not perfect, likely because it does not account for other abiotic and biotic phenological drivers, it is nevertheless a straightforward, low–cost tool for predicting insect species responses to climate warming. In light of the paucity of historical data for most species of interest, this approach could prove useful for identifying and mitigating potential disruption of crucial plant–pollinator interactions.

66.1 NAIR, S.*; BAROCAS, J.; HADISOLOMOU, S.; GRASSO, F.W.; Brooklyn College, City University of New York; savithrinair@yahoo.com

Chemosensory and Mechanosensory Mediation of Inter–sucker Coordination in Octopus bimaculoides

Coleoid cephalopods possess suckers on their arms and tentacles but Octopus suckers are distinguished by their extrinsic muscles which permit the animal to move them independently of arm motions. The neuroanatomical sensory–motor structures (ganglia, nerve roots and tracts) of the suckers and arms that support arm–sucker coordination have been mapped, but the information that is shared between them has not been thoroughly explored. We hypothesized that mechanical and chemical stimulation of a single sucker would be communicated to adjacent suckers. We found significant responses (movements made after stimulus application) to both types of stimuli in neighboring suckers. This relationship diminished with distance from the stimulated sucker. We also hypothesized that different chemical stimuli and different mechanical loads would elicit different types of reactions from the nearby suckers. Different types of chemical stimuli (low or high pH, octopus extract and artificial sea water, a neutral stimulus,) suspended in agar elicited differential reactions from neighboring suckers when placed in contact with a focal sucker. Different mechanical loads also produced differential responses in that recruitment of responses from suckers neighboring the stimulated sucker increased with load. We found a tendency for suckers proximal and distal to the stimulated sucker to respond differently to a given level of stimulation (chemical or mechanical). Our results demonstrate new functional properties of the sensory–motor neural networks that underlie arm–sucker coordination in Octopus.

S5–1.3 NAVARA, KJ; Univ of Georgia; knavara@uga.edu

Stress, hormones, and sex: how do we solve the puzzle of sex ratio adjustment in birds?

Ecologists and evolutionary biologists have shown time and again that birds have a striking ability to vary the ratios of male and female offspring they produce in response to environmental and social conditions. However, even after decades of similar observations, the physiological mechanisms responsible for the adjustment of offspring sex by birds remain elusive. What do we know is that female birds target hormones to the egg contents and utilize them to program the growth, development, and other phenotypic variables of their offspring for the environment into which they will hatch. It seems logical, then, that they might also use these hormones to adjust the sexes of offspring as well. Indeed, several studies have shown that situations that provoke the release of reproductive and stress hormones also provoke skews in offspring sex ratios, and that direct treatment with these hormones can also induce similar skews. We now need to address how the hormones may be acting, and at what point in the reproductive process offspring sex is being manipulated. We have shown that both testosterone and corticosterone can influence which sex chromosome is donated by the heterogametic bird, however these effects require exposure at a very specific time during ovulation and at a very specific dosage. In addition, the effects of these hormones are often inconsistent and likely depend upon other factors such as body condition and environmental variables. The adaptive significance of using hormones to mediate sex ratio adjustment depends on both the cellular mechanisms by which the adjustment of offspring sex occurs as well as how the use of those hormones fits into the larger environmental picture.
Expression of Wnt pathway genes in Ectopleura larynx (Hydrozoa: Aplanulata) and implications for their potential role in hydrozoan life cycle evolution

The canonical Wnt signaling pathway is conserved in its role in axial patterning throughout Metazoa. In hydrozoans (Phylum Cnidaria), Wnt signaling is implicated in oral–aboral patterning of the planula, polyp and medusa. Here, we present gene expression data for Wnt pathway components in the hydrozoan species Ectopleura larynx. Using next–generation sequencing, we isolated genes from the canonical Wnt signaling pathway and examined their expression in E. larynx. Unlike most hydrozoans, E. larynx lacks a larva and the polyp instead develops directly from a brooded embryo. These embryos develop within gonophores that represent a truncated medusa stage of the hydrozoan life cycle, with gonophores of E. larynx retaining evolutionary remnants of medusae, including tentacles. Our data are consistent with the Wnt pathway being involved in axial patterning of both the polyp and elements of the truncated medusa. Specifically, changes in the spatial expression of Wnt pathway genes are correlated with the development of different oral structures in male and female gonophores. The absence of expression of components of the Wnt pathway, and presence of a Wnt pathway antagonist in the developing anterior end of the gonophore, suggest that downregulation of the Wnt pathway may be implicated in the evolution of medusa reduction in Hydrozoa.

Differential limb function during locomotion on the level and over obstacles in the tarantula

Understanding how the motor control system maintains sufficient flexibility to navigate the natural variability of the environment is important for elucidating evolutionary mechanisms, robotic design, and understanding disease states. The goal of this study was to determine the function of different limbs during steady state running and obstacle maneuvering in spiders. We ran five juvenile Usambar Orange Baboon tarantulas (Pterinochilus murinus) (body length: 1.4±0.1 cm) along a flat trackway while filming the dorsal view. We also ran the spiders across obstacles of 0.5x, 1x, and 2x knee height. On average, spiders ran at 25 ± 3 cm/s and did not appear to slow down on the 0.5x and 1x obstacle treatments. We found limb function differed among the four sets of limbs. The posterior (fourth) set of legs functioned as propulsors, as evidenced by large changes in effective limb length (‘eLL; 43.2±5.13 %) and the small angle of excursion (20.4±3.4°) during a stride. Similarly, the first (anterior) set and second set of limbs also exhibited large ‘eLL (57.3±2.26% and 49.5±8.9%, respectively), but swept through a greater excursion angle (61.6±4.8° and 59.4±5.8°, respectively), suggesting they played both a propulsive and stabilizing function. In contrast, the third set of legs were mostly extended throughout a stride (‘eLL: 15.4±1.6 %) and followed a large excursion angle (44.3±4.0°), consistent with a stabilizing function. Preliminary results suggest some change in limb function during obstacle crossing, with the first set of legs taking on a sensory role in locomotory role, while the fourth set of limbs maintain a primarily propulsive function.

Regulation of metamorphosis in Hydroides elegans: not what we thought

Larvae of the serpulid polychaete Hydroides elegans require contact of their episphere with specific bacterial substrata to initiate metamorphosis. While apical sensory organs (ASO) have long been thought to bear receptors for metamorphic cues, we have recently shown that laser–ablation of the ASO in these larvae does not inhibit metamorphosis. To investigate alternate sites of this chemoreception, we used immunohistochemistry and pharmacological assays to determine if cells expressing catecholamines or nitric oxide (NO) are necessary for the induction of metamorphosis. Antibodies raised against tyrosine hydroxylase, an enzyme required for catecholamine biosynthesis, labeled numerous sensory cells within the larval episphere. One or two hr exogenous pulses of the catecholamines dopamine (DA), noradrenalin (NA) and adrenalin (AD) induced larvae of H. elegans to metamorphose in the absence of biofilms. Because AD is synthesized from both DA and NA, it may be used to transmit inductive cues within the central nervous system of H. elegans. Consistent with these data, antagonists to ±–adreno–receptors inhibited metamorphosis. Contrary to the responses of other invertebrate larvae, application of agents that act as NO synthase inhibitors, NO scavengers, and NO donors had no effect on metamorphosis, suggesting that NO may not play a role in regulating metamorphosis in H. elegans. Taken together, these data suggest that, within Lophotrochozoa, there is evolutionary plasticity in the detection of metamorphic triggers, transmission of inductive cues, and the responses of target tissues to metamorphic signals.

Evolutionary morphology of the prehensile tail in syngnathid fishes: from pipelike to seahorse

Seahorses and pipehorses both possess a prehensile tail, a unique character among teleost fishes, allowing them to grasp and hold onto substrates, like sea grasses. Recent phylogenetic studies suggest that the prehensile tail in syngnathid fishes evolved more than once and also suggest the existence of intermediate forms in the lineage giving rise to the seahorses. The caudal system of the seahorse is characterized by parallel myoseptal sheet spanning multiple – up to eight – vertebrae (compared to a conical organization in pipefishes), the presence of medial ventral muscles (absent in pipefishes) and by the reduction of the caudal part of the dermal plates covering the body (compared to solid bony arm in pipefishes). How this system could evolve is still unknown. In this study, we compared the tail morphology of seahorses and pipefishes with (1) the musculoskeletal system of two species belonging to the lineage giving rise to the seahorses, i.e. the bastard seahorse (Acentronura gracilissima) and the ribboned pipehorse (Halihichthys taeniophorus), expecting to find an intermediate morphology with characteristics of both seahorses and pipefishes and (2) the tail morphology of three pipehorse species that are nested within the pipefish lineages, expecting to find different convergent strategies to obtain a prehensile tail. To test these hypotheses, µCT-scanning and histological sectioning were combined with 3D-reconstructions.
Knifefish surfage like eels while heaving like trout

Knifefish generate thrust with their elongated ventral anal fin. This ribbon fin has over 100 bony rays, which oscillate laterally around the fulcrum at the base of the fin. When viewing a transverse section of the fin, the oscillatory kinematics of one ray resemble the flapping motions of the caudal fin of a trout. However, the rays oscillate with certain relative phases to one another, creating a traveling wave along the longitudinal axis of the fin similar to the undulatory body motions of a swimming eel. Using a robotic ribbon fin with 32 oscillating rays connected with a fabric fin, we investigate how the flow structure generated by the ribbon fin compares with flow structures generated by eel-like and trout-like swimming. We use particle imaging velocimetry to visualize orthogonal planes transecting the wake of the fin. A propulsive jet emanates at an angle ventral to the ribbon fin, with the strongest part of the jet occurring just posterior of the fin. A horizontal slice through the jet shows a reverse Von Kármán vortex street, the same vortex pattern that is shed off of the oscillating caudal fin of a trout. 3D simulation of the fin-fluid interaction confirms that this vortex pattern originates from the oscillatory motion of the rays and that shed off of the fin ventrally along the heave axis. The eel-like traveling wave of the fin adds momentum to the fluid longitudinally along the surge axis, reorienting the vertically shed trout-like structures along the angled axis of the jet. This reorientation could be an accidental side effect with negative consequences for thrust, or it could actually accentuate the thrust. Regardless, the resulting flow structure combines features evident in the wake of both the trout and the eel.
26.1 NIITEPOLD, K*; PEREZ, A; BOGGIS, CL; Stanford
University; niitepold@stanford.edu

Pieris niitepoldi: Resting and flight metabolic rate,
fecundity and longevity

Deciding how much to invest in survival and reproduction is fundamental for all organisms, especially when the available resource pool is limited. Resource availability can be affected by small-scale disturbances such as weather conditions or herbivory, or large-scale environmental changes such as habitat loss and fragmentation, and climate change. To understand the mechanistic basis of population dynamics in a changing world we need experimental work on resource allocation under stressful conditions. We limited adult food intake in two butterfly species with different ecologies and life-history strategies: Colias eurytheme and Speyeria monneta. Colias is multivoltine and has no larval diapause; Speyeria is univoltine and has no larval diapause. Females were hand-fed twice a day. We measured the unlimited sugar–water intake of control females and gave treatment females half of that. We found that body mass decreased with age in both treatments, but females fed ad lib were clearly heavier than food limited females. Mass–corrected peak flight metabolic rate was not affected by food limitation. This indicates that flight capacity is conserved, which may allow dispersal to more favorable areas. Flight is also critical for most other life-history traits. Lifespan was not affected by food reduction. Fecundity was sacrificed in both species. The decrease in fecundity was stronger in Speyeria. This may be due to a high ratio of adult–derived carbon in Speyeria eggs, a likely consequence of larvae relying on solely maternal resources during the winter. Control females had higher resting metabolic rate in early life. This may reflect the energetic cost of egg production which food limited females could not bear. Food limitation results in lower fecundity and may reduce population growth rate, but the sensitivity of each species is related to its life-history strategy.

123.5 NOH, S*; HAHN, DA; MORGAN, TJ; Kansas State
University; surgene.noh@gmail.com

The genetics of cold tolerance in fruit flies dissected using bulk segregant analysis of artificial selection lines

A species ability to adapt to cold temperatures can determine species distributions and influence seasonality. Drosophila melanogaster, the fruit fly, falls into a reversible coma when exposed to zero subzero temperatures. The recovery time is variable among individuals within the species, as well as populations along latitudinal clines, and also among other Drosophila spp. Chill coma recovery (CCR) is affected by developmental temperatures as well as previous exposures to cold. More significantly, it is possible to select flies for increased or decreased CCR, reflecting the significant genetic component underlying this trait. We used a bulk segregant analysis to dissect the genetics of this ecologically important complex trait. Previously, two replicate artificial selection lines were created from a single wild–caught population for high and low CCR. Two F2 populations were generated from each replicate and pooled Illumina sequencing libraries were prepared from the top and bottom 2.5% of each replicate phenotypic distribution. 50 bp paired–end reads from these libraries were sequenced on 4 lanes of an Illumina HiSeq 2000 instrument. Reads were aligned using a custom 2 step (stringent, then lenient) alignment procedure. Alignments were realigned around indels, bases recalibrated for platform and experiment–specific covariates, then used for variant calling and recalibration. We used a modified G–test to detect allele frequency shifts in the two replicate F2 populations. Variants exceeding a false discovery rate threshold were used to identify candidate genes that were common to the two replicates in order to identify biological processes relevant to CCR. These candidates were compared to results from a parallel association mapping experiment using the Drosophila Genetic Reference Panel.

13.9 NOREN, SR*; TRIGGS, L; OLAND, L; PASCHKE, J;
KRAMER, AW; UDEVITZ, MS; JAY, CV; University of California,
Santa Cruz; Point Defiance Zoo and Aquarium, Indianapolis Zoo, Six Flags Discovery Kingdom, U.S. Geological Survey, U.S. Geological Survey; snoren@biology.ucsc.edu

Body Condition and Caloric Demand of Female Pacific Walruses (Odobenus rosmarus divergens)

With declining sea ice availability, walruses are increasing their use of terrestrial haul–outs, which could deplete localized prey resources. Estimates of caloric demand and techniques for monitoring body condition are required for assessing the potential for population level effects on walruses. Caloric intake and body condition (length, girth, and blubber thicknesses) were measured monthly over one year from non–reproductive female walruses housed at Indianapolis Zoo (n = 1); Twater = 18.7 ± 14ºC, Tair = 12.2 ± 0.1ºC, Six Flags Discovery Kingdom (n = 2); Tair = 19.6 ± 6ºC, Twater = 13.9 ± 4.5ºC), and Point Defiance Zoo and Aquarium (n = 2; Tair = 13.8 ± 7ºC, Twater = 10 ± 2ºC). These individuals had an average (±SD) annual body mass of 683 ± 11 kg, 747 ± 14 kg, 764 ± 28 kg, 716 ± 28 kg, and 936 ± 27 kg comprised of 24 ± 2%, 26 ± 2%, 27 ± 2%, 27 ± 1%, and 30 ± 1% blubber, respectively. These body conditions were maintained with an average of 31,249 ± 4,449 kcal dy−1, 26,847 ± 4,100 kcal dy−1, 20,123 ± 4,247 kcal dy−1, 32,065 ± 5,448 kcal dy−1, and 29,403 ± 4,474 kcal dy−1. Based on our published bioenergetics model, these caloric intakes represent 61%, 47%, 35%, 45%, and 48% of those required by wild non–reproductive female walruses of equivalent body size. Much of this discrepancy is likely due to differences in activity level between captive and wild animals, as our bioenergetics model assumed that animals are active 83% of the time. Nonetheless, the basic physiology measured from animals in human care provides bounds on parameters used in bioenergetic models and serves as a basis for developing criteria for assessing body condition of wild walruses.
Locomotion with constant ventral contact in skinks: a three-dimensional kinematic and dynamic analysis

Fossilized tracks attributed to members of the Caphthorinidae, a group of fossil early amniotes, imply a constant ventral contact between the animal and the substrate during locomotion. During this belly-walk, the trunk is not or only partially lifted off the ground. In extant saurians belly-walking is found in many skinks (Lepidosaurier, Scincidae), rendering them as potential extant models for caphthorinid locomotion. We investigated the biomechanics of locomotion in blue-tongued skinks (Tiliqua scincoides) in order to better understand how propulsion is generated during locomotion in species with constant ventral contact with the substrate. We combined markerless X-ray of moving morphology (XROMM) with the measurement of single limb substrate reaction forces. Biplanar X-ray recordings of two animals during locomotion on a treadmill were taken in order to three-dimensionally analyze locomotor biomechanics over the complete sustainable speed range of the skinks. Subsequently, the skinks were motivated to transverse a trackway instrumented with two 8 x 9 cm custom built force plates. Bone morphology was reconstructed from CT scans of the same individuals. 3D kinematic profiles and single limb substrate reaction force traces are presented. 3D kinematics demonstrate limbs to function according to the double crank system previously described for salamanders. The vertical component of the substrate reaction force is significant enough to substantially reduce frictional forces between the smooth-scaled belly and the substrate. The substrate reaction force vector is used to assess moment arms acting at the elbow, shoulder, knee, and hip joints over time. An additional analysis of the tracks produced by the skinks implies comparable locomotor mechanics in skinks and the fossil Caphthorinidae.

Multiplying mitochondria in the cold: how do fish do it and why?

High mitochondrial densities are characteristic of oxidative muscles in cold-bodied fishes. There is a latitudinal trend in mitochondrial abundance, with Antarctic fishes displaying the highest densities. Antarctic icefishes, lacking hemoglobin, are at the extreme end of this continuum, with mitochondria displacing as much as 52% of the cell volume in some species. High mitochondrial densities enhance ATP production and minimize diffusion distances for oxygen and metabolites in the cold. Previous studies have shown that mitochondrial-rich muscles may be necessary for cold-adapted fishes because mitochondrial function has not completely compensated for the cold. We measured rates of respiration and proton leak in mitochondria from both red- and white-blooded Antarctic fishes and found that state III respiration rates are similar to some temperate fish, and most surprising, proton leak is markedly lower. These results suggest that high mitochondrial densities in muscles of Antarctic fishes may be more important for minimizing diffusion constraints than compensating for inefficiencies. How high mitochondrial densities arose during the evolution of Antarctic fishes, and in icefishes in particular, is largely unknown. Our studies suggest membrane proliferation played a role in icefishes, in a pathway distinct from mammalian mitochondrial biogenesis.

Ocean acidification weakens attachment of Mytilid mussel byssal threads

Organism interactions with the physical environment are mediated by biological structures such as shells, which isolate organisms from the external environment, and adhesives, which keep organisms located in suitable habitat. Like many chemical processes, creating these structures takes place in the context of the local seawater chemistry. Many investigations have explored the effects of altered carbonate chemistry on the rate at which structures are produced, but little is known about the relative quality of these materials for performing their assigned tasks. Here we report on the properties of biological materials created by Mytilus trossulus exposed to a range of pCO2 conditions (from ~400 to 1600 µatm) to elucidate the shape of the response curve. Byssal threads attach Mytilid mussels to the shore. Most regions of these threads showed no variability in response to altered pH with the exception of the adhesive that secures the thread to the substratum which showed a significant decline in tenacity. Additional metrics, including gonad index, shell strength, and overall condition also showed no effect of CO2. However, byssal thread weakening likely compromises the ability of the byssus structure to hold individuals to the substratum.
Evolutionary origins of an animal light interaction tool-kit

Eye evolution is touted as a prime example of deep homology, whereby novel structures arise sometimes convergently – by modification of homologous regulatory circuits that draw upon a common genetic tool kit. What is this genetic tool kit, how common is it, and when and how did its components originate? Here I discuss a light interaction toolkit (LIT) of genes and examine its evolution. LIT genes variously function in sensing, blocking, bending, and reflecting light or in developmental processes to specify cells and organs that interact with light. First, I highlight that LIT genes are often used in cells outside of eyes, for example, in dispersed photoreceptors and in light-producing organs. While some genes like opsin have very ancient origins and conserved light interaction function, several LIT genes have recent origins and/or newly function in light interaction. Light interaction genes indicate that while deep homology is a galvanizing concept of the genomic era that is valid in some instances, we must take care not to over-generalize and miss the rich variation of the evolutionary process.

A single origin for nymphalid butterfly eyespots followed by widespread loss of associated gene expression

Understanding how novel complex traits originate involves investigating the time of origin of the trait, as well as the origin of its underlying gene regulatory network in a broad comparative phylogenetic framework. The eyespot of nymphalid butterflies has served as an example of a novel complex trait, as multiple genes are expressed during eyespot development. Yet the origins of eyespots remain unknown. Using a dataset of over 400 images of butterflies with a known phylogeny, and gene expression data for five eyespot-associated genes from over twenty species, we tested origin hypotheses for both eyespots and eyespot-associated genes. We show that eyespots evolved once within the family Nymphalidae, approximately 90 million years ago, concurrent with expression of at least three genes associated with early eyespot development. We also show multiple losses of expression of most genes from this early three-gene cluster, without corresponding losses of eyespots. We propose that complex traits, such as eyespots, may have originated via co-option of a large pre-existing complex gene regulatory network that was subsequently streamlined of genes not required to fulfill its novel developmental function.

Evolution of animal clock: an echinoderm prospective

Almost all living organisms show circadian rhythmicity. Endogenous time-keeping mechanisms that regulate daily physiological and behavioral processes are genetically encoded and show a conserved network structure. Comparative studies highlighted a transcriptional–translational oscillator (TTO) based on interlocking negative feedback loops as key circadian clock network architecture. Molecular and cellular components of circadian clocks have been extensively characterized in land animals such as mammals and insects. In contrast, less is known about clocks in marine organisms despite the fact that the marine environment is characterized by an interplay of multiple periodicities and complex life cycles. To better understand metazoan circadian clock evolution, we are undertaking a molecular analysis of clock genes and their expression in the sea urchin, S. purpuratus. A genome survey identified in sea urchin both protostome and deuterostome components indicating a more complex origin of the metazoan clock tool-kit. Our comparative genomic analysis revealed a high plasticity of negative players of the TTO during animal evolution. Temporal gene expression analysis during sea urchin development showed that almost all of the clock genes are maternally expressed with decay around blastula stage, consistently with a potential role in gametogenesis. Many of them are also expressed later in development and at free–living larval stages. However, we have found no evidence of oscillatory genes expression during embryonic development. On the contrary, fully differentiated larvae, once exposed to different light regimes, show circadian oscillations of few clock genes. Their cellular localization, using high-speed video, then used inverse dynamic modeling to calculate kinematics, moments, powers, and work for the ankle, knee, and hip of one hindlimb, around each of the three axes of rotation. The correct positioning of the limbs prior to jumping was necessary to effectively generate power at the joints. Prior to jumping, the lizards took a small step forward bringing the hindlimbs into a crouched position with the feet oriented forward along the long axis of the body. A more laterally oriented foot at the start of the jump reduced the angular excursion of ankle extension resulting in a lower peak power and less work from that movement. Ankle and knee extension and femur retraction did the majority of positive work during the jump and more work was done by knee extension and femur retraction in jumps with a higher peak COM velocity. Increasing the angle of the body relative to horizontal at takeoff decreased the work done by knee extension and the peak power output at that joint. These results suggest that the individual joints may be modulated differently when whole–animal performance increases.

Three-dimensional joint mechanics and kinematics of jumping lizards

Hindlimb kinematics are often examined and related to locomotor performance in lizards, but establishing a causal link between individual joint movements and whole–animal performance requires an understanding of joint mechanics. This study examines the mechanical contributions of each hindlimb joint movement and the patterns of joint mechanics that result from increased demand on the hindlimb (increased whole–animal performance) during jumping, an ecologically important form of locomotion for many species of lizards. We placed collared lizards, Crotaphytus collaris, on a custom 6-axis force plate and encouraged them to jump onto a vertical wall near the force plate. We recorded simultaneous force data and 3D high-speed video, then used inverse dynamic modeling to calculate kinematics, moments, powers, and work for the ankle, knee, and hip of one hindlimb, around each of the three axes of rotation. The correct positioning of the limbs prior to jumping was necessary to effectively generate power at the joints. Prior to jumping, the lizards took a small step forward bringing the hindlimbs into a crouched position with the feet oriented forward along the long axis of the body. A more laterally oriented foot at the start of the jump reduced the angular excursion of ankle extension resulting in a lower peak power and less work from that movement. Ankle and knee extension and femur retraction did the majority of positive work during the jump and more work was done by knee extension and femur retraction in jumps with a higher peak COM velocity. Increasing the angle of the body relative to horizontal at takeoff decreased the work done by knee extension and the peak power output at that joint. These results suggest that the individual joints may be modulated differently when whole–animal performance increases.
Dabbling, grazing and diving: Skull shape is related to beak foraging behaviors in the avian order Anseriformes

Anseriforms, the avian order that includes ducks, geese, swans and mergansers have a diversity of beak shapes and foraging behaviors, including grazing, diving and dabbling. This morphological diversity is not limited to the beak, however. Posterior to the upper bill, lie kinetic (mobile) cranial bones that enable rotation of the upper bill relative to the braincase (cranial kinesis) and these bones also have diverse morphologies. Given that these bones transmit force to the upper bill and given the diverse functional requirements of beaks among anseriforms we tested whether the morphological diversity of these bones is explained by the efficiency with which different morphologies transmit force or motion to the upper bill. We collected 3D morphometric data from more than 80 specimens representing more than 30 genera in Anseriformes. Using a custom static force model, we predicted the torque at the upper bill given an input torque to the quadratic. Within Anseriformes, upper bill–torque transmission ranged from 0.93 to 1.87, where lower values correspond to displacement amplification and higher values correspond to force amplification. Additionally, grouped by foraging behavior, dabblers have lower torque transmission values than grazers and deep divers. Thus, we find support for our hypothesis: anseriforms with foraging behaviors expected to require more force (grazers and deep divers) have linkage morphologies that more efficiently transmit force through the linkage bones to the upper bill relative to anseriforms with beak behaviors expected to require continuous motion and lower force (dabblers).

Environmental Modulation and Endocrinological Correlates of Same−Sex Affiliative Behavior in Female Meadow Voles

The prevalence of female−biased affiliations in group−living mammalian species suggests that same−sex relationships are of particular importance for females. However, little is known about the influence of environmental and physiological factors on same−sex social bonds. Female meadow voles present an interesting opportunity for the investigation of these questions because free−living females display seasonal variations in same−sex affiliation. As they transition from summer to winter, females transition from an aggressive, territorial phenotype to an affiliative, group−living phenotype. The thermometabolic advantages of huddling have been offered as an explanation for winter sociality in meadow voles; thus, we designed a study to assess the effects of ambient temperature, day length, food availability, and frequency of handling on same−sex affiliative behavior and several potential physiological correlates. In a separate study, group size and social preferences were evaluated in male and female meadow voles. Our findings suggest that: 1) day length, food availability, and ambient temperature interact to regulate same−sex affiliative behavior in female meadow voles; 2) low temperature exposure can modify social preferences without increasing huddling behavior; 3) differences in huddling modulate plasma corticosterone and estradiol without modifying same−sex affiliation; 4) under certain environmental conditions, variations in same−sex affiliative behavior are correlated with plasma corticosterone and estradiol; and 5) the propensity to join a group consisting of novel individuals varies by day length and sex.
In marine environments, ocean warming and ocean acidification, both consequences of anthropogenic production of CO₂, will combine to influence the physiological performance of species. In this study, we used an integrative approach to forecast the impact of future ocean conditions on larval purple sea urchins (Strongylocentrotus purpuratus) from an area of the Northeast Pacific Ocean already affected by climate change. In laboratory experiments that simulated ocean warming and ocean acidification, we examined larval development, skeletal morphology, metabolism and genome–wide expression under four different temperature (13°C and 18°C) and pCO₂ (400 and 1100 ¼atm) regimes. Ocean warming and ocean acidification have both singular and synergistic effects on the performance of early life stages of S. purpuratus. Simultaneous exposure to increased temperature and pCO₂ significantly reduced larval metabolism and triggered a widespread down–regulation of histone encoding genes. pCO₂ but not temperature impaired calcification and reduced the expression of a major spicule matrix protein, suggesting that calcification will not be further inhibited by ocean warming. Importantly, shifts in skeletal morphology were not associated with developmental delay. Collectively, our results indicate that climate change variables will interact to exceed thresholds for optimized physiological performance in this key marine species.
Characterizing the conversion of yolk estradiol to estrogen sulfates during embryonic development in the red–eared slider.

In the red–eared slider turtle (Trachemys scripta), the process of sex determination is estrogen sensitive, with the application of exogenous estradiol resulting in the production of female hatchlings. Because the sex of developing embryos is estrogen sensitive in this species, we have been investigating the role that maternally derived estradiol may play in sex determination. We have previously demonstrated that early in development, exogenous estradiol is metabolized via sulfonation to several estrogen sulfates metabolites. Additionally, the application of exogenous estradiol sulfate to developing eggs influences sex determination in much the same manner as estradiol itself. This study examined the metabolic fate of endogenous estradiol by measuring maternally derived estradiol at oviposition and comparing those levels to levels of estrogen sulfates (estradiol sulfate, estrone sulfate, and estriol sulfate) both at the time of oviposition and after 20 days of development. We found that estrone sulfate was the only detectable estrogen sulfate and that levels increased over the first 20 days of development. Also, clutches with higher estradiol levels in the yolk had significantly higher estrone sulfate levels at both day 0 and day 20. Together these data suggest that maternally derived estradiol is converted to estrone sulfate during development. We are currently investigating the effect of estrone sulfate on sex determination.

Endosymbiosis in an Anchialine Crustacean

Sulfidic marine habitats, such as the benthic intertidal and hydrothermal vents, are widespread. Fauna in these ecosystems have developed many physiological and morphological adaptations to cope with the depleted oxygen and toxic sulfide levels typical of such habitats. In addition, many invertebrates, such as mussels, have evolved epiphytic chemosymbioses with chemosynthetic bacteria for host nutritional benefit. Surprisingly, only epibiotic chemosymbionts have been described in members of the Crustacea. Here, we present the first findings of chemosynthetic endosymbiosis in the Crustacea, as exhibited in Typhlatya pearsi (Aristaeidae; Malacostraca), a shrimp endemic to anchialine caves. In these karst systems, marine layer flows beneath one or more layers of less saline water and water exchange with nearby oceans is severely restricted, creating stable physico–chemical gradients often characterized by anoxia and high sulfide levels. Transmission Electron Microscopy (TEM) of cave shrimp have revealed numerous and likely symbiotic gram−negative bacteria found in specialized bacterioocytes. In addition, Scanning Electron Micrographs (SEM) suggest that Remipedia (Speleonectes tulumensis), a class of Crustacea endemic to anchialine systems, as well as T. pearsi are also colonized by epibiotic bacteria. TEM analyses of both taxa have also reveal morphological adaptations typical of hosts containing sulfide oxidizing symbionts, such as clustered mitochondria in epithelial cells surrounding sulfide oxidizing bodies. Stable isotope analyses further support chemosymbiotic food sources in these crustaceans. These data suggest that a greater phylogenetic diversity of hosts and more ecosystem types support intracellular chemosynthetic mutualisms than we previously thought.

Complex interplay of body condition, life–history, and prevailing environment shape immune defenses of garter snakes in the wild

Evidence for links between ecology, immune function, and life–history strategy remains contradictory; especially regarding the pace–of–life (p–of–l) hypothesis that proposes that fast–living organisms should invest more in innate immune defenses and less so in adaptive defenses compared to slow–living ones. Some support for this hypothesis has been found in two life–history ecotypes of the garter snake Thamnophis elegans: fast–living individuals show higher levels of three innate immune indices compared to slow–living ones. Here we assess the complementary prediction that slow–living individuals should in turn show stronger adaptive defenses. We also tested the alternative hypothesis that differences in immune defense are the result of contrasting environmental conditions currently faced by the organisms. This environmental hypothesis predicts the opposite pattern for the garter snake system: slow–living individuals should show lower levels of innate immune defenses (both innate and adaptive) compared to fast–living ones given the harsher environmental conditions (lower temperature, lower and less predictable food availability, and presence of trematode parasites) they face in their habitats. In vitro B– and T–lymphocyte proliferation responses were on average higher in slow–living snakes, opposing the pace–of–life and supporting the environmental hypothesis. Nevertheless, our results do not negate an influence of life–history on immune defenses: while proliferation of B– and T–lymphocytes increased with increasing body condition in slow–living snakes, the opposite relationship was found in fast–living ones.
10.1 PANKEY, MS*; OAKLEY, TH; Univ of California, Santa Barbara; sabrina.pankey@lifesci.ucsb.edu
Parallel molecular signatures underlie convergent evolution in two bioluminescent squid

The phenomenon of convergent phenotypic evolution fascinates biologists, largely because the extent to which convergent molecular processes drive convergence at the phenotypic level remains unclear. Natural selection is frequently invoked to explain how taxa facing similar biotic or abiotic pressures may arrive at similar phenotypic solutions. This study seeks to understand if the range of possible molecular solutions for a complex trait is similarly limited. Cephalopod molluscs include two distinct clades of squid that harbor closely related strains of luminous bacterial symbionts within elaborate, optically enhanced organs called photophores. Using next-generation sequencing, we have generated transcriptomes from two divergent squid to characterize the gene expression patterns of bacterial photophores that have originated independently. Comparisons between these transcriptomes have uncovered striking similarities in the molecular profiles underlying these distinct traits. Notably, homologous genes known to be involved in mediating pathogenicity, bacterial recognition, and light perception are highly expressed in both organs. Within each species, additional transcriptional similarity between eyes and photophores suggests a molecular mechanism for the functional convergence observed in these traits. This study contributes not only to symbiosis biology, but also to our understanding of how similarity in molecular profiles relates to morphological and functional similarity.

41.5 PARSLEW, B; The University of Manchester, UK; ben.parslew-2@postgrad.manchester.ac.uk
Simulating and Visualising Flapping-Wing Flight

Predictive simulation methods have previously been used to model animals walking, running, galloping and hopping. These methods have been applied extensively to the prediction of kinematics of human terrestrial locomotion and, more recently, have been used to simulate animal flight. One of the key challenges in applying this approach to flight is selecting a modelling strategy that accurately predicts fluidic forces, which are more significant than inertial forces in most flight conditions. Many of the available methods of fluid dynamic analysis are computationally expensive and therefore not appropriate for use in a predictive simulation approach. This presentation reports on the progress made in developing a generic theoretical model that can be used to simulate a range of flapping-wing species in different flight conditions. The results of this work are illustrated through animated visualisations of the Rock Pigeon in cruising, accelerating and climbing flight. Predicted flight kinematics are validated through comparison with experimental data and the model is shown to be capable of capturing the strong kinematic similarity that is observed between flying animals of varying scale.

143.3 PARRILLA, L.*; OWERKOWICZ, T.; OMORI, M.; HICKS, J.; ROURKE, B; California State University, Long Beach, California State University, San Bernardino, University of California, Irvine; leah.parrilla@student.csulb.edu
Myocardial stress and Myoglobin expression in cardiac tissue of Hypoxic and Hyperoxic reared Alligator mississippiensis (A.m.)

We use Alligator mississippiensis (A.m.) as a model species of longevity and adaptability. Incubated A.M. eggs were raised in oxygen conditions of 16%, 21%, 26%, 31%, and 36% representative of oxygen levels over the last 500my. We hypothesized that A.m. raised in hypoxic environments would have constraints on cardiovascular load thus increasing oxygen related protein expression and myosin heavy-chain (MyHC) plasticity related to cardiovascular demands. Heart was examined at embryonic, hatching and post-hatching time points as indicators of phenotypic plasticity to differing oxygen environments. No differences in MyHC expression were found between hypoxic and hyperoxic treatment groups although typical growth related shifts from fast contracting alpha isoforms to the slower more economical beta isoforms were seen only in right atria. Myoglobin (Mb), a major oxygen storage protein in cardiac muscle was identified in the hypoxic treatment groups using 2-D proteomic analysis. Hyperoxic alligators also expressed heat shock proteins 70A, 70B, and 27 suggesting increased loading as a contributor to myocardial stress. Additional identification and quantification using SDS-PAGE mini gels combined with mass spectroscopy found hypoxic treatment groups were expressing significantly higher levels of Mb in the right ventricle. Mb may be contributing to a compensatory response in hypoxic alligators. Funded by NSF grant:IOS-0922627 NSF RUI

110.3 PARSONS, KJ; POWDER, KE; ALBERSTON, RC*; Univ. of Glasgow, Univ. of Massachusetts, Amherst; rcraigalbertson@gmail.com
Wnt-signaling and the evolvability of cichlid craniofacial diversity

Evolvability refers to a population or clades ability to evolve in space or time. It deals with both constraint and opportunity, and has profound implications for how biodiversity arises and is maintained over time. East–African rift–lake (EA) cichlids are unquestionably one of the most successful adaptive radiations of any living organism, making them an ideal system in which to examine evolvability in the context of rapid diversification. Here we show that expanded Wnt–signaling has facilitated the evolution of phenotypic novelty and ecological opportunity in this group, but has done so at the expense of evolvability. Specifically, we show that increased Wnt–signaling is associated with the development of lineage specific craniofacial morphology, and that experimental modulation of Wnt–signaling recapitulates natural variation in craniofacial form. We demonstrate further that relative to other closely related and phenotypically similar species the lineage at the extreme end of EA cichlid craniofacial diversity expresses an adult phenotype much earlier in development, suggesting that the source of novel craniofacial variation may involve shifts in developmental timing. Moreover, this species expresses a phenotype that is both more robust to environmental change and more sensitive to molecular perturbation, which should act to limit adaptive responses. In short, the evolution of phenotypic novelty has increased ecological opportunity, but potentially at the expense of future evolution. These data offer some of the first empirical support for long–standing theories in evolutionary biology, and have important implications for the evolution and maintenance of biodiversity.
In the larvae of most protostome invertebrates, detection of directional light is facilitated by simple pigmented eyes containing rhabdomeric photoreceptor cells. To extend the understanding of protostome eye evolution, we have investigated photoreceptor morphology, opsin expression, and photoreceptor behavior in the articulate brachiopod Terebratalia transversa. Terebratalia develops as a distinctive, free-swimming trilobed larva with multiple pigmented eye spots, before metamorphosing into the sessile benthic adult form. Our analysis of the cells of the Terebratalia larva eyes has shown that they have the morphology of ciliary photoreceptors, distinct from the rhabdomeric photoreceptors in the eyes of most other protostomes. Consistent with this, we have also found that a ciliary opsin gene is expressed in these cells. In addition, both the ciliary opsin gene and a Go opsin gene are expressed early on in embryonic development, before neural differentiation is observed. This early expression is associated with a positive photoreceptor by the embryo, suggesting this behavior may be mediated by a cell-autonomous modification of ciliary beating in response to light. These findings provide novel models for understanding the increase in complexity during the course of eye evolution.

Many insects are known to augment their respiration via rhythmic tracheal compression and re-inflation. A significant decrease in the volume of tracheal tubes during compression displaces air out of the body and likely mixes air within the tracheal system, thereby enhancing gas exchange. In carabid and tenebrionid beetles, compression of tracheae occurs mostly in the head and thorax, and only some tracheae collapse in the abdomen. Different mechanisms have been suggested to explain tracheal collapse, including collapse by contraction of surrounding muscles, abdominal or thoracic pumping, auto-ventilation by leg or wing movement, and hemolymph transport. None of these hypotheses have been investigated in detail, and the mechanism of tube collapse in most insect taxa remains unknown. To determine the mechanism of collapse in beetles, we have been probing multiple physiological processes that are correlated with tube collapse to explore possible mechanical linkages in the system. Although previous work has used synchrotron x-ray imaging to observe tracheal compression, we have been able to take advantage of small locations of transparent cuticle in the thorax, abdomen, and legs to observe compression within the lab. Additionally, we use synchronous measurements of movement, pressure, and CO2 to quantify internal and external processes while tracheae collapse. These measurements have revealed the relationship of collapse with abdominal pumping, hemolymph pressure, gut movement, and CO2 release. Simultaneous pressure pulses of different magnitude throughout the body suggest that the abdominal pump helps to produce pressure, which is mediated by gut movements and regional compartmentalization. This research demonstrates how the use of multiple coordinated processes can result in collapse of tracheal tubes and the augmentation of gas exchange. Support: NSF 0938047 (JJS).
Integrating environmental signals for reproductive timing

Most animals are required to respond to a changing environment on a daily and seasonal basis to survive and produce young successfully. In order to match internal physiology with external requirements for survival and reproduction, animals have evolved systems that allow them to anticipate and respond to changing environmental conditions. The neuroendocrine system represents the critical relay between transduction of environmental cues via sensory systems into functional changes in physiology, morphology and behavior. In order to understand how climate change impacts this process of matching internal physiology with the external environment, we must first better understand which environmental cues are relevant and how they are transduced within an animal. I will discuss how environmental cues related to activation of the reproductive system for breeding (and specifically in female birds for egg laying) elicit changes in gene expression in the brain and in peripheral tissues. Further, I will demonstrate how a single cue provided to a single species can have different effects depending on gender and on population.

Scaling of the ctenidium in juvenile suspension feeding bivalves

The ctenidium, or gill, of suspension-feeding bivalves has two major functions. It is a respiratory organ, but it is also the primary organ used for feeding. Cilia on the ctenidium form the pump that circulates water past the ctenidium, and, in most cases, also function to move particulates, primarily microalgae, caught on mucus to the mouth for feeding. Although the effects of size and form of the ctenidium on these functions has been explored in adult bivalves, the scaling of the elements of this organ and possible consequences on function, especially in newly metamorphosed bivalves has not. As juveniles, the ctenidium is a simple curtain of straight filaments, and animals do not attain the complex form of adults for months past metamorphosis. We studied the size scaling of ctenidia in juveniles (from 0.2 mm − 2 mm) of Argopecten irradians, Mytilus edulis and Crassostrea virginica. Although ctenidial filament diameter differed among species, within a species the width of the filaments did not change with body size. However, the length of ctenidial filaments for each species increased linearly with body size, and the body size-specific length of filaments was the same across species.
76.3 PERLMAN, BM*; KAWANO, S; BLOB, RW; ASHLEY−ROSS, MA; Wake Forest University, Clemson University; periunivmailsageperunwfu.edu
Citius, altius, fortius: jumping kinematics and kinetics in two distantly related teleosts
Many fish stranded on land will use axial movements to generate C−jumps in efforts to return to water. However, mangrove rutilus, Kryptolebias marmoratus (Cyprinodontiformes), generate coordinated jumps on land using a tail flip to locate new food resources, avoid predators, escape poor water conditions, or return to water. How do the mechanics of such directed jumps differ from those of typical stranded fishes? We quantified and compared the ground reaction forces (GRF) generated during directed jumps by K. marmoratus with those produced by similarly−sized largemouth bass, Micropterus salmoides (Perciformes), performing typical jumps of stranded fishes. Individual specimens were placed on a force platform that recorded the GRF in three dimensions (fore−aft, mediolateral, and vertical). Forces were normalized to the body weight of each animal. Two Phantom high−speed video cameras recorded the duration of the jump (from initial movement to launching off the force platform) and the jump trajectory with respect to the ground. Horizontal forces were greatest for K. marmoratus with peak GRF occurring at ~75% through the jump. M. salmoides had the greatest vertical GRF, occurring at ~60% of the jump. The trajectory of the bass C−jump was ~90° with respect to the ground compared to lower jump trajectories in K. marmoratus, leading to greater horizontal displacement in the latter. M. salmoides had faster jump durations (~40 ms to reach maximum body curvature), whereas K. marmoratus reached maximum body curvature at ~75 ms. While the jumps of M. salmoides strongly resemble aquatic fast starts, differences in force production and motion trajectory in K. marmoratus may indicate the use of different motor patterns to increase duration (and thus impulse) of the jump.

5.3 PETERSON, S.; HASSRICK, J.; DEBIER, C.; CROCKER, D.; COSTA, D.; University of California, Santa Cruz, Université catholique de Louvain, Belgium, Sonoma State University; saepeter@ucsc.edu
Polychlorinated biphenyl (PCB) bulk concentrations and congener profiles in a highly migratory marine mammal
PCBs are widely distributed and detectable far from anthropogenic sources. Northern elephant seals (Mirounga angustirostris) travel thousands of kilometers to forage in coastal and pelagic regions of the North Pacific. Our study (1) quantified PCB concentrations in adult female northern elephant seals at the start and end of their biannual foraging trips to assess if age, foraging region, or the fastening state and time of year had significant relationships with tissue concentrations, (2) examined PCB congeners relative to age, foraging region, and fasting state, and (3) examined correlations between tissue concentrations. Between 2005 and 2007 we sampled blubber (inner and outer layers) and serum before and after a foraging trip from 58 seals that carried satellite−tags and time−depth recorders. PCB concentrations in the inner blubber were significantly affected by the foraging trip and fasting state of the animal, with the highest concentrations observed at the end of the molting fast. Age did not significantly affect bulk PCB concentrations; however the proportion of PCB congeners with different degrees of chlorination was significantly affected by age, especially in the outer blubber. Younger animals had a significantly greater proportion of low−chlorinated PCBs (tri−, tetra− and penta−CBs) than older seals, with the opposite trend observed for hepta−CBs, indicating that an age−associated process significantly affects congener profiles. These results highlight the importance of sampling across the entire blubber layer when assessing toxicant levels in seals and taking into account both the fasting state and reproductive status of an animal when conducting contaminant research.

7.25 PETERSON, K.*; DUDLEY, R.; FEARING, R.S.; Univ. of California, Berkeley; keving@eecs.berkeley.edu
Hybrid aerial and terrestrial robots and their implications for avian flight evolution
DASH+Wings and BOLT are small hybrid legged and winged robots capable of both aerial and terrestrial locomotion. Investigation of the effects of the robots wings on both their aerial and terrestrial locomotion allows the direct evaluation of the consequences of wing flapping for locomotor performance. By contrast, current support for the diverse theories of avian flight origins derive from limited fossil evidence, the adult behavior of extant flying birds, and developmental stages of already volant taxa. DASH+Wings originally derives from a hexapedal running robot, and allows the consequences of adding wings to a cursorial locomotor to be examined. Experimental controls for the effects of flapping wings are provided by the use of inertial spars and passive airfoils. The addition of flapping wings increased the maximum horizontal running speed from 0.68 m/s to 1.28 m/s along with increasing the maximum incline angle of ascent from 5.6 degrees to 16.9 degrees. Free measurements also show a decrease of 10.3 degrees in equilibrium glide slope between the flapping wings and passive airfoils. In contrast with DASH+Wings, BOLT is a bipedal robot designed with a focus on flight performance. To better examine avian flight evolution, we modify the original design to more closely resemble avian prerequisites. The design of BOLT also enables the evaluation of the effects of wing amplitude, flapping frequency, and wing area on both aerial and terrestrial performance. Computer models elucidate the effect of interactions between periodic leg and wing forces during high speed wing−assisted running. We discuss our findings in the context of existing hypotheses for the origins of flapping flight in vertebrates.
**Phenotype manipulations confirm the role of pectoral muscles in avian thermogenic capacity**

In winter, resident bird living at northern latitudes exhibit changes in body composition and metabolic performance in response to cold. Whole body mass, digestive organs and muscles mass as well as basal metabolic rate (BMR, reflecting minimal maintenance energy costs) and maximal thermogenic capacity (MSUM, a measure of cold tolerance) have been shown to be higher in winter relative to other seasons. Because birds undergoing cold stress produce heat by shivering, correlational studies suggested that MSUM directly depends on pectoral muscle size. However, this relationship has yet to be experimentally demonstrated. To investigate the relationship between pectoral muscle size and MSUM, we manipulated pectoral muscle size in free-living wintering black-capped chickadees (Poecile atricapillus). We removed half of the flight feathers of experimental individuals and compared their muscle morphology and metabolism with control birds captured over the same period. Results show that 1) clipped chickadees (n=12) had similar body mass (+1.8%), fat reserves (~13.4%), hematocrit level (+2.0%), BMR (+5.8%) and MSUM (+8.2%) but expressed larger pectoral muscles (+17.0%) than controls birds (n=15) and 2) that mass-independent MSUM varied with muscle score and was positively related to hematocrit. Birds showing the highest muscle scores had in average a MSUM +20.4% higher than birds with the smallest scores. These findings therefore support previously observed correlations.

Large pectoral muscles are indeed associated with a better mass-independent thermogenic capacity in small resident birds. The possibility of negatively impacting fitness by hampering an animal’s ability to run, walk, or swim. Although Atlantic ghost crabs (Ocypode quadrata) are decapods, they use only eight of their ten locomotor limbs may thereby place different amounts of functional importance on each of the limbs, requiring functional compensation for limb loss and/or a decrease in locomotor performance. The goal of this study was to quantify natural patterns and frequencies of limb loss, and to determine whether these patterns reflect the ability for crabs to compensate more effectively for the absence of certain limbs over others. Patterns of limb loss were quantified at five independent sites in Brevard County, Florida for 159 crabs over 22 nights. Interestingly, limb loss was infrequent among the nocturnally-active individuals. We used the highest (3rd leg: 37.5%) and lowest (1st leg: 6.25%) observed limb loss frequencies to define the two autotomy treatments for laboratory-based performance studies. Each crab was first run with all limbs intact to serve as its own control autotomy treatments. Ten crabs (five per treatment) were run on a track filled with 200 µm diameter glass particles characteristic of a fine sand beach, and filmed with a single dorsal view at 250 fps (Redlake). The three fastest, constant velocity runs per individual for treatment and control were analyzed for differences in limb use and performance. Results indicate that limb loss reduces sprint speed, in comparison to when running with all limbs intact. How limb autotomy affects function of the remaining limbs, as well as its potential impact on its behavioral ecology will be discussed.

**A mitochondrial sponge gene unique among animals: the evolution of the Tat pathway in Oscarella**

The twin–arginine translocation (Tat) pathway is a protein transport system that serves in moving folded proteins across energy–transducing membranes, and is widespread in all domains of life. Genes encoding different components of the pathway have been found in the genomes of many bacteria, archaea, plants, and plant mitochondria. However, the same genes have been lost from most other mitochondrial genomes, including nearly all animals. The only exception in animals is the homoscleromorph sponges in the genus Oscarella (family Oscarellidae), whose mitochondrial genomes encode a gene for TatC, the subunit with the largest number of transmembrane helices. However, the functional significance of the presence of this gene in Oscarellidae remains unclear. Here we characterize the genetic makeup of the Tat pathway in Oscarellid sponges, and address the origin and evolution of the mitochondrial TatC gene. Since previous studies have found the entire Tat pathway to be missing from mammalian genomes, we will address the question of whether other components of the Tat pathway have been transferred to the nucleus in Oscarellidae, or if TatC is operating alone with a possibly different function. The possibility that the Tat pathway was inherited from the ancestral eukaryotic mitochondrial genome and is present in Oscarellidae would imply multiple independent losses of the entire mitochondrial Tat pathway during the evolution of animals, and an unprecedented high rate of loss for an animal mitochondrial gene.

**The effect of aspect ratio on the stability of leading-edge vortices over insect-like wings**

Flying insects exhibit a vast range of wing planform shapes which vary widely in aspect ratio. In past CFD studies, it has been shown that the aspect ratio of an insect wing is a potentially important parameter in determining the stability of the leading-edge vortex (LEV), a lift–augmenting flow structure exploited by many insects, bats, and birds. Here, a stable LEV implies that it remains present on the upper surface of the wing throughout the wing stroke and does not detach and shed into the wake. An experimental investigation was conducted to investigate the potential effect of aspect ratio on the stability of the LEV. Experiments were accomplished with a custom–designed, mechanical flapping–wing apparatus (the ‘Flapperatus’) that mimics insect–like flapping–wing motion, with adjustable kinematics up to a 20 Hz flapping frequency in air. This approach enables highly repeatable wing kinematics to be achieved between test cases, thereby allowing the effects on flow structures caused by changes in wing aspect ratio to be observed in detail. Stereoscopic Particle Image Velocimetry (stereo–PIV) measurements of the flow field generated by wing planform shapes varying in aspect ratio were performed to characterize the formation, growth and stability of the LEV.
PHUONG, M. A.*; LIM, M.; WAIT, D. R.; ROWE, K. C.; MORITZ, C.; University of California, Berkeley, Museum Victoria, Melbourne, and Australian National University, markphuong@gmail.com Understanding discordance among diverse datasets in an integrative taxonomy: a case study in ground squirrels Species represent the fundamental taxonomic unit in nearly all disciplines of biology. Integrative taxonomy is a relatively new approach to identify lineages in which multiple lines of evidence are gathered to diagnose species and discordances between diverse datasets are resolved by invoking evolutionary explanations. Recent molecular work using mitochondrial DNA on species within the genus Otospermophilus showed discordant inferences of species boundaries relative to the current taxonomy. As such, genetic (1 mitochondrial locus, 11 nuclear loci, and 11 microsatellite markers), ecological (8 bioclimatic variables), and morphological (23 skull measurements) data were collected and analyzed to delimit species within the genus Otospermophilus. Genetic results support the presence of four species of paraphyletic origin with very little differentiation along morphological and ecological axes. Discordances between these lines of evidence can be explained by a model of peripatric speciation. Our results demonstrate the utility of considering models of speciation in understanding conflicting species boundary inferences from diverse lines of evidence.

PIERCE, SP*; HUTCHINSON, JR; CLACK, JA; The Royal Veterinary College, UK, University Museum of Zoology, Cambridge, UK, spierce@rvc.ac.uk Historical evolution of early tetrapod movement Conceptualizations of the evolution of tetrapod locomotion have changed drastically in the past 50 years. When early tetrapod fossils were first discovered, the animals were reconstructed as salamander-like in their mode of locomotion, walking around on four sturdy legs. In fact, the "prototetrapod" was envisaged as a terrestrial, capable creature with a fish-like body and modified pectoral/pelvic fins equipped with weight supporting joints and the beginnings of digits, but no sacrum. "Conquest of land" was seen as the driving force in the evolution of limbs. However, intensive re-examination of fossil material and the discovery of key specimens has gradually redefined our perception of the tetrapod hauplan. The prevailing theory is that early tetrapods were primarily aquatic in habit and that limbs evolved before the ability to walk on land. New fossil footprints have challenged this idea by inferring early tetrapods were walking – perhaps partially supported by water – 20 million years before any known tetrapod body fossils. Another recent study has posited that sarcopterygian fishes evolved hindlimb powered locomotion, which was later exapted for usage in tetrapods. However, our recent work on the late Devonian tetrapod Ichthyostega has demonstrated that its limb joints did not permit a walking gait like that of a living salamander, and that land locomotion was forelimb-driven. Considering that other closely related stem tetrapods seem to have had similar limb joint structure, this may have been an ancestral state, although the anatomy of earlier Devonian tetrapods remains unknown. The historical transformation of locomotion potential, and the drivers of land dwelling in the earliest limbed vertebrates, has thus changed drastically, with several different hypotheses having been put forward over the past few years. New information and methodological techniques are helping to refine and shape our understanding of this pivotal evolutionary event.

S3-1.3 PIECZAK, N.*; HANKEN, J.; Harvard University; npiekarski@oeb.harvard.edu Neural crest derivation of the bony skull of the Mexican axolotl and its implications for vertebrate skull evolution Cartilages and bones of the cranial skull are derived from two embryonic sources, neural crest and mesoderm. Contributions of these tissues to the skull have been revealed in great detail in one amniote model using the quail-chick chimera system, and to lesser extent in a few other species. However, the degree to which patterns of embryonic derivation are evolutionary conserved or labile remains an intriguing question, given the extensive variability in skull morphology observed among craniates. Living amphibians are a non-ammniote tetrapod group with a highly derived skull morphology and ontogeny. Recent technical advances enable us to derive fate maps at a level of detail previously known only from avian studies. We employed embryonic transplantations, using GFP-transgenic axolotls as donors, to document the nature and extent of neural crest contribution to the adult osteocranium. Comparisons between axolotl, chicken and mouse reveal a highly conserved embryonic origin of the tetrapod skull. Conversely, a comparison between axolotl and Xenopus reveals tremendous differences in the embryonic origin of skull bones between these two taxa. The unique features seen in Xenopus may be a consequence of the dramatic transformation of cranial morphology that is associated with the extreme posthatching metamorphosis characteristic of most anurans.
Evolution of selfing and the extension of lifespan
It has been difficult to determine the factors that affect life span in different genders because they are often genetically and morphologically different. We are studying a so far undescribed nematode that provides a useful model to study this question because it produces hermaphrodites and females that are genetically identical and have the same body size. Hermaphrodites differ from females by their ability to produce a limited amount of sperm that is used for self-fertilization. We found that the decision to become either female or hermaphrodite is plastic and environmentally determined, and that hermaphrodites live a third longer than females. A hypothesis for the evolution of different life span between genders is that females have a higher rate of extrinsic mortality caused by mating with males. We found that mating shortens life span of both females and hermaphrodites, and that the secretion of male attractants by females makes them more susceptible to extrinsic mortality. Older hermaphrodites that exhaust their self-sperm also produce sex pheromones, indicating that the longer lifespan of hermaphrodites is an adaptive trait.

PIRES DA SILVA, A*; CHAUDHURI, J.; KACHE, V.; BOSE, N; SCHROEDER, F; VON REUSS, S.; Univ. of Texas at Arlington, Cornell University, Ithaca, Max Plank Institute for Chemical Ecology, Jena, Germany, apires@uta.edu

Using functional genomics to characterize the physiological response of polar fishes to a multi-stressor scenario
Antarctic fishes of the suborder Notothenioidei have displayed incredibly narrow physiological limits in previous single stressor studies and may be particularly vulnerable to the impacts of global climate change. Given the propensity for both adaptive and potentially mal-adaptive traits found among many nototheniid species, this system provides a unique opportunity to examine physiological trade-offs associated with acclimation to a multi-stressor environment. Using both field and laboratory-based analyses, we have combined approaches from the fields of functional genomics and organismal physiology to examine how global climate change may impact species performance. Our previous data has shown the emerald notothen, Trematomus bernacchii, displays a rapid acclimatory response with respect to resting metabolic rates following exposure to elevated temperature or pCO2, and that these two stressors can act synergistically to further impact their physiological response. Here, we highlight the molecular mechanisms underlying the physiological response of T. bernacchii after long-term acclimation to elevated pCO2 and temperature. RNAseq analysis of mRNA levels in gill, liver and brain tissue from fish acclimated up to 28 days under the multi-stressor treatment revealed a tissue specific response in this nototheniid species. Prominent cellular pathways identified in the analyses include metabolic adjustments involving mobilization of lipid stores and a moderate up-regulation of genes involved in the classical cellular stress response. These transcriptome profiles give us insight into the physiological impacts of sub-lethal stress and may provide an indication of the costs associated with adapting to global climate change.

PLACE, S.P.; Univ. South Carolina; places@mailbox.sc.edu

Assessments of immuno- and inflam-maging following a photoperiodic regime that delays female reproductive aging in Siberian hamsters
Aging and reproductive senescence are thoroughly intertwined, as evidenced by the ability of calorie restriction to both increase longevity and delay reproductive aging in a variety of animal models of aging. We have previously shown that exposure to short days (SD) between 3 and 9 months of age delayed reproductive aging in 12-month-old, female Siberian hamsters (Phodopus sungorus). Herein we report our initial assessments of somatic aging in male and female hamsters under the same photoperiodic conditions. Because hamsters held in SD decrease food intake and body mass, and also inhibit reproduction, we predicted that 6-months of SD would attenuate the age-associated changes in some biomarkers of somatic aging. We evaluated biomarkers of immuno- and inflam-maging in hamsters that have been shown to be reliable indicators of aging in mice. The ratio of T-helper (CD4) to total T-cells (CD3) declined with age in hamsters held in long days (LD), as was previously demonstrated in mice. However, 12-month-old hamsters held in SD from 3 to 9 months of age had a CD4:CD3 ratio that was not significantly different than in age-matched hamsters held in LD. Thus, this measure of immuno-maging was not modulated by the previous exposure to SD. Ongoing research is now determining if age-associated changes in pro- and anti-inflammatory cytokines (e.g., interleukin-6 and -10, respectively) occur in Siberian hamsters held in LD, and if 6 months of SD delayed the transition to a pro-inflammatory state in 12-month-old hamsters. The outcomes of these investigations will help determine if the physiological and behavioral changes associated with decreasing photoperiod modulate somatic aging, or if the benefits of SD are limited to a deceleration of reproductive aging in female hamsters.

PLACE, N.J*; PARK, S–U; ZYSLING, DA; Cornell University; njp27@cornell.edu

A Comparative Study of Cetacean Respiratory Mechanics: Implications for diving and health assessment
The cetacean respiratory system has undergone diverse and highly specialized anatomical and mechanical adaptations to accommodate a strictly aquatic lifestyle. In contrast to terrestrial mammals, the cetacean respiratory system is adapted to operate on an inspiratory breath–hold. During a dive, air in the lungs is carefully managed to perform multiple, simultaneous functions, including gas exchange, buoyancy control, echolocation, vocalization and foraging. Because their respiratory system carries out multiple roles, respiratory diseases have the potential to greatly impact a cetacean’s ability to thrive in the wild. Cryptococcus gatti, an endemic fungus to the Pacific Northwest has been the source of mortality in human, terrestrial and cetacean cases, and is a focus of diseases cases in this study. Excised lungs from 8 cetacean families were collected during necropsy. A multi-faceted approach was utilized to examine structural, biomechanical and pathological differences across species. Each lung was imaged in three inflated states using computed tomography followed by static pulmonary mechanics to generate pressure-volume curves. Across families, mass-specific total lung capacity (TLC) decreased with increased diving ability, and opening airway pressures increased with smaller alveolar diameters. Severe infections in diseased lungs decreased mass-specific TLC by up to 93%, increased lung mass four-fold, and decreased compliance. In conclusion, pulmonary mechanics is a useful tool in both understanding the normal physiology of diving mammals and in assessing the pathophysiology of stranded marine mammals.

SHADWICK, R.E.; Univ. of British Columbia, Vancouver, British Columbia Ministry of Agriculture, Food, and Fisheries; pscitelli@unbc.ca

January 3–7, 2013, San Francisco, CA
S10−1.4 PLACHETZKI, D/C; UC Davis; plachetzki@ucdavis.edu
The control of cnidocyte discharge by light
Cnidocytes facilitate both sensory and secretory functions among cnidarians and have been heralded as the most complex animal cell type. Cnidocyte discharge is known to integrate both chemical and mechanical cues from the environment, but, despite more than a century of work aimed at understanding the sensory biology of cnidocytes, the specific sensory receptor genes that regulate their function have remained unknown. Here, in studies of the freshwater hydrozoan Hydra magnipapillata, we show that light constitutes another environmental cue that regulates cnidocyte function and that this property is driven by an opsin-mediated phototransduction cascade. We report that several components of the ciliary phototransduction cascade, including opsin, arrestin and cyclic nucleotide-gated (CNG) ion channel are specifically expressed in a previously described sensory–motor neuronal cell type that enervates components of the hydrozoan battery complex, including cnidocytes and ganglion cells. Next, we describe behavioral data from cnidocyte discharge experiments that were conducted under different light conditions. Our results show that a significant attenuation of cnidocyte discharge is induced by bright light, and that this behavior is ablated when experiments are conducted in the presence of a CNG ion channel inhibitor. Our findings suggest a new, likely ancestral, role for phototransduction in the coordination of cnidocyte discharge amongst cnidian taxa. The implications of these and other recent findings for our understanding of the sensory attributes of the hydrozoan battery complex are discussed.

116.3 POMPONI, S.A.*; JEVITT, A; PATEL, J; Florida Atlantic University, Fort Pierce, Florida State University, Tallahassee; spomponi@blii.fau.edu
Sponge Hybridomas: Applications and Implications
Many sponge-derived natural products with human health applications have been discovered over the past three decades. In vitro production has been proposed as a biological alternative to ensure adequate supply of marine natural products for preclinical and clinical drug development. Although primary cell cultures have been established for many marine invertebrate phyla, no cell lines with an extended life span have been established for marine invertebrates. For human health applications, hybridoma technology is used for production of monoclonal antibodies. We hypothesized that a sponge cell line could be formed by fusing sponge cells of one species with those of another, or by fusing sponge cells with rapidly dividing, marine-derived, non-sponge cells. Using standard methods for formation of hybridomas (i.e., incubation with polyethylene glycol), with appropriate modifications for temperature and salinity, cells from individuals of the same sponge species, as well as cells from individuals of two different sponge species, were successfully fused. Although other research has demonstrated that sponges are capable of cellular immune responses, our experiments demonstrate that no rejection occurred between the sponge species we tested. We conclude that either rejection responses are species-specific or the fusion technique suppressed cellular immune responses. Research in progress is focused on optimizing fusion to produce a cell line and to stimulate production of novel natural products. Hybridomas may also be used to stimulate production of novel natural products, as well as an experimental platform to test questions related to sponge chimeras in nature.

96.4 PODOLSKY, R.D.; College of Charleston; podolskyr@cofc.edu
Plasticity of egg mass architecture: effects of spatial oxygen gradients on the density and distribution of embryos
The grouping of encapsulated embryos in dense clutches can impose several physical challenges on early development. For example, oxygen delivery to embryos can be limited by diffusion, creating a spatial gradient of increasing hypoxia from peripheral to central positions within a clutch. Such limitations are thought to constrain the thickness of egg masses and could alter other aspects of egg mass architecture related to the density or positioning of embryos. The balloon shaped egg masses of Melanochromis diomedeae, an opisthobranch mollusc that oviposits on the surface of tidal flats, have embryos distributed throughout a gel matrix. This architecture allows for fine-scale analysis of changes in embryo positioning in response to environmental conditions. I examined whether the radial distribution of embryos changes in parallel with the radial gradient of hypoxia, predicting that embryo densities would be lowest toward the center of masses. I also manipulated oxygenation levels experienced by adults to determine whether they effect plastic changes in the density or positioning of embryos in their masses. As predicted, embryo density declined toward the center of egg masses and decreased as an inverse function of adult oxygenation. Contrary to expectations, adult oxygenation levels did not generally alter the slope of embryo density as a function of radial position. These results suggest that adults tend to position their embryos away from more hypoxic positions but respond to changes in ambient oxygen by altering overall densities rather than the steepness of density gradients. Prior work found that in some populations, egg mass architecture is altered by changing the number of embryos packaged per capsule, but multi-embryo encapsulation was not apparent in the population used in this study.

61.3 PORRO, L.B.*; IRIARTE−DIAZ, J.; O'REILLY, J.; ROSS, C.F.; University of Chicago, IL; lbporro@gmail.com
In vivo cranial bone strain during feeding in the agamid Uromastyx geyri
Due to its specialized skull and dental morphology, the herbivorous lizard Uromastyx has been the subject of numerous feeding studies. Previous research has collected data on cranial, mandibular and tongue kinematics, jaw and tongue muscle activity, and bite force generated under stimulation. Additionally, the computer modeling techniques of multibody dynamics analysis and finite element analysis have been applied to the skull of Uromastyx, allowing researchers to test hypotheses regarding the link between bone/suture morphology and mechanical behavior. To date, no data have been collected on bone strain in the skull of any herbivorous lizard, including Uromastys. Bone strain data provide the most direct evidence of deformation, stress, and strain regimes in the skull under loads. We collected in vivo bone strain data from the crania of three Uromastys geyri (along with simultaneously recorded electromyographic, videofluoroscopic and bite force data) during feeding on a variety of foods and while exhibiting different feeding behaviors (capture, chew, swallow, etc.). Analysis of principal and shear strains over 1300 individual gape cycles reveal that principal strain orientations vary little between individual animals, or with changes in food type and bite point; instead, variability in both principal strain orientations and magnitudes is primarily determined by feeding behavior. Furthermore, cranial bone strain magnitudes recorded in Uromastys during feeding are substantially higher than those recorded in mammalian crania. These results shed new understanding on cranial biomechanics in Uromastys during feeding and will be used to validate and improve the accuracy of previous computer models.

SICB 2013 Annual Meeting Abstracts
13.0 PORTER, M.E.; DIAZ, C; LONG, JH, Vassar College, University of Akron; meporter@vassar.edu
Extracellular matrix dominates the mechanical properties of shark vertebral columns in bending
In contrast to the acellular bone in fishes, cells are present in the calcified cartilage of the skeletons of sharks. In the vertebral column (VC), chondrocytes are arrayed in the centra and fibroblasts are present in the intervertebral ligaments. These cells build the surrounding extracellular matrix (ECM). We hypothesized that these cells also structurally contribute to the mechanical properties of the VC. To test this hypothesis, we lysed cells by freezing the tissues. We compared mechanical properties in dynamic bending before and after by freezing from phylogenetically distant, conspecific, shark species, Squalus acanthias and Mustelus canis. We hypothesized the mechanical properties of the fluid–filled intervertebral joints will be impacted by cell lysing resulting in an overall change in the vertebral column properties. We used a customized rig on dynamic testing machine (MTS Tytron 250) to translate single axis movement into bending. In an environmental chamber filled with Elasmobranch ringers, we tested fresh segments of ten centra over a range of frequencies and curvatures, similar to those experienced by these species during swimming. Segments were frozen at −18°C for six months, defrosted to room temperature (22°C) under hydration and tested over the same range of curvatures and frequencies. We found that freezing the specimen does reduce both work, W (J), and structural stiffness, K (Nm−1), of frozen vertebral columns. This work was supported by NSF IOS–0922065.

20.2 PORTUGAL, S.; HUBEL, T; FRITZ, J; WILSON, A; USHERWOOD, J; ROYAL VETERINARY COLLEGE, UNIVERSITY OF LONDON, UK, ROYAL VETERINARY COLLEGE, WALDRAPPTEAM, AUSTRIA; sportugal@rvc.ac.uk
The aerodynamics of flapping V formation flight
The characteristic V formation flight of birds has fascinated scientists for centuries. One of the main theories that has persisted to explain this distinctive V–formation is that birds are attempting to conserve energy by taking advantage of the upwash vortex fields created by the wings of the other birds within the flock. A fixed wing aerodynamic theory has traditionally been applied to understand V–formation flocking in birds, very much unlike that of the actual scenario of a flapping bird and wing. Previously, little consideration, either theoretically or empirically, has been possible concerning the effects of flapping on V–formation aerodynamics. Recent technological advances have now made it possible to explore factors of V–formation flapping flight for extended periods of time, in free–flying birds. Using high–frequency sampling GPS and accelerometer units, we will present data from two migratory flights of the critically endangered Waldrapp Ibis. This opportunity was made possible by human–led migrations taking place as part of a reintroduction scheme, whereby imprinted young ibis are taught to follow a microlight. These data allow us to investigate aspects of V–formation flocking previously not possible, in particular the temporal and spatial wing–beat phasing of flock members during flapping V–formation flight. Furthermore, it is possible to examine height differences between individual flock members, a feature predicted by aerodynamic theory but previously impossible to test in free–flying birds.

84.6 POTTER, K. A.; PINCEBOURDE, S; WOODS, H. A.; University of Montana, Université François Rabelais; kristen.potter@mso.umt.edu
Microclimatic research priorities for predicting the effects of climate change
Considerable effort now focuses on predicting how species will respond to climate change. Nonetheless, statistical models that predict species’ distributions remain difficult to generalize, both from one species to another and into novel sets of environmental conditions. One reason is the conceptual difficulty of connecting macro and micro scales: there is an enormous gap between the spatial and temporal scales at which organisms live. Most organisms are small enough that they live in microclimates, which can be highly heterogeneous in space and time, and often quite different than surrounding macroclimates. To resolve the spatial and temporal mismatches between models versus organisms, we advocate: 1) gathering better microclimate data using automated devices, 2) developing better mechanistic models for downscaling coarse environmental data, and 3) improving our statistical understanding of variation at the finest scales. We will discuss why these approaches should be high priorities for future work, and how they will increase our ability to predict the biological effects of climate change.
41.4 POTVIN, J*; REYES, P; MCQUILLING, M; GOLDBOGEN, J A; SHADWICK, R E; Saint Louis University, Cascadia Research Collective, Univ. of British Columbia, Smithsonian Institution; potvin@slu.edu
Rorqual whale hydrodynamics and body drag during non-feeding transport, as revealed by Computational Fluid Dynamics (CFD)
Rorqual whales (Balaenopteridae) represent a group of marine mammals that include the largest vertebrates to have ever lived and thus to have necessitated the highest absolute energy requirements. Recent hydrodynamic modeling (Goldbogen et al 2012 Func. Ecol.; Potvin et al. 2012 PLoS One; Weidenmann et al 2011 Ecol. Model.) has shown how these are met, thanks to high body streamlining and efficient hunting (lunge feeding). The obvious impossibility of studying the energetics of large whales in laboratory settings makes computer modeling the only tool available for assessing the factors driving the costs of both feeding and non-feeding transport. A crucial input for non-feeding travel, diving and prey-approach simulation is the drag coefficient of the body, which for rorquals can be meaningfully defined (i.e. as decoupled from thrust), with their propulsion originating from the oscillatory motion of short chord-length appendages located aft of the body (the flukes). So far rorqual drag has been estimated from a flat plate-based approach dating from the 1930s (Gray 1936 J. Exp. Biol.). This is revisited here in terms of the more modern approach of CFD, with a presentation of preliminary drag calculations obtained from simulations performed about realistic body shapes representative of the genus balaenoptera, and over the body length and morphology spectrum characteristic of fin whales (B. physalus). Other issues to be discussed include (digital) model construction and manipulation, boundary layer modeling and sensitivity on body shape details (including tail flexion).

40.5 POTVIN, J*; GOLDBOGEN, J A; SHADWICK, R E; PYENSON, N D; Saint Louis University, Cascadia Research Collective, Univ. of British Columbia, Smithsonian Institution; potvin@slu.edu
Fish versus krill: Comparing the energetic costs of engulfment by rorqual whales lunge-feeding on slow and fast prey
Lunge feeding is a strategy employed by rorquals (Balaenopteridae) to catch schooling krill or (small) fish in bulk, via the engulfment of the water in which the prey is embedded. Recent modeling informed with kinematic and morphological data (Goldbogen et al 2012 Func Ecol; Potvin et al. 2012 PLoS One) indicate that lunge feeding on krill comes at high costs, largely incurred from quickly setting into motion a very high mass of water. Particularly with regards to the expended metabolic power, such costs are high enough at large body lengths to impose a physical limit on the largest size attainable by these whales. Whether the same mandible kinematics (mouth opening rates and maximum gape), body-water dynamics and body size limit involved in krill-feeding apply to the engulfment of fish has never been assessed. Here we show via modeling that, due to the significantly higher escape speeds of the prey, such extrapolation involves unrealistically high metabolic outputs, as well as mouth opening rates that are much higher than measured by tags deployed on humpback whales (horizontally lunging towards fish). On the other hand, fish-engulfment costs become smaller and more realistic, i.e. similar or lower than the highest active metabolic output of any terrestrial mammals (mass-specific), if engulfment is modified by resorting to smaller maximal gapes (i.e., 50 rather than 80deg) and by keeping the mouth opened over longer durations (i.e., 2-3 time longer than for krill-feeding). Also, applying such revised lunging kinematics over the body size spectrum of humpback and fin whales shows costs decreasing with the smaller bodies and trending to levels characteristic of krill-feeding.

144.2 POWDER, KE*; ALBERTSON, RC; Univ Massachusetts; kepowder@bio.umass.edu
A novel transcriptional regulator, Ibh, regulates cranial neural crest development and craniofacial evolution in East African cichlids
East African cichlids exhibit a rapid and extensive adaptive radiation. One major axis of their divergence is trophic specialization, which is reflected in their craniofacial skeleton. We previously identified a quantitative trait locus (QTL) that contributes to the mechanical advantage of closing the lower jaw (i.e. a functional tradeoff of force versus speed). This region includes the genes bone morphogenetic protein 4 (bmp4), expression of which is associated with more robust, lbh lbh lbhbmp4 limb bud and heart homolog (lbh), expression of which is associated with more robust, lbh lbh lbhbmp4 previously identified in cichlids with differing jaw morphologies. The other alternately fixed SNP characterizes this linkage, we re-sequenced the region in wild-caught cichlid jaws and avian beaks, and both contribute craniofacial evolution in cichlids, and offer Ibh as a molecular inroad into the developmental processes that mediate this process.

13.6 POWELL, M/L*; D'ABRAMO, L/R; WATTS, S/A; The Univ. of Alabama at Birmingham, Mississippi State Univ.; mpowell@uab.edu
Effects of Dietary n6 and n3 Fatty Acids on Zebrafish Total Body Composition
In 2003, the WHO identified diet and lifestyle as contributing factors to the growing epidemic of metabolic diseases. High-fat diets are often cited as a major contributing factor in the progression of these diseases; however, some fats may play a crucial role in reducing the incidences and/or severity of these diseases. In humans, n3 fatty acid components of lipids may slow the progression of some diseases, and conjugated n6 fatty acid components have been shown to increase lean body mass in mice. To achieve maximum health benefits of these fatty acids, an ideal dietary ratio of n6/n3 fatty acids has been suggested. Mice are used extensively to study aspects of human diet and corresponding disease, but zebrafish can serve as an effective, high throughput vertebrate model to study effects of diet on development and progression of many diseases. Using the first open formulation zebrafish diet, recently released by our lab for research applications, we incorporated known quantities of specific lipids for evaluation of weight gain and lipid content. Juvenile zebrafish (28 dpf) were fed identical isocaloric diets that differed only in the ratio of n6/n3 fatty acids (15/1, 3/1, 1/1) for 5 months. The final wet weight of fish fed the 15/1 (n6/n3) diet was significantly greater than that of fish fed the 1/1(n6/n3) diet. However, total percent lipid of female fish fed the 15/1(n6/n3) was significantly lower than that of female fish fed the 1/1(n6/n3) diet. These data suggest that zebrafish exhibit similar trends in body composition in response to dietary lipids as those reported for other vertebrate models and can be used as a model to further investigate the health benefits of these fatty acids. UAB NORC grant (P30DK056336).
Metabolic Power, Mechanical Efficiency, and Heat Production during Hovering and Forward Flight in Calliope Hummingbirds (Selasphorus calliope)

Flight requires higher power output than other forms of animal locomotion, and the effects flight speed upon power have important implications for the ecology and evolution of different flight styles. We studied the conversion efficiency of metabolic power (MBP) produced during hovering and forward flight in calliope hummingbirds (Selasphorus calliope; ~2.5 g) to mechanical power (MEP) production by the pectoralis muscle. Measurements were made in a wind tunnel at speeds ranging from 0–12 m/s. To determine MBP we measured oxygen consumption using negative–pressure, open–flow respirometry. To measure MEP we used stereo particle image velocimetry (PIV). We sampled the wake along planar, parasagittal transects separated by 1 cm, then integrated velocity with respect to area to obtain total kinetic energy flux within one wingbeat. Because mechanical efficiency (ME) is low we accounted for the balance of MBP, most of which is released as heat, using infrared thermography to calculate heat dissipation from the general body surfaces. MBP exhibited a typical U–shaped curve, MEF for hovering and 10 m/s was ~8%, similar to previously reported values. MEF at 2–8 m/s was only ~4%, this might be an underestimate arising from the complexity of the aerodynamic wake at intermediate flight speeds. Heat dissipation exhibits strong negative correlation with wind speed (R2 range 0.75–0.93) but does not correlate with calculated MEF further highlighting that our estimates of efficiency at intermediate speeds might be underestimated. Funded by NSF IOS–0923606 & IOS–0919799, NASA 10–BIOCLIM10–0094, the Richter Scholar Program (GFU), and FLIR Systems, Inc.

Comparing disparity between traits using the Ornstein–Uhlenbeck model: a test of functional constraint on traits of labrids

In vertebrates, shifts in profiles of circulating steroid hormones are critical for reproductive success because they regulate fundamental aspects of reproductive life–history/phenotype. Analyses of region–specific expression and activity of steroidogenic enzymes in the brain have confirmed both the presence of locally regulated steroidal signaling and the importance of neurosteroids for regulating behavior. Thus, rapid control of sex–specific reproductive behavior is likely driven by neural rather than gonadal hormones. Here, we demonstrate neuroendocrine regulation of paternal care in a highly social, polygamous marine fish, the bluebanded goby (Lythrypnus dalli), by in vivo neurochemical manipulation of males in social groups. Parenting was perturbed by modulation of local levels of steroids in the brain via intracerebroventricular injection of a critical enzyme blocker that elevates stress hormones and decreases androgens. Males treated with the drug took longer to enter their nest and had dramatically reduced egg care bouts. Social behaviors, such as agonistic interactions and courtship, remained unaffected. To determine which pathway was involved in inhibiting parenting in our manipulation, we tested two alternate hypotheses. We did not observe a significant reduction in parenting after injection of the glucocorticoid, cortisol. Injection of 11–ketotestosterone, an androgenic product of enzyme synthesis, along with the enzyme inhibitor reversed the negative effects on parenting. Our results show that brain–derived hormones are sufficient to regulate a crucial reproductive behavior, brain androgens directly regulate parenting behavior, and the speed of behavioral effects are consistent with non–genomic mechanisms.
Take-off and landing are crucial components of avian flight but the mechanical aspects of these phases are not well-understood. A previous analysis on the relative contributions of the wings and legs during these two phases has demonstrated the prominent role of the hindlimbs in the propulsion during take-off and deceleration during landing, Moreover, the importance of trunk 3D motion control during these two phases of flight.

The 3D kinematics of the trunk and hindlimbs during take-off and landing in zebra finch (Taeniopygia guttata) take-off and landing in zebra finch (Taeniopygia guttata)

Take-off and landing are crucial components of avian flight but the mechanical aspects of these phases are not well-understood. A previous analysis on the relative contributions of the wings and legs during these two phases has demonstrated the prominent role of the hindlimbs in the propulsion during take-off and deceleration during landing, Moreover, the importance of trunk 3D motion control during these two phases of flight.

The 3D kinematics of the trunk and hindlimbs during take-off and landing in zebra finch (Taeniopygia guttata) take-off and landing in zebra finch (Taeniopygia guttata)

Take-off and landing are crucial components of avian flight but the mechanical aspects of these phases are not well-understood. A previous analysis on the relative contributions of the wings and legs during these two phases has demonstrated the prominent role of the hindlimbs in the propulsion during take-off and deceleration during landing, Moreover, the importance of trunk 3D motion control during these two phases of flight.

The 3D kinematics of the trunk and hindlimbs during take-off and landing in zebra finch (Taeniopygia guttata) take-off and landing in zebra finch (Taeniopygia guttata)

Take-off and landing are crucial components of avian flight but the mechanical aspects of these phases are not well-understood. A previous analysis on the relative contributions of the wings and legs during these two phases has demonstrated the prominent role of the hindlimbs in the propulsion during take-off and deceleration during landing, Moreover, the importance of trunk 3D motion control during these two phases of flight.
41.1 QIAN, F*; GOLDMAN, DJ; Georgia Tech; qianfeifei1114@gmail.com

Locomotion on heterogeneous granular substrates

Natural particulate substrates like deserts are often composed of collections of multi-size particles: fine sand, pebble, and boulders. While much is known about locomotion on hard ground and increasingly on homogeneous granular media like fine sand, the principles by which organisms and robots locomote over heterogeneous granular substrates are unexplored. To investigate how particle size and distribution affect speed and stability, we performed laboratory experiments in a legged robot. Our hexapedal robot (15 cm, 150 g) used an open-loop alternating tripod gait and c-shaped rigid plastic limbs (radius 1.5 cm). We filled a trackway (75 cm long, 30 cm wide) with 3 mm glass particles (sand) and two parallel lines of eight 2.54 cm large glass particles (boulders) embedded one-quarter within and separated by 10 cm. Without the boulders, for a limb frequency 3 Hz, the robot moved forward at 1.7 BL/s. Forward speed oscillated periodically in a run, and run-to-run variation in standard deviation of speed was 0.50 ± 0.04 BL/s. Locomotion across the boulder field reduced the average speed to 1.2 BL/s. Large fluctuations in speed within a run and across runs were observed (standard deviation 0.69 ± 0.25 BL/s) resulting from a diversity of foot-boulder interaction modes. Of these we identified two important modes: 1) A slipping mode, where a leg contacted and slid near the top of a boulder, causing the robot to pitch, yaw and roll, while the boulder remained still or rotated against the sand. Large fluctuations in speed were observed. 2) A forced intrusion mode, where a leg forced a boulder to penetrate vertically into the sand, yaw was comparable to movement on sand, and instantaneous speed fluctuations were smaller than in mode 1. We conclude that non-trivial interaction effects can lead to complex locomotion dynamics even for a simple locomotor.

79.2 RADE, CM*; SANFORD, CP; HERNANDEZ, LP; George Washington Univ, Hofstra Univ; cristinuraread@gmail.com

Using sonomicrometry to compare pharyngeal jaw kinematics in cypriniform fishes

While much of the documented functional diversity in fish feeding systems involves the mechanics of suction feeding and prey capture, the pharyngeal jaw apparatus (PJA) is an understudied element of fish trophic diversity. The PJA is a second set of jaws behind the gill arches that serves to separate organic and inorganic matter, manipulate prey, and process food items. These jaws promote trophic diversity by decoupling feeding and processing events, thus providing an opportunity for different prey types. Cypriniforms is a diverse clade of teleosts characterized by a novel PJA that has significantly hypertrophied ceratobranchials 5 and a loss of the upper pharyngeal jaws, a feature seen only at the base of this group. Here we examine the use of the cypriniform PJA during prey handling in two species by employing sonomicrometry to interpret the kinematics of this novel biomechanical system. Using the positional relationships of five piezoelectric crystals we monitored the movements of the lower pharyngeal jaw in transverse and sagittal planes for goldfish (Carassius auratus) and sailfin suckers (Myxocyprinus asiaticus) to account for phylogenetic and behavioral differences, with goldfish being a member of Cyprinidea and sailfins representing the other major clade, Cobitoidea. Goldfish predominantly use the pharyngeal jaws for crushing and grinding, while catostomids presumably use these jaws for sifting purposes. M. asiaticus is especially important for understanding functional difference within this group as there is no published functional work on catostomid fishes to date. Statistical analyses reveal that the catostomid generates more chewing cycles per event and less lateral movement in the transverse plane than the cyprinid species.

113.2 RACK, JM; Univ. of Connecticut; jessica.rack@uconn.edu

Ambystoma maculatum larvae evolve to recognize local predator

In an aquatic environment where visual cues are limited, prey animals often respond to predator-released chemical cues with changes in behavior, morphology, or life history traits. Assuming sufficient additive genetic variation, natural selection should act to improve the prey populations recognition of local predator populations. Across a geographic landscape of varying selection pressures, prey and predator populations could evolve altered recognition systems or cues, respectively. If predators respond to prey evolution, then we might expect a coevolutionary arms race. Alternatively, prey might retain generalized cue recognition systems and predators might differ little in their cue chemistries, creating more predictable predator-prey interactions. I performed an experiment to determine if prey behavior differed in response to local predator chemical cues versus cues from a geographically distant population of the same predator species. Larvae of the spotted salamander, Ambystoma maculatum, were presented with predator cues isolated from two species of amphibian predator (marbled salamander larvae, Ambystoma opacum and red-spotted newts, Notophthalmus viridescens) collected from ponds stratified by distance from a focal population. I found that larval Ambystoma maculatum took more time to move in response to cues from local predatory newts, suggesting a recognition and avoidance mechanism based on adaptation to local predators. Rearing condition of the larvae (raised in the presence or absence of predator chemical cues) also affected prey behavior, suggesting that experience is a factor in such interactions. These results provide evidence for higher relative fitness in the prey animals home environment, and support the hypothesis that prey can evolve to recognize the specific chemical cues released by the local predator population.

31.6 RAGLAND, GJ; University of Notre Dame; gragland@nd.edu

Relaxed, but ready: dormancy responses are the opposite of stress responses at the transcriptional level

Dormancy is a metabolically and developmentally suppressed state that many organisms use to withstand stressful environments unfavorable for growth and reproduction. As an adaptation to extreme environmental stress, it is unsurprising that dormant life history stages almost universally exhibit enhanced resistance to multiple stressors compared to active, non-dormant stages. However, transcriptomic data show that at the level of global gene expression, the dormant/diapause phenotype is nearly the opposite of a stress response phenotype as illustrated by strong, consistent negative correlations. Here I present these patterns both within and across species and discuss functional explanations and evolutionary implications.
126.5 RAINWATER, E*; FASSBINDER–ORTH, C; Creighton University; elleciarainwater@creighton.edu
Enteric inoculation of nesting house sparrows (Passer domesticus) with Buggy Creek virus
The etiology of arboviral infections in wild nesting birds has been understudied. In this study, captive house sparrow (Passer domesticus) nestlings were inoculated with Buggy Creek virus (BCRV). BCRV is an alphavirus that is vectored by the swallow bug (Oeciacus vicarious) and amplified by house sparrow nestlings in the wild. Seven–day–old nestlings were inoculated with 3.5 log_{10} plaque forming units (PFU) of BCRV lineage A (BCRV–A), BCRV lineage B (BCRV–B), or vehicle control, and the infection was monitored for 4 days post inoculation (4 DPI). Peak viremia occurred 1 DPI for both BCRV–A and BCRV–B groups, with a mean peak virus titer of 4.24 ± 0.18 log_{10} PFU/ml sera for BCRV–A and 4.29 ± 0.12 log_{10} PFU/ml serum for BCRV–B. Viremia lasted for 2 DPI for both lineages, and no significant differences in viremia were detected between the two lineages (P = 0.967). Cytopathic BCRV was isolated from all lung and cerebral tissues in both BCRV–A and BCRV–B groups 2–4 DPI. Additionally, virus was isolated from the skin, skeletal muscle, heart, kidney, and small intestine for both BCRV–A and BCRV–B groups. Mucosal viral shedding was exhibited in 50% of BCRV–B nestlings and only 17% of BCRV–A nestlings. The impact of alphavirus infection on digestive parameters was also investigated. Digestive efficiency was 11% lower in BCRV–A group compared to the control (P < 0.016). Our results suggest that BCRV–A and BCRV–B are both effectively amplified in nesting house sparrows, and the infection results in widespread viral dissemination. Additionally, BCRV–A appears to negatively impact digestion in nestlings, while BCRV–B does not. Reduced digestive capabilities may contribute to the higher virulence that is seen for BCRV–A in wild nesting house sparrows compared to BCRV–B.

79.5 RAMSAY, J.B.*; WILGA, C.D.; University of Rhode Island; jasonramsay@my.uri.edu
Preorbitalis and quadratodentibialis function during feeding in little skates, Leucoraja erinacea
The horizontal preorbitalis (PO) muscle of little skates originates from the cranium and inserts onto the lateral surface of the quadratodentibialis (QM) and the lower jaw. The PO is considered to function as a jaw protractor and also may assist the QM in adding the jaws. However, manual depression of the hyomandibulae and lower jaw results in anteroventral rotation of the PO with little obvious stretching of the muscle as the jaws protrude. Thus, instead of strictly shortening to actuate jaw protrusion and adduction, the PO may potentially contract isometrically or eccentrically; functioning to stabilize and guide the jaws during protrusion driven by hyomandibular depression during the expansive phase of feeding. Hyomandibulae, upper and lower jaw kinematics, as well as motor activity in the PO and QM, and fascicle strain in the PO and QM were recorded simultaneously with buccal pressure during feeding. During prey capture the PO activates isometrically during the expansive phase and continues into the compressive, while the QM actively shortens during the compressive phase. In contrast, during prey processing the PO and QM are passively lengthened during the expansive phase and actively shorten during the compressive phase. The strain patterns exhibited in the PO of little skates suggests that the PO is functioning as an additional suspensory element during rapid prey capture and an additional jaw adductor during prey processing. The dual function of the PO as a supportive and actuating element may be another critical feature resulting in the increased functional versatility of the feeding apparatus in batoids compared to sharks.

106.6 RAMIREZ, D*; OAKLEY, TH; Univ. of California, Santa Barbara; ramirez@lifesci.ucsb.edu
Dispersed sensory neurons express opsin in the skin of Octopus bimaculoides
Although we have known for some time that animals can detect light with dispersed, dermal photoreceptor cells and can guide behavior, in most cases we do not know which molecules or dispersed cells actually confer this light sense. This holds true for molluscs, which have well documented photo–behaviors likely mediated by dispersed cells, but very limited data about the cells or molecules involved. In cephalopod molluscs, behavioral evidence of dispersed photoreception is scarce, but there are two brief reports of a direct chromatophore response to light in Octopus spp. As for molecular data, r–opsin is expressed in the skin of the cuttlefish Sepia officinalis. We have also found five major phototransduction components expressed in the skin of Octopus bimaculoides, including r–opsin and G–protein &alpha–q. Further, we found primary sensory neurons (PSNs) expressing opsin in octopus skin using antibodies raised against octopus eye opsin and mouse tubulin. These cells consist of small ciliary bundles emerging from the skin surface connected to cell bodies within the epidermis. They are relatively evenly spaced across the entire surface of the animal, except for a subset of these PSNs. These form lines on the siphon and dorsal head and mantle, and have previously described as mechanoreceptors based on both morphology and electrophysiology. We propose that these opsin–expressing PSNs are octopus dispersed photoreceptors and may contribute to a dermal light sense in both octopus and other coleoid cephalopods. Further, ultrastructure studies have identified this same cell type in several other classes of molluscs, including bivalves and gastropods. They may underlie the known dispersed photoreception behaviors in these other taxa, although it remains to be seen whether these other putative molluscan dispersed cells also use opsin–based phototransduction pathway genes.

90.6 RANK, NE*; MARDULYN, PM; ROBERTS, KR; HEIDL, S; SMILEY, JT; DAHLHOFF, EP; Sonoma State University (SSU), University of Brussels, SSU, White Mountain Research Center, Santa Clara University; rank@sonoma.edu
Variation in nuclear and mitochondrial genes important for energy metabolism along a climatic gradient in montane populations of a leaf–miner title
Many montane organisms live in fragmented populations that are especially vulnerable to climate change. The ability of small populations to persist depends partly on whether they possess genetic variation in their capacity to respond and adapt physiologically to altered environments. In the Sierra Nevada Mountains of California, the willow leaf beetle Chrysomela aeneicollis occurs at high elevations just below tree line (2400–3600 m). Variation at genetic loci is concordant to variation in PGI. Geographic variation along this transect is much greater for the allozyme phosphoglucom isomerase (PGI) than for other nuclear loci. In prior studies, we described functional, physiological, and reproductive differences among PGI genotypes that correspond to differences in frequency over a latitudinal transect. Here we show that PGI variation and environmental variability jointly affected persistence of local populations over the past decade. In addition, we found that latitudinal variation in frequencies of mitochondrial COII haplotypes is concordant to variation in PGI frequencies previously observed. Natural selection may act on COII and PGI. Genetic variability at loci, such as COII and PGI, which are especially vulnerable to climate change, may contribute to population persistence in the face of rapid environmental change.
34.2 RASTORGUEFF, P.-A.*; CHEVALDONNÉ, P.; LEJEUSNE, C.; Aix-Marseille Université – UMR CNRS 7263 IMBE, Estacion Biológica de D'ohana – CSIC, pierre-alain.rastorgueff@imbe.fr
Unexpected patterns of connectivity and phylogeographic breaks in Mediterranean marine cave mysids
Habitat fragmentation is a major threat to biodiversity by reducing habitat availability and interpopulation connectivity. Submarine caves represent a naturally fragmented habitat allowing to understand how habitat fragmentation affects connectivity. We worked on the Mediterranean brooding cave–dwelling mysids Hemimysis margalefi and H. mariannae which disperse only as adults. At the Mediterranean scale, our phylogeographic study based on several mitochondrial and nuclear molecular markers revealed that H. margalefi is actually composed of five highly divergent lineages, likely representing as many events of ongoing allopatric speciation. Populations of the different lineages are highly structured genetically mostly according to the general current circulation and the geography of the Mediterranean, habitat fragmentation and poor dispersal abilities. However, some well–known barriers to gene flow appear to have a surprisingly reduced influence on this species. Compared to H. margalefi, the little–known H. mariannae shows far less structured populations. This is particularly puzzling since this species, considered rare, has a more fragmented habitat. At small geographical scale, the use of microsatellite markers has evidenced differences in the genetic population structuring of H. margalefi compared to mitochondrial data. Understanding marine population connectivity in fragmented habitats has proved more complex than previously thought and may benefit from unconventional biological models such as marine cave mysids.

39.4 RAY, R.; HENNINGSSON, P.; NAKATA, T.; BOMPHEYRE, R.J.*; CRUK London Research Institute, United Kingdom, University of Oxford, United Kingdom; richard.bomphrey@zoo.ac.uk
Wing shape characteristics exaggerated by RNA interference modulate aerobic performance in fruit flies
The diversity of insect wing morphology seen in nature reflects the time–integrated sum of evolutionary pressures. Extant designs represent a compromise of ecological factors including but not necessarily dominated by aerodynamic performance characteristics. Correlating wing design with flight performance usually involves crossing species boundaries and can, therefore, be confounded by phylogenetic history. Since biomechanical data sets can be technically challenging and time–consuming to obtain, implementing the comparative method is often unfeasible. One approach to this problem lies in the development of a standardized procedure for a single species that affords either discrete or continuous variation of morphological parameters that are expected, from aerodynamic theory, to play important roles in aerobic capabilities. Aerial prowess may be crucial to individual fitness and has certainly been instrumental in the success of the insects as a class. Thus, the ability to modify experimentally wing shape alone is a powerful tool with which to investigate the underlying mechanisms of functional morphology. Here we use RNA interference to down–regulate the expression of a gene that determines wing shape in fruit flies (Drosophila melanogaster). The resulting phenotypes differ markedly in wing tip curvature and aspect ratio. We used stereo photogrammetry to acquire three–dimensional free flight trajectories from the range of phenotypes, calculated flight performance metrics, and found them to be significantly correlated with the modified wing morphology.

64.2 RAVI, S.*; CRALL, J; COMBES, S; Harvard University; sravi@fas.harvard.edu
On the flight of foraging bumblebees in the near–wake of objects
The high energy demands of a growing hive require bees to forage relentlessly, even under unfavorable weather conditions such as cool temperatures, precipitation or high winds. Bees forage in the complex environments surrounding flowering plants, bushes and trees, and the flow structures that they encounter on days with mild or strong winds can be vastly different from those encountered on calm days. Vortices shed from structures in the surrounding environment (trees, flowers, branches, etc.) can vary dramatically in size, strength and orientation, and these flow structures may influence the flight trajectories of foraging bees. Efficient flight trajectories, effective control strategies, and precise landings on nectar sources are vital to maximizing foraging success. To shed light on the interaction between bees and the wakes generated by objects in their environment, freely flying bumblebees (Bombus impatiens) were filmed with high speed cameras as they flew upstream in a wind tunnel at a range of freestream velocities, towards artificial flowers mounted on cylinders of varying size and orientation. Measurements of bumblebee approach trajectories were augmented with smoke flow visualization and high speed anemometry to obtain qualitative and quantitative insight into the flow structure in the vicinity of the cylinders. We found that bumblebees do employ approach patterns that depend on the geometric properties of the upstream object and its associated flow structures. This suggests that certain types of plants or particular habitats may be more challenging and/or costly for bees to forage in under adverse weather conditions.

S8-1.2 REDMOND, NE*; MORROW, CC; THACKER, RW; DIAZ, MC; BOURY–ESNUALT, N; CÁRDENAS, P; HAJDU, E; LOBÓ–HAJDU, G; PICTON, BE; COLLINS, AG; NMNH, Smithsonian Institution , Queens University, Belfast, Northern Ireland, University of Alabama at Birmingham, Museu Marinho de Margarita, Venezuela, Université d’Aix–Marseille, France, Uppsala University, Sweden, University of the Federal Rio de Janeiro, Brazil, Universidade do Estado do Rio de Janeiro, Brazil, National Museums Northern Ireland, UK; redmondo@si.edu
New 18S rDNA Sequence Data Suggest Exciting New Hypotheses for Internal Relationships of Demospongiae (Phylum Porifera)
The systematics of sponges (Porifera) is extremely difficult to decipher and constantly evolving. Here we present some exciting results on the phylogenetic relationships within Demospongiae based on 18S rRNA data. We add over 420 new nearly complete demosponge 18S sequences to approximately 180 existing sequences from GenBank. Our dataset includes over 35 genera that had not been included in molecular phylogenies to date, shedding new light on their familial affinities. We present several new hypotheses suggesting further revision and refinement of the emerging, more consensus–based, systematics of demosponges. Among numerous results are the following hypotheses: 1) within Myxospongia Chondrosia is sister to a monophyletic Verongidia making the order Chondrosidida paraphyletic; 2) within Keratosa, Dendroceratida is weakly supported as monophyletic, while Dictyonectida has high support and is split into two highly supported clades. Spongiidae + Irinidae + most Thorectidae and Dysidea + remainder Thorectidae; 3) numerous lineages within Haploscleromorpha have undergone simplification of skeletal structure; 4) within Democladia (=Heteroscleromorpha), nearly all of the independently derived clades of Morrow et al. 2012 are valid; and 5) freshwater Spongilla and lithistid Vetiuliniidae are sister groups with a close relationship to Scopaliniidae.
90.5 REED, W. L.*; CLARK, M. E.; North Dakota State University, Fargo; wendy.reed@ndsu.edu
Seasonal maternal effects on post–hatching growth and development in Franklin's gull
Theoretical predictions and empirical evidence suggest that parental investments in offspring decrease across the breeding season. However, it is not well documented how offspring fitness responds to variation in seasonal timing of reproduction. Our hypothesis is that offspring respond to cues of season and adjust their phenotypes to maximize their fitness based on conditions at hatching. We evaluated the impact of seasonal changes in parental investment on offspring growth and development in common garden experiments with Franklin's gull (Leucophaeus pipixcan), a long distance migrant. We previously documented that Franklin gull embryos are able to integrate cues of season from egg investments and photoperiod and can adjust growth and development during embryonic development. In this experiment we evaluated the impact of season and photoperiod during embryonic development on post–hatching growth and development. Freshly laid eggs were collected, incubated under photoperiods similar to early and late season, and chicks were reared in a common environment. The effects of photoperiod on development appear to be limited to embryonic development, but the maternal effects of season extend through the nestling period. Late season gull chicks grow faster, reach maximal growth rates at earlier ages, and reach lower peak masses than early season gull chicks. Early and late season chicks ultimately achieve similar asymptotic or final masses, which suggests that growth in late season chicks can compensate for a poor start.

120.3 REFT, A.J*; DALY, M; Ohio State University; ajreft@gmail.com
Small and mighty: the phylogenetic significance of mastigophore nematocysts in sea anemones
An account of the size, distribution, and morphotypes of microscopic stinging capsules called nematocysts is historically included in species descriptions of sea anemones (Cnidaria: Anthozoa: Actiniaria). Differences in the observed size ranges of capsules may justify the separation of species, and the occurrence of particular morphotypes justifies higher–level taxonomic distinctions. Nonetheless, the identity of some types of nematocysts remains obscure, and their phylogenetic significance remains untested. Here we use scanning and transmission electron microscopy, light microscopy, and shape analysis to evaluate the similarities among mastigophores, the most common type of nematocyst in sea anemones. We recognize several new types of mastigophores, and find that many of these occur uniquely in particular lineages or tissue types.

134.2 REICHAIRD, D.G.; RICE, R.J.; SCHULTZ, E.M.; KETTERSON, E.D.; Indiana Univ., Bloomington, Univ. of California, Davis; dgreicha@indiana.edu
Whispers of love and war? Inferring the function of low–amplitude song in a songbird
Males of many species produce high amplitude long–range songs during the breeding season that often serve a dual function in attracting mates and repelling rivals. In some species, males also produce low–amplitude (whispered) songs during close–proximity interactions that can precede a physical confrontation between males or be paired with visual courtship displays to females. We investigated the function of these songs in the dark–eyed junco (Junco hyemalis), a species of songbird with two distinct low–amplitude songs: (1) soft, long–range song, which does not differ structurally from loud long–range song, and (2) short–range song, which is substantially divergent in structure from long–range song. We presented free–living, male juncos with a live, caged male or female conspecific and quantified the number and type of songs produced to each sex. We also performed a series of playback experiments that tested whether male territorial response differed between high– and low–amplitude songs and whether male response differed according to the fertility status of his mate. Males produced soft and loud long–range song to both male and female conspecifics, but directed short–range song only to females. When confronted with playback of these song types in the absence of a visual stimulus, males responded significantly more aggressively to short–range song than long–range song but did not differ in their response to loud or soft long–range song. When their mates were fertile, males elevated their aggressive response to short–range song but not soft long–range song. Considered together, these results suggest that soft and loud long–range song may serve a similar dual function, while short–range song is a female–directed signal important in courtship.

42.5 REISER, P.J*; BICER, S; Ohio State University; reiser.17@osu.edu
Cardiac, Slow and Fast Troponin–T Isoform Expression Patterns in Dog and Rat Extraocular Muscles
Mammalian extraocular muscles (EOMs) consist of two distinct layers. Global layer fibers insert directly onto the eyeball and orbital layer fibers insert onto an outer connective tissue complex. Orbital fibers appear to modulate the force vector associated with EOM contractions. EOMs express a large number of myosin heavy and light chain isoforms and this diversity is a major contributor to the broad range of eye rotation velocities. We previously reported (Reiser and Bicer, 2011 Annual Meeting of the Biophysical Society) an unusual isoform expression pattern of the thin filament protein, tropomyosin (Tm), in the orbital layer. Specifically, fast orbital fibers express all three isoforms of Tm (±, ² and ³), whereas fast and slow global and limb muscle fibers consistently express two Tm isoforms, ± and ³ or ² and ³, respectively. Given the critical dependence of interactions between Tm and troponin–T (TnT) during muscle activation, the objectives of this study were to identify TnT isoforms in fast and slow fibers in the global and orbital layers of dog and rat extraocular muscles and to quantify their relative amounts in homogenates of both layers. SDS–PAGE and immunoblotting results indicate that fast global and orbital fibers express only fast isoforms of TnT, but the relative amounts of the individual isoforms are different from those in limb skeletal muscles. Slow fibers in both layers express slow TnT isoforms and the relative amounts also differ from those in limb slow fibers. Unexpectedly, cardiac TnT isoforms were detected in slow orbital fibers. These results further distinguish extraocular muscle fibers from limb muscle fibers and suggest that unique calcium–activation properties, especially among orbital fibers, subserve EOM contractions that drive oculomotor functions.
S7–1.2 REITZEL, A.M.*; TARRANT, A.M.; Univ. of North Carolina, Charlotte; Woods Hole Oceanographic Inst.; areitzel@whoi.edu
Circadian clock of the starlet sea anemone Nemastoma vectensis: a conserved network and missing links
The molecular components of the circadian clocks of mammals and diverse insects have been well-characterized, revealing that many of the core clock genes are conserved in these two disparate animal groups. This deep conservation suggests that this molecular clock dates back to at least the ancestor of deuterostomes and protostomes (Bilateria). The origin of these clock components and their molecular interactions earlier in animal evolution is unknown but represents a tremendous opportunity for studying the emergence of deeply conserved gene networks in animal behavior and physiology. Comparative genomic analyses support a hypothesis that the genes composing the circadian clock defined in bilaterians arose just prior to the cnidarian–bilaterian ancestor. Recent studies, using reef-building corals, and especially the sea anemone Nemastoma vectensis, have provided considerable insight into circadian regulation within cnidarians. Several lines of evidence that we will present, including computational biology, gene expression profiling, co-immunoprecipitation, and reporter assays, suggest that the cnidarian clock shares many conserved components of the circadian clock with bilaterians. Investigation into conserved and novel mechanisms of the circadian clocks from cnidarians and other early-diverging animal groups will elucidate the antiquity of this gene regulatory network and provide insight into regulation of reproduction, physiology, and development – processes that are frequently correlated with daily oscillations in environmental cues.

65.2 RENSEL, M.A.*; KOSARUSSAVADI, S.; SCHLINGER, B.A.; Univ. of California, Los Angeles; mrensel@ucla.edu
Real-time measurement of hippocampal corticosterone in a songbird
Traditional models of steroid hormone action assume release from distinct endocrine glands into the bloodstream. However, recent studies indicate that tissues such as the brain are capable of synthesizing some steroids de novo, providing a means of local regulation independent of the periphery. The steroid hormone corticosterone (CORT) is produced in the adrenal glands and potentially within the brain, and is an important mediator of physiological and behavioral responses to stress in addition to numerous other functions. Most studies of CORT focus on measurement of circulating hormone levels as a proxy for levels at target tissues, but less is known about the actual amounts of hormone that reach these targets. The goals of the current study were to 1) validate the real-time measurement of CORT in brain tissue using in-vivo microdialysis in a songbird, the zebra finch, 2) determine whether the circadian pattern of CORT commonly found in the bloodstream is present in the hippocampus, an important site for negative feedback of the hypothalamic–pituitary–adrenal axis, and 3) assess whether hippocampal CORT levels are elevated in a matter similar to that seen in the bloodstream in response to a standard handling stress paradigm. We reliably measured CORT in the hippocampus of awake zebra finches. Baseline levels over the course of 24 hours were cyclical, with significantly depressed levels during the night, a time when levels in the bloodstream are also low. Future studies will examine endogenous fluctuations in CORT that may occur during cognitive tasks such as the formation and recall of spatial memory.

11.1 RENN, S.C.P.; Reed College, Portland; renns@reed.edu
Genetic accommodation and behavioral evolution: insights from genomic studies
We know that gene expression level, a first order phenotype, underlies much behavioral variation. Using a genomic approach we can ask how many and which genes show expression level variation related to plastic behaviors? and how many and which genes show expression level variation related to evolved changes in behavior? Our model system includes two closely related species of African cichlid fishes, Julidochromis transcriptus, exhibits conventional sex-biases in behavior such that the larger male provides territory defense while the smaller female provides nest care whereas J. marlieri naturally pair in the reverse size ratio, and exhibits a reversal of behavioral roles. In both species, there is plasticity, such that behavioral patterns can be experimentally manipulated by controlling the relative size of the male and female in the pair. By examining gene expression in this system and borrowing terminology from the field of phenotypic plasticity, we characterize changes in gene expression level according to the concept of a norm of reaction and describe the various patterns of gene regulation evolution that accompany the evolution of behavioral plasticity. It is interesting to see the extent to which norms of reaction for evolved gene expression parallel the norms of reaction for the behavioral phenotypes they orchestrate.

S7–2.4 REPPERT, SM; UMass Medical School, Worcester; Steven.Reppert@umassmed.edu
The monarch butterfly reveals the prototype ancestral TTFL clock of insects: a focus on cryptochromes
In Drosophila and mammals, the classic clock mechanism is comprised of a core negative transcriptional/translational feedback loop (TTFL), which drives self-sustaining rhythms of essential clock components. The monarch butterfly (Danaus plexippus) core feedback loop possesses all the critical clock genes found in Drosophila clock (clk), cycle (cyc), period (per), timeless (tim), and type-1 cryptochrome (designated cry1) but differs in that it also possesses a type-2 vertebrate-like cry2, which encodes the main transcriptional repressor in the monarch clock, a function fulfilled by per in Drosophila, which does not possess cry2. The discovery of type-2 vertebrate-like CRYs in insects, derived from the discovery of CRY2 in monarchs, has profoundly altered our view of how circadian clocks of non-drosophilid insects work. To further our understanding of animal clock evolution, we reinvestigated the existence of type-1 and type-2 CRYs in all arthropods in which a draft genome has been published. All possess a type-2 CRY, except for all Drosophila species, which only possess the light-sensitive type-1 CRY. This supports the existence of both CRY types at the base of arthropod evolution. In addition, type-1 CRY and TIM appear to have been lost prior to the radiation of the hymenopterans, suggesting that the Hymenoptera have evolved different mechanism(s) for photic entrainment. Perhaps the TIMELESS paralog, TIMEOUT, which has some influence on the light input pathway in Drosophila, is the key, as it is expressed in all available insect genomes.
**16.2 REYNOLDS, L. A.*; GIBBS, A. G.; University of Nevada, Las Vegas; reyno172@unlv.nevada.edu**

**20–hydroxyecdysone (20E) Signaling Delay in Starvation Resistant Drosophila**

We selected for adult starvation resistance in replicated outbred populations of *Drosophila melanogaster*. These populations accumulate greater lipid stores as larvae that they then use to survive adult starvation. Lipids are accumulated during the 3rd instar larval feeding period, which is ~24 hr longer in starvation–selected populations than controls; the rate of lipid accumulation during larval feeding is the same between starvation–selected populations and controls. To understand how the developmental delay is achieved we studied timing of gene expression during the 3rd instar. Genes associated with the 20–hydroxyecdysone (20E) pulse that results in puparium formation had delayed expression times. We rescued delayed larval development by feeding 20E to 3rd instar larvae, decreasing adult lipid stores, and further supporting a change in the timing of the 20E titer. We conclude that selection for adult starvation resistance has resulted in physiological changes in larvae that are mediated by 20E signaling. Supported by NSF award IOS–0719551 and NIH award R15GM100395.

**S11–2.2 RHEN, Turk*; SCHROEDER, Anthony; FAGERLIE, Ruby; LEGGE, Heath; WESSMAN, Laurel; HEIMLER, Jon; BONAPACE–POTVIN, Michelle; ZHANG, Kurt; University of North Dakota; turk.rhen@email.und.edu**

**Genetics, Genomics, and the Evolution of Temperature–dependent Sex Determination in Reptiles**

Temperature–dependent sex determination (TSD) is found in some fish and amphibians and many reptiles. Yet, the genes(s) that transduce temperature into a signal for ovary versus testis development is not known in any species. We are using genomic and genetic approaches to dissect the molecular basis for TSD in the snapping turtle, *Chelydra serpentina*. We used next generation sequencing to characterize the transcriptome in gonads from embryos incubated under male and female thermal regimes. We used the 454 system to sequence two normalized libraries, producing 2.8 million reads (1.4 million/temp) with average read length of 350 bp. We assembled and annotated these sequences. In a second study, we used the Illumina platform to sequence 20 RNA samples (2 temps x 5 days x 2 biological replicates). This study produced 156.4 million reads (100 bases/read) for a total of more than 15 trillion bp of cDNA sequence. We used DEseq within the R statistical package to analyze transcript abundance (i.e., reads/contig). We identified numerous differentially expressed transcripts during the temperature sensitive period of sex determination: 302 genes on day 1, 145 genes on day 2, 247 genes on day 3, 630 genes on day 4, and 1071 genes on day 5. We used quantitative PCR to verify differential expression of candidate genes. We are also identifying polymorphisms in candidate genes. These polymorphisms will be used in allele specific expression assays in embryonic gonads and genetic association studies in hatchlings from a temperature that produces mixed sex ratios. Here we report results of our transcriptome analyses and describe results of structural equation modeling of the gene network underlying TSD. We discuss TSD within the context of the reproductive biology and ecology of the snapping turtle.

**S2–2.1 RICHARDS, CL*; BORUTA, Martyna; BOSSDORF, Oliver; COON, Courtney AC; FOUST, Christy M; HUGHES, A Randall; KILVITIS, Holly J; LIEBL, Andrea L; NICOTRA, Adrienne B; PIGLIUCCI, Massimo; ROBERTSON, Marta H; SCHREY, Aaron W; Univ. of South Florida, Univ. of Bern, Florida State Univ., Australian National Univ., City Univ. of New York, Armstrong Atlantic State Univ.; clr@usf.edu**

**Epigenetic mechanisms of phenotypic plasticity**

Our understanding of the translation of genotype to phenotype is still in its infancy, but the ability of an organism to express plasticity in a given trait must be mediated at the molecular level. Epigenetic mechanisms, such as DNA methylation, can result in different phenotypes from the same genotype and therefore fit a classic definition of phenotypic plasticity. However, demonstrating a role of molecular epigenetics in phenotypic plasticity is difficult, especially in natural populations. We present conceptual issues related to measuring phenotypic plasticity and discuss designs that have been used to explore phenotypic plasticity at different levels of organization from the genotype to the species level. Further, we explore the translation of genetic variation into epigenetic effects by presenting data from several plant and animal systems. Our data suggest that differential DNA methylation can contribute to an organism’s ability to elicit a variable phenotype. However, deciphering the relationship between phenotypic plasticity and epigenetic variation will require manipulative studies that isolate specific epigenetic changes and their phenotypic effects.

**S2–1.4 RICHARDS, Eric J*; HENKHAUS, Natalie; ANAND, Ila S.; Boyce Thompson Institute for Plant Research, Cornell University; ejr77@cornell.edu**

**Natural Epigenetic Variation in Arabidopsis**

The accumulating evidence documenting the prevalence of stable inherited epigenetic alleles, which can be transmitted from one organismal generation to the next independent of strict control by genetic variation, forces a re–examination of the role that epigenetic variation might play in a ecological and evolutionary context. In a survey for natural variation in transcriptional activity and cytosine methylation, we uncovered epigenetic variation in the *Sadhu* retrotransposon family in the flowering plant, *Arabidopsis thaliana*. I will present an update on our work charting the genetic behavior of *Sadhu* element epigenetic alleles, as well as an investigation of the impact that this epigenetic variation exerts at both genome and phenotypic level.
104.1 RICHTER, M.M.*; LEE, T.N.; TOIEN, O; BARNES, B.M.; BUCK, C.L.; Univ. of Alaska, Fairbanks, Univ. of Alaska, Anchorage; mrichter@ualaska.edu

Hibernation at Extremes: How low can you go?

During hibernation, soil temperatures adjacent to hibernacula (Ta) average a low of ~15.8 &degC and can drop as low as ~23.4 &degC. Thus, unlike many hibernators, AGS must remain continuously thermogenic during hibernation to defend the gradient between core body temperature (Tb) and Ta. Here we determined the lowest ambient temperature at which AGS will remain torpid. First, we progressively decreased Ta at 2 &degC increments from 2 &degC to ~20 &degC, measuring metabolic rate (MR) during steady state torpor at each Ta and arousing animals between trials. We found MR increased from 0.01 ml O2/g/hr at 2 &degC to 0.29 ml O2/g/hr at ~20 &degC. We also held AGS in steady state torpor at 2 &degC, 0 &degC, -10 &degC, -20 &degC and then decreased Ta in 2 &degC increments until animals failed to hibernate. Similar to our first findings, MR steadily increased until it reached a maximum of 0.36 ml O2/g/hr at ~26 &degC. Lastly, we held animals in steady state torpor at ~20 &degC and within a bout of torpor decreased Ta at 0.2 &degC/min. Decreasing Ta within a torpor bout continued until the animal spontaneously aroused or no longer increased MR despite decreasing Ta. We found animals spontaneously aroused at Ta between ~23.1 &degC to ~29.8 &degC, with an average of ~26.0 &degC ± 2.7 &degC. Our results show that AGS are able to remain in steady state torpor at Ta as low as ~26 &degC, guarding a temperature gradient of 23 &degC between their core body temperature and the ambient environment.

129.2 RICO–GUEVARA, A.*; RUBEGA, M.A.; Univ. of Connecticut, a.rico@uconn.edu

Tongue loading and intraoral transport of nectar in hummingbirds

Hummingbirds have remarkably high metabolic rates, amazing speed and aerodynamic control, and they are classic examples of coevolution with flowering plants. All of these facts are related to a single reality: they have evolved to efficiently find and rapidly consume small, scattered nectar pools. We describe here the biomechanics of every step of fluid capture and transport, including the processes by which the nectar is loaded onto and fills the tongue, offloaded inside the bill and transported to the throat. We filmed (high-speed videos up to 1000 fps) 20 species of hummingbirds in localities throughout the Americas. We coupled high-speed cameras to a dissecting microscope to film how the whole tongues of four recently deceased specimens filled with nectar at the tongue–nectar interface. Instead of the capillary filling long thought to be responsible for loading the tongue, we found a surprising mechanism of elastic expansion of the tongue that accounts for its complete filling with nectar. To further understand the feeding process, we used MicroXCT scans to create three-dimensional reconstructions of bills and tongues at a scale that allows measurement of internal volumes and hence calculation of nectar flow rates. Lastly, to elucidate fluid transport inside the bill, we used illumination techniques that allowed us to film nectar flow through the whole beak of live hummingbirds. We were able to visualize nectar flow through the keratin, to track nectar menisci, and to follow bubble formation. We found that hummingbirds exploit hydrostatic pressure to move fluid inside the bill and we describe an unexpected role of the tongue base in nectar transport. These combined data help us understand how their ability to efficiently extract all of the nectar from flowers affects hummingbird ecology and evolution.

113.5 RICHMAN, S.E.*; MCWILLIAMS, S.R.; LEAFLOOR, J.O.; KARASOV, W.H.; University of Rhode Island, Environment Canada, Winnipeg, MB, University of Wisconsin–Madison; cruciger70@gmail.com

Growing Fast and Dying Young: Influence of Forage Quality on Growth and Survival of Arctic Avian Herbivores

Keystone herbivores such as geese in Arctic ecosystems are highly sensitive to reduced quantity and quality of available forage like that caused by overgrazing. To determine the effects of diet quality on growth and survival of sympatric goose populations, we raised 100 Canada and 100 Snow goose goslings on grass–based diets that included a factorial combination of three levels of protein (10, 14 and 20%) and two levels of neutral detergent fiber (30 and 45%), but similar energy content (~18 kJ/g). Survival of Snow but not Canada goslings was significantly affected by both dietary protein and fiber content. Goslings fed the low protein diets had ~40–65% lighter body mass and reduced structural growth compared to goslings raised on the higher protein diets. The effects of dietary fiber were more extreme for Snow compared to Canada gosling in part because Canadian increased food intake (corrected for body size) by ~100% while Snows increased food intake by only 15% when fed the high–fiber diets. Apparent Metabolizable Energy was similar between species, but lower for diets with high fiber content. Canada goslings had larger gizzard mass and small intestine length than Snow goslings in response to increased fiber content. These results indicate that Snow gosling had higher protein requirements than Canadian, and that there were interspecific differences in compensatory growth that were explained by their digestive physiology. Although phenotypic flexibility in gosling growth and digestive system allows geese to respond successfully to habitat change, there appears to be a lower limit to the quality of forage eaten (<10% protein and high fiber) that is to a degree species–specific.

148.4 RICHTER, J.P.*; RUMPLE, C.R.; QUIGLEY, A.P.; RANSLOW, A.N.; NEUBERGER, T.; RYAN, T.M.; STECKO, T.D.; PANG, B.; VAN VALKENBURGH, B.; CRAVEN, B.A.; Penn State University, University of California, Los Angeles; jpr244@psu.edu

Comparative Anatomy and Functional Morphology of the Mammalian Nasal Cavity

The mammalian nasal cavity is a complex anatomical structure, having many functional roles. The convoluted nasal airway labyrinth provides a tortuous airflow path and a large surface area for respiratory air conditioning, filtering of inspired contaminants, and olfaction. Due to the small and contorted structure of the nasal turbinals (or turbinates), the anatomy and function of the nasal cavity remains poorly understood in most mammals. However, recent advances in medical imaging, image processing methods, and three-dimensional anatomical reconstruction techniques are now permitting comparative studies of nasal anatomy and function across species. In this study, we present high–resolution magnetic resonance imaging (MRI) and computed tomography (CT) scans of the nasal cavity in different mammalian species that include terrestrial and aquatic carnivora (cougar, bobcat, sea otter), ungulates (white–tailed deer), and rodents (gray squirrel). Using these data we compare the nasal anatomy, based on the MRI and CT scans and three–dimensional anatomical reconstructions. The functional implications of respiratory and olfaction are then presented, based on non–dimensional analyses that incorporate airway morphometry data (e.g., airway diameter, perimeter, cross-sectional area, surface area, volume) extracted from the anatomical reconstructions. These analyses are used to quantitatively assess and predict functional nasal airway performance. Supported by NSF grants IOS–1120375 (to BAC), NSF IOS–0817748 (to BVV), and NSF IOS–1119768 (to BVV).
Extending thermal games of predator–prey interactions in a spatially–explicit context

For many organisms, biotic interactions are mediated by abiotic features of the environment. Interactions amongst predators and their prey are no exception. For prey, behaviors are the result of balancing trade–offs between the risks of mortality associated with detection by predators and the energetic costs associated with movement while foraging and thermoregulating. In response, predators must adapt to changes in the behavior of prey while also balancing energetic requirements. To date, models of thermally–mediated predator–prey interactions have predicted the extent to which prey specialize on thermal resources in response to predator lethality. However, these predictions have not considered costs associated with movement amongst thermal patches, nor have they considered constraints on movement amongst patches imposed by thermal conditions. Here, we extend these models to include spatially explicit constraints on movement as mediated by thermal features of the environment. The results of these models suggest that the configuration of patches in the environment drives the behavioral decisions in predator–prey interactions. Configurations of habitat that concentrate prey detection tend to favor generalization of the thermal preferences of prey; whereas configurations that reduce prey detection tend to favor specialization.

Complexity of the labial lamina propria increases with increasing range of fundamental frequency in songbird song

The mechanical properties of connective tissue are determined by the morphology of its extracellular matrix. These properties are especially pivotal in sound generating organs where soft connective tissue, is set into flow–induced oscillations, and differences in the morphology of the connective tissue must contribute to vocal differences. In the vocal organ of songbirds (syrinx) labia are the main sound generating tissues. When air is pushed through the syrinx, two pairs of labia are set into oscillation, and these flow–induced tissue oscillations are the basic mechanism for converting aerodynamic energy into acoustic energy. However, during sound production the connective tissue of the labia is exposed to mechanical stresses, and their morphology determines how they respond to stresses such as tensile, shear, and collision stress. Most importantly, these forces contribute to how fast the labia oscillate. We investigated the relationship between morphological features of the labia and fundamental frequency (F0) features in the vocal repertoires of eight songbird species. Species differed in the layered structure of the labia and the degree of labial asymmetry between the left and right syrinx. These differences in species–specific syringeal anatomy explain a significant portion of the variation in the size of a songs F0 range of these species. The relation between F0 range and the number of layers indicates a vocal–repertoire–dependent morphological feature that is independent of body size.

Tendon function during swimming; does compliance enhance performance?

Tendons can enhance performance by storing elastic energy produced by the muscle, then releasing it rapidly during recoil, assisting the muscle to accelerate the load. Under certain conditions, tendon dynamics cause power amplification, where peak muscle–tendon (MT) power exceeds the theoretical limits of contractile element (CE) power. While power amplification is likely in jumping, its role during swimming is less known. Recent models of MT dynamics during hydrodynamic loading suggest that multiple morphological configurations may maximize MT power, sometimes causing power amplification. However, as this work was performed in still water, it is unclear whether compliant tendons enhance or reduce swimming speed. To address this, we used a forward translating bio–robotic foot actuated by motors simulating Xenopus laevis muscle dynamics. We simulated muscle contractions with and without translation at tendon stiffness values ranging from 750 to 30,000 N/m allowing us to relate MT and whole body swimming performance. While peak CE power was similar with and without translation, and across stiffness levels, peak MT power increased with decreasing stiffness with translation, but not in still water. Differences in peak MT power with and without translation stem from timing differences in tendon recoil (starting earlier and lasting ~2x as long without translation). Among translational cases, we observed power amplification for all but the stiffest tendon; for example, in the most compliant case, peak MT power was ~33% greater than the limit for muscle alone. However, there was no enhancement of either swimming speed or muscle work as compliance increased. Hence, it remains unclear whether tendon compliance is beneficial for swimming performance.
Native predator eats invasive toxic prey: evidence for increased incidence of consumption rather than aversion−learning

Contemporary adaptation of native prey species to invasive predators has been relatively well documented, but that of native predators to invasive prey has received less attention. Because the level of impact an invasive species will have on its predators versus its prey will determine changes in community trophic structure, it is important to understand how native predators respond to novel prey. Here we examine the response of native fence lizards to the invasion of red imported fire ants, a novel toxic prey. Examining invaded and uninvaded lizard populations, we tested whether or not aversion−learning occurs in juvenile fence lizards over successive feedings (within lifetime), how previous fire ant exposure may affect avoidance behavior (over generations), and whether population differences are consistent when prey choice exists. We also examine rates of phenotypic divergence in traits associated with the native species as both predator and prey. Aversion−learning did not occur in either population. Instead, the incidence of fire ant consumption increased over both successive feedings and generations. Lizards from the fire ant invaded population had a higher propensity to eat fire ants than fire ant−naive lizards, even when given a choice between prey items. We found greater phenotypic divergence in traits associated with the native species as predator on, versus prey to, fire ants. Although the strategy of eating these novel toxic prey can impose survival costs in the short term, over the longer−term, eating fire ants may cost little or even benefit survivors.
S1–3.3 ROBINSON, H.E.*; KOEHL, M.A.R.; Univ. of California, Berkeley; eroбинson@berkeley.edu

Suspension predation: the effects of turbulence and wavy flow on benthic predator–prey interactions

Suspension feeders are important components of bottom–dwelling marine communities. Passive suspension feeders that do not generate feeding currents are dependent on surrounding flow to deliver particles and small organisms suspended in the water column. In coastal habitats, turbulence and waves affect food availability, encounter rates, and prey capture by sessile, suspension–feeding sea anemones. The zooplankton prey that anemones ingest, such as veliger larvae, barnacle nauplii, and copepods, exhibit differences in swimming behavior and escape capabilities. To address how the fluid environment and prey behavior shape predator–prey interactions, we used in situ flow measurements taken above beds of the aggregating sea anemone, Anthopleura elegantissima, to recreate realistic flow characteristics in a laboratory flume. Zooplankton swimming behavior and suspension feeding by sea anemones were observed in still water and in turbulent, wavy flow. During predator–prey interactions, encounter rates and capture success by anemones were compared to determine the impact of physical and behavioral effects on suspension feeding.

62.4 ROGNSTAD, R.L.*; WETHEY, D.S.; HILBISH, T.J.; Univ. of South Carolina, Columbia; rregnostad@gmail.com

The effects of rare events on climate–driven range expansion/contraction in marine communities

Species distributions are frequently determined by temperature and thus species range limits experience expansions and contractions as climate changes. Shifts in range limits are not always linear and rare climatic events can potentially counteract or exacerbate the effects of climate change on species distributions. Temperature affects range limits via multiple mechanisms, both direct, such as heat–induced mortality, and indirect, such as reducing growth or inhibiting reproduction. We examined the effects of recent extraordinarily cold winters on the southern range limit of the arctic acorn barnacle, Semibalanus balanoides, in Southwestern England. Additionally, we examined the historical frequency of such events to determine whether rare cold events could be responsible for observed historical and contemporary oscillations in the density and southern range limit of S. balanoides. We found that recent cold winters have led to a range expansion of S. balanoides, likely because temperatures are now meeting the critical temperature for reproduction of this species. However, the frequency of such cold winters, which are necessary for S. balanoides persistence in the area, has declined over the past thirty years. If repeated cold events occur within the lifespan of S. balanoides, there is potential for a storage effect and the species could persist in an area, even when faced with unsuitable years caused by warming. We also investigate the interplay between cold winters, which promote reproduction, and cold summers, which reduce mortality. This study demonstrates the importance of considering the role of rare events in controlling species distributions, particularly when they oppose the overall trend of climate change.

55.5 RODNICK, KEN; Idaho State University; rodnkenn@isu.edu

Does glucose metabolism limit rainbow cardiac performance in rainbow trout at high temperatures?

Fundamental questions remain regarding the limits and regulation of cardiac function in fish challenged with elevated water temperature. While the use of glucose for energy metabolism – especially during hypoxia – is well established in the fish heart, it is unclear how increased metabolic needs of cardiomycocytes are supported. Our recent work suggests that increases in cardiac output to meet the fish’s overall metabolic demands at high temperatures are met primarily through an increase in heart rate, because tachycardia is an unavoidable physiological response. For quiescent rainbow trout, an acute increase in water temperature to near lethal values (from 14 to 24°C at 2°C h−1) raised heart rate in a linear fashion (from 60 beats min−1 to 125 beats min−1). However, in isolated, electrically–stimulated ventricle strips, the presence of exogenous glucose did not support or improve contractile function at elevated temperatures or heart rates. An increase in temperature from 14 to 24°C also did not affect the uptake (transmembrane transport and intracellular phosphorylation) of 2–deoxyglucose (Q10 = 1.1–1.2) by quiescent ventricle strips, providing evidence for a lack of thermal sensitivity over this range and a limited ability to support increased glycogen and glycogenolysis play significant roles in supporting contracting cardiomycocytes. In contrast to the uptake of extracellular glucose, the thermal sensitivities of ventricular glycogen phosphorylase (Q10 = 1.9–2.2) and acid alpha glucosidase (Q10 = 1.8) between 14 and 24°C suggest greater enzymatic capacities to increase intracellular glucose metabolism and an important function of glycogen for cardiac energy production in rainbow trout at elevated temperatures.
17.2 ROS, I.G.*; BIEWENER, A.A.; Harvard University; ivo.ros@gmail.com Potential control inputs for aerial turning in the pigeon

To investigate the role of head stabilization in flight control of aerial turning, we analyzed 3D head and body orientations during 90° level turns in pigeons. Assuming the eyes maintain a fixed orientation within the head, the velocity and orientation of the head can be used to approximate the visual feedback. Specifically, the position of the focus of expansion (FOE) of a visual flow field on the retina can be approximated by the degree of head side slip (the offset between the head–fixed gaze and head bearing). During low speed aerial turns, all four pigeons displayed periods of head stabilization alternated with brief repositioning movements (saccades). Translational head saccades consisted of periodic fore–aft speed fluctuations of ~1 m/s for flight speeds of 3–4 m/s. Rotational head saccades occurred near the downstroke–upstroke transition, immediately following peaks in translational head speed. Rotational saccades were of fixed duration (17±3% of wingbeat–cycle period), but of varying magnitude (5–30°) and speed (400–1200 °/s). Rotational head saccades were directed away from the flight direction and into the turn. The degree of head side–slip immediately after a saccade predicted the change in flight trajectory during the subsequent wingbeat–cycle and the body rotation component underlying those flight trajectory changes. Additionally, when the head was not measurably side–slipping, the degree of neck bending or twisting predicted body rotations that re–acquired the forward flight orientation of the body, without substantially affecting flight trajectory. These correlative results indicate that in slow turning flight pigeons use visual information to control flight trajectory, complemented by head deviations relative to their body to control body orientation. (NSF IOS–0744056 & ONR N0014–10–1–0951)

51.1 ROSE, C.S.; James Madison University, Harrisonburg, Va; rosec@jmu.edu The Cellular Basis of Cartilage Growth and Shape Change in Frogs

Unlike bone, skeleton that is comprised entirely of cartilage grows and changes shape as a result of cell behaviors inside the tissue as well as on its surface. The pharyngeal arch skeleton of the frog Xenopus laevis offers an excellent model for studying how cartilage growth and shape change are controlled at the cell level because the three ventral elements (Meckels cartilage or MC, ceratohyal or CH, and branchial arch cartilages or BA) are not replaced by bone and their cell behaviors are not localized to specific regions, yet they grow isometrically at tadpole stages and undergo diverse shape changes at metamorphosis. MC lengthens and increases its curvature, CH transforms from a broad plate into a narrow cylinder, and BA is resorbed. Our goal is to understand how these growth and shape changes are accomplished at the level of cell division, enlargement, shape change, matrix secretion, and death. We used BrdU to label dividing cells, DAPI to stain dying cells, and CellProfiler to quantify cell size, shape and orientation in frontal and transverse sections through MC and CH at early, mid and late tadpole and metamorphic stages. BrdU pulse labeling was used to estimate the duration of chondrocyte cell cycles at mid and late tadpole stages. MC and CH have different ontogenetic profiles of cell division, death, size, shape and matrix secretion. However, with the exception of cell death in CH, no cartilage exhibits a dramatic change in frequency or spatial pattern of any behavior going from growth to shape change. Most cells that complete S phase do not complete mitosis, and only a small percentage complete a second mitosis. These data will be used to generate rules of cell behavior for cartilage growth and shape change and to test multiple models for their developmental regulation.

59.1 CH transforms from a broad plate into a narrow cylinder, and BA is resorbed. Our goal is to understand how these growth and shape changes are accomplished at the level of cell division, enlargement, shape change, matrix secretion, and death. We used BrdU to label dividing cells, DAPI to stain dying cells, and CellProfiler to quantify cell size, shape and orientation in frontal and transverse sections through MC and CH at early, mid and late tadpole and metamorphic stages. BrdU pulse labeling was used to estimate the duration of chondrocyte cell cycles at mid and late tadpole stages. MC and CH have different ontogenetic profiles of cell division, death, size, shape and matrix secretion. However, with the exception of cell death in CH, no cartilage exhibits a dramatic change in frequency or spatial pattern of any behavior going from growth to shape change. Most cells that complete S phase do not complete mitosis, and only a small percentage complete a second mitosis. These data will be used to generate rules of cell behavior for cartilage growth and shape change and to test multiple models for their developmental regulation.

62.3 ROSARIO, M.V.*; DUMONT, E.R.; PATEK, S.N.; UMass, mrosario@bio.umass.edu Shrimp springs: how shape affects strength in energy storage

Elastic systems are widespread in nature and vary in morphology across taxonomic groups. A key question in elastic systems is how shape influences strength, thereby affecting how much energy can be stored before failure. To address this question, we analyzed the spring system in the striking appendages of mantis shrimp (Stomatopoda). The fastest–striking mantis shrimp squash prey by using their springs to generate strikes exceeding 24 ms. Shrimp that shear are less dependent on elastic energy and strike at slower speeds. First, we asked if cross–sectional shape of singer appendages results in higher strength. Second, we tested how the location of the saddle (a major spring component) and its removal influence energy distribution in spearers and smashers. Shape factor analysis was used to analyze the effect of cross–sectional shape on bending strength. We also used finite element analysis and manipulations in silico to assess the effect of spring location and removal on strain energy density throughout the appendage. We found thatisher appendages achieve equivalent bending strengths as spears while using less than 1/5 of the material. Removal of the saddle increases energy storage while variation in its position can decrease energy storage. We also found functional differences between smashers and spearers in the non–spring components of the appendages; the smash configuration uniquely reduces energy in other regions of the appendage. These results suggest that species with higher dependence on fast, spring–loaded movements (i.e., smashers) may have cross–sectional shapes that increase spring strength, and that variation in the configuration of spring components affects the energy in regions other than the spring during spring compression.

82.3 ROSEN, O.*; MANOR, R.; WEIL, S.; SAGI, A.; Ben Gurion University of the Negev; roseno@post.bgu.ac.il A newly identified IGFBP in crayfish: another piece in the insulin–like androgenic hormone’s puzzle?

In malacostracan crustaceans, male sexual differentiation is known to be induced and also maintained by a secreted insulin–like androgenic gland hormone (IAG). The involvement of this peculiar insulin–like factor was thoroughly examined using RNAi in decapods in which changes ranging from de–masculinization to even male sex–reversal can be induced and also maintained by a secreted insulin–like androgenic hormone’s puzzle? A newly identified IGFBP in crayfish: another piece in the insulin–like androgenic hormone’s puzzle?

83.1 ROSE, C.S.; James Madison University, Harrisonburg, Va; rosec@jmu.edu The Cellular Basis of Cartilage Growth and Shape Change in Frogs

Unlike bone, skeleton that is comprised entirely of cartilage grows and changes shape as a result of cell behaviors inside the tissue as well as on its surface. The pharyngeal arch skeleton of the frog Xenopus laevis offers an excellent model for studying how cartilage growth and shape change are controlled at the cell level because the three ventral elements (Meckels cartilage or MC, ceratohyal or CH, and branchial arch cartilages or BA) are not replaced by bone and their cell behaviors are not localized to specific regions, yet they grow isometrically at tadpole stages and undergo diverse shape changes at metamorphosis. MC lengthens and increases its curvature, CH transforms from a broad plate into a narrow cylinder, and BA is resorbed. Our goal is to understand how these growth and shape changes are accomplished at the level of cell division, enlargement, shape change, matrix secretion, and death. We used BrdU to label dividing cells, DAPI to stain dying cells, and CellProfiler to quantify cell size, shape and orientation in frontal and transverse sections through MC and CH at early, mid and late tadpole and metamorphic stages. BrdU pulse labeling was used to estimate the duration of chondrocyte cell cycles at mid and late tadpole stages. MC and CH have different ontogenetic profiles of cell division, death, size, shape and matrix secretion. However, with the exception of cell death in CH, no cartilage exhibits a dramatic change in frequency or spatial pattern of any behavior going from growth to shape change. Most cells that complete S phase do not complete mitosis, and only a small percentage complete a second mitosis. These data will be used to generate rules of cell behavior for cartilage growth and shape change and to test multiple models for their developmental regulation.

SICB 2013 Annual Meeting Abstracts
Cranial bone strain in the teiid lizard Tupinambis merianae and the diversity of optimality criteria in vertebrate skulls

In vivo bone strain data provide the most direct evidence of patterns of strain in the skull during feeding and have provided important insights into skull design in mammals and Alligator. These data suggest that bone strain magnitudes in the calvaria and upper face of mammals are absolutely low, and low compared with strain magnitudes elsewhere in the skull. This suggests that the calvaria and upper face are not optimized for resisting feeding forces where optimality is defined as maximum strength with minimum material because they are optimized for other functions, including protection of the brain and eyes. Here we present in vivo bone strain data recorded from the cranium of the teiid lizard, Tupinambis merianae during transducer biting and feeding. Tupinambis experiences very high strain magnitudes in the frontal and parietal bones during feeding, much higher than those recorded at comparable sites in mammals. These results suggest that the cranium of Tupinambis, like those of Alligator and Sphenodon, is more optimized for resisting feeding forces than is the cranium of mammals. During feeding the snout of Tupinambis is bent, sheared and twisted, depending on bite point and behavior, emphasizing the importance of recording strain data across a wide range of natural behaviors. In contrast, the deformation regime in the parietal bone is relatively constant across behaviors. This suggests that the mesokinetic hinge between frontal and parietal bones absorbs strain energy associated with forces acting on the snout of Tupinambis during feeding.

No pain, big gain: coevolution between bark scorpion pain–inducing toxins and grasshopper mouse nociceptors

Traits that mediate interactions between predator and prey rely on fast, specialized sensory inputs. Ion channels expressed in excitable membranes are critical for encoding information about and producing responses to sensory stimuli. Given their critical role, it is not surprising that some animals have evolved toxins that bind ion channels and disrupt their activity. Disruption of channel activity may impose strong selection on the receiver, driving the evolution of counter adaptations. Arizona Bark scorpions ([AZB] Centruroides sculpturatus) produce toxins that selectively bind sodium– (Na+) ion channels expressed in pain–pathway neurons (nociceptors), inducing intense pain in sensitive mammals. Southern grasshopper mouse [SG] (Onychomys torridus) attack and consume these toxic scorpions. Natural stings and paw–licking assays showed that SG mice respond only briefly to venom, suggesting they have evolved insensitivity to pain–inducing toxins. Recordings of Na+ current from ion channels expressed in SG mice nociceptors revealed a novel mechanism where a component of AZB scorpion venom is co–opted by these Na+ channels to block the very pain signals that the toxins are generating. Cloning and sequencing of genes that encode nociceptor–expressed Na+ channels from grasshopper mouse revealed structural modifications in the channel that are positioned to co–opt toxin activity. Current work is focused on using site–directed mutagenesis, an expression system and electrophysiology to determine if structural modifications of grasshopper mouse Na+ channels produce functional changes in nociceptors that explain insensitivity to bark scorpion pain–inducing toxins.

Effects of Selenium–enriched meal on growth performance, endocrine control of growth and selenoprotein expression in tilapia (Oreochromis mossambicus)

Selenium is a naturally occurring essential trace element required for normal nutrition and health in animals. It has been shown to aid in the function of a healthy immune system as well as an antioxidant during cellular stress in tissues. Organic Se has been shown to prevent cardiomyopathies and improve antioxidative status as a nutritional supplement. Studies with Se supplemented diets in some fish species have shown increased growth with decreasing mortality and improved antioxidative status. However, the effects of Se supplementation on growth and metabolism in tilapia have yet to be investigated. Tilapia were offered varying doses of an organic Se–enriched or a control diet for 12 weeks. Tilapia fed Se–enriched diets exhibited decreased growth compared to the control group after 12 weeks. However, there was no difference in liver mRNA levels of two important proteins (IGF–1 and GHR–2) of the growth axis across treatment groups. Liver mRNA levels of the antioxidative enzyme (glutathione peroxidase) and selenoprotein (SelS) were decreased across treatments compared to the control. At this point it is not known if Se supplementation affected circulating levels of these proteins. There was also an increase in the concentration of Se in the liver of the Se–enriched treatment. Further speculation confirmed the Se present in the liver was predominantly selenomethionine, which is also the highest form of Se available in the supplemented diets. Currently, these data suggest that the dose and/or length of Se supplementation used in this study inhibits growth and down–regulates the activity of important selenoproteins in tilapia.

Influence of tendon compliance and activation level on fibre operating lengths of skeletal muscle

The region over which skeletal muscles operate on their force–length (F–L) curve is fundamental to the mechanics of movement. Function at the plateau region of the F–L curve may be regarded as favourable since force capacity is optimized. The activation level (ACT) of a muscle will, to a large extent, dictate its force output and in turn will affect tendon stretch and muscle fibre lengths. It remains possible that muscle–tendon units with high tendon compliance have a restricted range of ACT over which optimal fibre lengths can be achieved compared to muscles with low tendon compliance. To test this question we developed a three–dimensional (3D) musculoskeletal model of the guinea fowl hind limb that included 3D bone geometry, muscle–tendon paths and wrapping surfaces, and muscle–tendon architecture properties including muscle PCSA, optimal fibre lengths and tendon stiffness. We simulated the region of the F–L curve occupied by the lower–limb muscles under 4 ACT conditions: 1) 100% ACT (maximal), 2) 50% ACT, 3) 25% ACT and 4) 0% ACT (passive). We found that muscle–tendon units with low tendon compliance (hip muscles) have a length operating range that is largely insensitive to ACT. On the other hand, muscles with high tendon compliance (lower limb muscles with long external tendons) have a length operating range that is highly sensitive to ACT. Interestingly, certain muscles (gastrocnemius) operate across the plateau region of the F–L curve at high ACT whereas other muscles (digital flexors) do so at low ACT. The interaction between tendon compliance, ACT and muscle lengths sheds new light on muscle recruitment and function during movement tasks. This interaction is particularly important in animals with high tendon compliance (e.g. cursorial species).

32.6 RUPP, M.F.*; HULSEY, C.D.; University of Tennessee Knoxville; mrupp@utk.edu

Evolution and Kinematics of Pectoral Fins in Malawi Cichlids

In adaptive radiations such as Malawi cichlids there is a high degree of variation in the way pectoral fins are used in locomotion during feeding and other routine activities. To try and better understand the factors behind the evolution of pectoral fin musculature we tested for differences in the pectoral fin morphology between groups of species, calculated rates of pectoral fin muscle evolution, and differences in the pectoral fin morphology between groups of species. Preliminary results from mature M. domestica indicate the predominant expression of M. domestica

23.2 RYAN, C.P.*; DAWSON, A.S.; SHARP, P.J.; WILLIAMS, T.D.; Simon Fraser University, Canada, Centre for Ecology and Hydrology, Edinburgh, U.K., The Roslin Institute, University of Edinburgh, U.K., Simon Fraser University; calenRyan@sfu.ca

Hormone–trait relationships for experimentally enlarged clutches continue to challenge the prolatin–based model for clutch–size determination

Clutch–size is a chief predictor of avian lifetime reproductive success, with fitness ramifications for both females and their offspring. While adaptive variability in clutch–size in response to predation, seasonality, or condition–dependent cues has theoretical and empirical support, remarkably little is known about the proximate mechanisms that enable both plasticity and repeatability in this trait. The only formal mechanistic hypothesis for clutch–size determination in birds predicts an anti–gonadal effect of Prolactin, a peptide hormone commonly associated with incubation and chick rearing. Now over 20 years old, this model has become widely accepted despite a scarcity of experimental support. Correlational findings from captive–breeding zebra finches (Taeniopygia guttata) in our lab do not substantiate a relationship between prolactin and clutch–size. In a follow–up experiment, we accompanied egg removal with sequential blood sampling in an attempt to further investigate any hormone–trait relationships. Egg removal significantly increased clutch–size (from ~6 to 15 eggs, on average), exposing latent phenotypic plasticity, and was associated with changes in circulating prolactin levels. Still, the nature of this relationship was not consistent with a role for either absolute threshold or rate of prolactin increase accompanying the cessation of laying. These findings continue to challenge the applicability of the only mechanistic model available to explain a key fitness trait in birds.
The Hydrodynamics of Olfaction in the Hammerhead Shark

The hammerhead shark is widely known for its unique head morphology, which is thought to facilitate enhanced olfactory performance. The nasal chambers, located at the distal ends of the cephalofoil, contain numerous lamellae that increase the surface area for olfaction. Functionally, for the hammerhead to detect chemical stimuli, water–borne odors must reach the sensory epithelium that lines these lamellae. Thus, odorant transport from the external aquatic environment to the sensory epithelium is the first critical step in olfaction. Here we investigate the hydrodynamics of olfaction in the hammerhead shark based on an anatomically-accurate, three-dimensional reconstruction of the head and nasal chamber of *Sphyrna tudes* from high-resolution computed tomographic (CT) and magnetic resonance imaging (MRI) scans of a cadaver specimen. Using this reconstructed model, high-fidelity computational fluid dynamics (CFD) simulations are used to elucidate the external and internal hydrodynamics of olfaction during swimming. Computed external flow patterns reveal the occurrence of flow phenomena that results in high and low pressures at the current and excurrent nostrils, respectively, which induces flow through the nasal chamber. Internal hydrodynamic flow patterns within the nasal chamber are also revealed and the implications regarding olfaction are discussed. Finally, we consider the effect of swimming speed on the hydrodynamics of olfaction, where we show the functional trade-offs of fast– versus slow–speed swimming.

81.6 RYGG, A.D.*; COX, J.P.L.; ABEL, R.; WEBB, A.G.; SMITH, N.B.; CRAVEN, B.A.; The Pennsylvania State University, University of Bath, Natural History Museum, London, Leiden University Medical Center; ada5023@psu.edu

The Hydrodynamics of Olfaction in the Hammerhead Shark (*Sphyrna tudes*)

The hammerhead shark is widely known for its unique head morphology, which is thought to facilitate enhanced olfactory performance. The nasal chambers, located at the distal ends of the cephalofoil, contain numerous lamellae that increase the surface area for olfaction. Functionally, for the hammerhead to detect chemical stimuli, water–borne odors must reach the sensory epithelium that lines these lamellae. Thus, odorant transport from the external aquatic environment to the sensory epithelium is the first critical step in olfaction. Here we investigate the hydrodynamics of olfaction in the hammerhead shark based on an anatomically-accurate, three-dimensional reconstruction of the head and nasal chamber of *Sphyrna tudes* from high-resolution computed tomographic (CT) and magnetic resonance imaging (MRI) scans of a cadaver specimen. Using this reconstructed model, high-fidelity computational fluid dynamics (CFD) simulations are used to elucidate the external and internal hydrodynamics of olfaction during swimming. Computed external flow patterns reveal the occurrence of flow phenomena that results in high and low pressures at the current and excurrent nostrils, respectively, which induces flow through the nasal chamber. Internal hydrodynamic flow patterns within the nasal chamber are also revealed and the implications regarding olfaction are discussed. Finally, we consider the effect of swimming speed on the hydrodynamics of olfaction, where we show the functional trade-offs of fast– versus slow–speed swimming.

32.4 RYERSON, WG*; SCHWENK, K; Univ. of Connecticut; william.ryerson@uconn.edu

The Optima of Innovation: tongue-flicking mechanisms in air and water in the water snake (*Nerodia sipedon*)

Snakes use oscillatory tongue-flicking to sample the environment for odor molecules. In air, the oscillations set up two pairs of vortices and regions of high velocity air flow. This pattern of air movement maximizes the rate of molecular mass transfer onto the tongue tips through convection, diffusion and sorption. Water snakes tongue–flick in water as well as in air, leading us to wonder if the same patterns would be observed in the more viscous fluid. We used high speed video analysis and particle image velocimetry (PIV) in air and water to examine differences between environments in the kinematics of tongue–flicking and the patterns of air/water flow it generates around the tongue tips. In water, both the kinematics and fluid dynamics are strikingly different from air–flicks. The velocity and duration of individual oscillations is reduced, as is the number of oscillations within a tongue–flick bout. In water the times are not kept rigid as they are during air–flicking; instead they bend in a continuous curve along with the body of the tongue and water appears to flow along the times rather than across them. Vortex formation is similar in both environments, but the reduced number of oscillations and decrease in velocity results in the formation of only a single pair of counter–rotating vortices before the tongue is retracted. It appears that the greater viscosity of water constrains the mechanics of tongue–flicking and that water snakes are unable to exploit the fluid dynamic mechanism used in air–flicking to maximize chemical collection. It is possible that slower and shorter bouts of tongue–flicking help to prevent the dissolution of the salivary fluid covering the tongue tips—the material that physically collects odor molecules during oscillatory tongue–flicking, which trades–off with the efficiency of mass transfer.

85.8 SALCEDO, N. J.; College of Charleston, Charleston; salcedon@cofc.edu

Monotypic genera: two unique armored catfish species (*Siluriformes: Loricariidae*), with naked snouts.

Although the external morphology of a new species of armored catfish suggested it could be closely related to the genus *Chaetostoma*, the lack of nuchal plate and dorsal spine, it suggested it could be closely related to *Lihogenes* or *Hemisilicthys*; and the narrow anterior process of its basipterygia suggested it could be closely related to *Ancistrus*. To determine the taxonomy of the new species and its phylogenetic position, the new species and *Lipopterichthys carioni* (a monotypic genus considered a synonym of *Chaetostoma*) were included in a published matrix of morphological traits (153 taxa and 215 characters). The results of the phylogenetic analysis retrieved 16123 most parsimonious trees (length 15558; CI=0.18; RI=0.76). The new species was retrieved as sister to *Lipopterichthys carioni*, this relationship is supported by nine unambiguously changing characters. Furthermore, the new species and *Lipopterichthys carioni* exhibit 11 and 18 unambiguously changing characters, respectively, but all these characters are homoplasies (CI=0.5). The decision was to describe the new species in a new genus, based on the unique morphology of its evertible cheek odontodes and on its intermediate characters, such as: a slightly projected anguloarticular, and narrow lateral anterior process of the basipterygia, almost in contact with the medial anterior process of the phylum.
Behavioral responses to sound stimuli in cuttlefish (Sepia officinalis)

Sound is an important sensory cue for many marine animals that use acoustics for mate attraction, habitat identification and predator avoidance. Cephalopod sound detection abilities were suggested over a century ago and have been a subject of debate since. Yet there are few data addressing potential behavioral responses of cephalopods to sound, their sensitivity range, or whether sound plays a functional ecological role. This study examined the behavioral responses of 12 cuttlefish (Sepia officinalis) to tone pips ranging from 80 to 1000 Hz and intensities of 110 to 165 dB re 1 Pa. The most dramatic responses (jetting and inking) were observed for sounds between 100 and 200 Hz and at 300 Hz (juveniles only), all at intensities above 140 dB re 1 Pa. Subtle skin patterning changes and fin movements were observed at all frequencies and intensities. Similarly to vertebrates, cephalopods showed a decrease in reaction latency when the sound intensity increased, suggesting an energy-based detector. Potential habituation to sound stimuli was examined using repeated presentations at 200 Hz and two sound intensities. A decrease in response intensity was observed, especially in younger animals, supporting behavioral adaptation and some habituation. However, response extinction was not reached. The gradation in behavioral responses, habituation and reaction times to acoustic stimuli have not yet been described for marine invertebrates and strongly suggest a functional role of sound detection in cuttlefish and other cephalopods.

Divergent Behavioral Strategies in Three Congeneric Rodents for Dealing with Fruit Toxins

Fleshy, ripe fruits facilitate seed dispersal by attracting animals that consume the fruits and disperse the seeds. However, many fruits contain secondary compounds (FSCs) that deter potential consumers. Previous studies have demonstrated class-dependent deterrence where frugivorous birds were not affected by the FSCs while granivorous rodents were deterred by them. Here we show divergent behavioral strategies for dealing with FSCs within a single genus of rodents. In a series of field observations, controlled feeding trials and biochemical analysis we investigated the fruit eating strategies of three congeneric rodents for Ochradosomes baccatus, a desert plant with unique compartmentalization of FSCs. The fruit pulp has high concentrations of glucosinolates (GSls) that are hydrolyzed into active toxic compounds upon contact with myrosinase released from the seeds crushed during consumption. We found that the granivorous rodents, Acomys cahirinus and A. minous, circumvent the activation of the GSls by, respectively, orally expelling viable seeds or by making a hole in the pulp and consuming only the seeds. In contrast, A. russatus activates GSls by consuming the whole fruit. We propose that A. russatus possesses physiological adaptations to cope with the toxic compounds generated from the GSls–myrosinase system whereas A. cahirinus and A. minous exhibit behavioral adaptations (seed or pulp spitting) to avoid the activation of these toxins. These findings demonstrate the extreme ecological/evolutionary lability of this plant–animal symbiosis to shift from predation to mutualism.

Ontogenetic shifts in oxygen uptake of Common Mudskipper (Periophthalmus kalolo) and its role in microhabitat selection

The Common Mudskipper, Periophthalmus kalolo, is a tropical, amphibious fish capable of utilizing both air and water as a respiratory medium. Although little is known about their early life history, smaller juveniles are thought to be more dependent on tidepools than adults. We quantified oxygen uptake in water and air of fish between 1.0 and 10.3 cm standard length to identify ontogenetic shifts in aquatic and aerial oxygen extraction ability. Mudskippers smaller than 4.0 cm in standard length exhibited aquatic mass-independent metabolic rates nearly twice those measured for larger fish (approximately 0.46 and 0.26 mg g⁻⁰.₅ h⁻¹, respectively). Aerial mass-independent oxygen uptake in juvenile mudskippers ≤ 2.0 cm in length was ten times greater than values estimated for larger fish (3.80 and approximately 0.34 mg g⁻⁰.₅ h⁻¹, respectively). Furthermore, water:air metabolic rate ratios showed that emerged mudskippers ≤ 2.0 cm in length consumed seven and one-half times more oxygen than when submerged. Our results suggest that tidepool dependence of small common mudskippers is not related to oxygen extraction limitations in air, but is more likely linked to attributes such as marked increases in metabolic rate, predation, desiccation or the need to enter pools to excrete ammonia.

Nonparametric bootstrapping of RNASeq data in polymorphic polyps of Hydractinia symbiolongicarpus

One of the most common utilities of RNASeq data is comparative gene expression between different tissues or individuals. These differences in expression data can be correlated to differences in environmental effects, morphology, and developmental stages. A colony of Hydractinia symbiolongicarpus comprises genetically identical yet morphologically distinct and functionally specialized polyp types. In order to identify differential expression patterns in these different polyp types, RNASeq libraries were constructed from feeding (gastrozooids), reproductive (gonozooids), and defensive (dactylozooids) polyps for Illumina sequencing. A hybrid transcriptome was assembled on the pooled Illumina reads. The raw reads of the individual libraries were then mapped back to the hybrid transcriptome to obtain expression counts of transcripts from different polyp types. Current differential expression packages measure statistical significance of differential expression by obtaining point estimates from expression data for known distributions (Poisson, Negative Binomial, etc.). With few or no technical replicates (extraction, library construction or sequencing) these methods have little power to discover significant results. In the absence of technical replicates, we used a nonparametric bootstrapping algorithm to assess confidence in potential differentially expressed transcripts. The bootstrapping algorithm simulates data under a binomial sampling distribution where the probability of sampling an individual transcript is equal to the number of times that transcript was found in the library. Confidence intervals on expression counts were taken for each transcript in each library to discern significant differential abundance. Here we report differentially expressed genes in different polyp types and the utility of applying nonparametric bootstrap methods to RNASeq data.
142.1 SANTANA, SE*: LYNCH ALFARO, J; NOONAN, A; ALFARO, ME; University of Washington, University of California Los Angeles; ssantana@uw.edu

Social life and ecology help sculpt Old World primate faces

Old World primates exhibit almost every possible hue in the spectrum of mammalian coloration, and these colors are often combined to form very complex facial patterns such as those seen in mandrills, guenons and mangabeys. Animal coloration is thought to experience selective pressures related to intra- and interspecific communication, physiology and ecology, but it remains unclear how facial patterns and coloration across Old World primates have been shaped by these factors. We use a phylogenetic comparative approach to explore the relationship among facial traits, sociality and ecology within three major radiations of Old World primates (Cercopithecidae, Hyllobatidae and Hominidae). Consistent with the hypothesis that facial patterns function in intra and interspecific communication, we find that species living in larger groups and in higher degrees of sympatry with congeners have evolved more complex patterns of facial coloration, and there have been changes in the rate of facial pattern evolution in some of these clades. Along with social factors, the evolution of facial colors is also strongly linked to ecological features. Species living in tropical, more densely forested and humid habitats have evolved darker faces, but this trend is only observed within the African clades. Along with similar results previously found for New World primates, this study highlights the interplay between behavioral and ecological factors in shaping the diversity of primate faces.

58.2 SANTINI, F.*; CARNEVALE, G.; SORENSON, L.; ALFARO, M.E.; Univ. di Torino, Torino, Univ. of California, Los Angeles, Univ. of California, Los Angeles; francesco.santini@alumni.utoronto.ca

Testing adaptive radiation scenarios in marine fishes by combining phylogenomic and paleobiological data

Adaptive radiation scenarios have been invoked to explain the diversity of some of the best studied groups of organisms (e.g., Rift lake cichlids, Hawaiian Silversword Alliance, passerine birds). Under the most traditional adaptive radiation model numerous lineages start diverging within a brief period of time from an ancestral adaptive type, with each new lineage filling an available ecological niche; subsequently this rapid initial morphological evolution is replaced by relative stasis due to most available niches having already been filled. A number of recent studies, based on molecular phylogenetics, questioned the generality of this model and found little evidence of an early burst of morphological diversification in most studies. For most of these clades, however, it is not known if inclusion of the paleodiversity would have modified the results. In this talk we will compare the results of our study of several major groups of marine teleosts, such as tetraodontiforms (puffers, triggerfishes and allies), acanthuroids (surgeonfishes, luar) and scromboids (tunas, snake mackerels and allies). All of these groups possess a rich fossil record, which to date has rarely been used in evolutionary studies. We will show how the results based on extant taxa and those based on extant plus extinct species differ, and how inclusion of fossil data can alter the conclusion of studies based on molecular phylogenies.

39.3 SANTHANAKRISHNAN, A.*; MILLER, L.A.; LOWE, A.; ALFARO, ME; University of California, Los Angeles; arvind7@gatech.edu

Clap and Fling in Tiny Insect Flight: Role of the Porous Flow Introduced by Bristled Wings

In contrast to the flapping flight of insects of length scales ranging from the fruit fly to the hawk moth, the aerodynamics of flight in insects such as thrips that are 1 mm or less in length is not as well understood. These smallest insects typically fly at Reynolds numbers (Re) of 10 or lower and are of ecological and agricultural importance. Flight aerodynamics change at Re in the range of 5–10 due to increased viscous forces, and the ratio of lift to drag forces decreases significantly. Nevertheless, these insects are capable of traveling long distances. A detailed study of the relevant aerodynamics is thus necessary to connect their locomotion to the observed ecological behavior and dispersal mechanics. These tiny insects have been proposed to augment lift through adaptations in flight kinematics, wing flexibility and wing morphology. With reference to flight kinematics, thrips and other tiny insects clap their wings at the end of each upstroke and fling them apart at the beginning of each downstroke. These insects also have highly bristled wing surfaces as opposed to solid wings. We explore the role of bristled wings by modeling them as porous structures. 2D numerical fluid–structure interaction simulations are then used to quantify aerodynamic forces generated during porous–wing clap and fling. The input parameters for the simulations are obtained from high–speed video recordings of actual insects. An idealized form of the clap and fling motion of two wings immersed in fluid is then considered. The effect of having bristles on the flow field is examined and compared to that of an equivalent solid wing.

26.5 SAPIR, N.*; ROTICS, S.; KAATZ, M.; DAVIDSON, S.; ZURELL, D.; EGGERS, U.; JELTSCH, F.; NATHAN, R.; WIKELSKI, M.; Max Planck Institute for Ornithology, Germany; nir.sapir@mail.huji.ac.il

Multi–year tracking of White storks (Ciconia ciconia): how the environment shapes the movement and behavior of a soaring–gliding inter–continental migrant

Understanding the ways in which environmental factors influence evolutionary fitness is of foremost importance for addressing both basic and applied issues, especially under current and expected scenarios of global change. We used satellite–tracking data to study bird response to stochastic environmental events and to test if these incidents carry over to following seasons throughout the birds annual routine. Twenty six birds were followed continuously for 1.5–8 years after being equipped with satellite transmitters. Tracking data were processed using MoveBank (www.movebank.org). We examine (1) whether departure for migration and en route staging depends on wind support and hindrance, respectively; (2) if bird cross–country flight speed is affected by wind support and soaring conditions; (3) whether droughts modulate over–winter habitat selection and, migration timing, staging and arrival time to breeding grounds; Environmental data to test these questions include remotely sensed tropical rain and vegetation productivity data, as well as observation–based atmospheric model products. Combining annotated and highly detailed environmental data with bird movement, behavior and breeding information enables better understanding of the causes, mechanisms, and consequences of white stork migration.

Downloaded from https://academic.oup.com/icb/article-abstract/53/suppl_1/e1/665382 by guest on 14 April 2019
Tritrophic interactions involving a global climate regulator mediate foraging in marine top predators: Evidence from a 50-year seabird dietary database in the Southern Ocean

Dimethyl sulfide (DMS) has been studied intensively in the context of global climate regulation, and has also been implicated as a key signal molecule in foraging cascades. It has been suggested that seabirds and other marine predators use DMS released by depredated phytoplankton as a foraging cue to locate zooplankton prey. However, the dietary links between DMS attraction and trophic foraging level have never been explicitly demonstrated. We conducted a meta-analysis to explore the hypothesis that DMS mediates a tritrophic interaction in a marine system. We focused on 18 species of Antarctic and sub-Antarctic procellariiform seabirds for which experimental data on chemical attraction were available. If DMS is an infochemical facilitating a tritrophic cascade, we predicted that the diets of DMS-tracking species would contain significantly higher proportions of primary consumers (e.g. crustacea) than other food types (cephalopods and fish). Our results supported this prediction (proportion crustacea: 0.814 ± 0.039, proportion cephalopod: 0.065 ± 0.019, proportion fish: 0.108 ± 0.024; F5,274=42.67, P<0.001). We further explored this hypothesis by examining the diets of species responsive to 3-methyl pyrazine, a scented compound associated with the next highest trophic level, depredated crustacea. These analyses were consistent in showing essentially the opposite relationship: the diets of non-pyrazine-tracking species were significantly more reliant on primary consumers than other food types (proportion crustacea: 0.564 ± 0.053, proportion cephalopod: 0.235 ± 0.042, proportion fish: 0.195 ± 0.034; F5,274=17.18, P<0.001). Together, this provides strong evidence that DMS, a globally important climate regulator, also functions in ecological contexts to facilitate a tritrophic interaction in the pelagic marine environment.

Allometry indicates giant eyes of Giant Squid are not exceptional

The eyes of giant and colossal squid are among the largest eyes in the animal kingdom, yet it is poorly understood how their eye size compares to that of squid and other aquatic organisms when scaling effects are considered. We performed a large-scale comparative study that included 88 squid species and 237 species of acanthomorph fish. While squid have larger eyes than most acanthomorphs, a comparison of relative eye size among squid suggests that giant and colossal squid do not have unusually large eyes. It is probable that the giant eyes of giant squid result from a phylogenetically conserved developmental pattern manifested in very large animals. It was recently proposed that sperm whale predation is the main driver of eye size evolution in giant squid, based on an optical model that suggested optimal performance in detecting large luminous visual targets such as whales in the deep sea. We revised the constants used in the model and conclude that large eyes perform equally well in detecting point targets and large luminous targets in the deep sea. Whatever the cause of large eyes, they appear to have several advantages for vision in the reduced light of the deep mesopelagic zone.

Body Composition, and Body Size in Song Sparrows

Variation in the pre- and postnatal environments can have long-term effects on adult phenotype. In particular, exposure to stressors during development can lead to long-term changes in physiology. These changes may predispose individuals to disease, especially disorders involving energy metabolism. In addition, by permanently altering metabolic rates and energy requirements, such effects could have important fitness consequences. We determined the effects of early-life food restriction and corticosterone (CORT) treatment on adult metabolic rates, body composition (assessed via quantitative magnetic resonance), and body size in song sparrows (Melospiza melodia). Nestlings were hand-reared in captivity from 3 days of age (d3) and exposed to treatments (ad libitum food, food restriction, or CORT-treatment) from d7−d60. Both experimental treatments had sex-specific effects on standard metabolic rates (SMR). Females exposed to food restriction or CORT treatment during development had higher SMRs in adulthood than control females, but neither stressor affected SMR in males. There were no effects of either treatment on adult body composition (lean or fat mass) or peak metabolic rates. Although both experimental treatments affected nestling growth there was no long-term effect of either treatment on adult body size. In addition, despite the fact that birds were raised in captivity from an early age (d3), their adult mass was positively related to the mass of their genetic father. This suggests that body size may be a canalized trait in this species. Our results also suggest that early-life stress may have sex-specific programming effects on metabolic rates and energy expenditure in song sparrows.

Ctenophore photocytes express a light-sensing opsin as well as bioluminescent photoproteins during development

The recent completion of a draft genome assembly of the ctenophore Mnemiopsis leidyi, a representative of the earliest branch of animals that emit light, has provided an excellent opportunity to examine the genome of an organism that uses photoproteins for bioluminescence. Interestingly, we found that photoprotein transcripts are co-expressed with two putative opsin genes in developing ctenophores. Opsin expression was also found in four small groups of neural cells in the floor of the apical sensory organ that coincides with structures described as ciliated lamellate bodies; these structures were suggested to be photoreceptors over 130 years ago. We present evidence that one of the opsin genes functions in vitro, absorbing light at wavelengths that overlap with peak photoprotein light emission. We also present genomic evidence of a complete ciliary phototransduction cascade in Mnemiopsis. These findings led us to hypothesize a novel dual role for ctenophore photocytes in both bioluminescence and opsin-mediated phototransduction. This work provides a foundation for further studies aimed at determining how the bioluminescence cascade operates in Mnemiopsis, as well as whether opsin and other phototransduction pathway genes play a role in either promoting or inhibiting luminescence production under different environmental conditions.

The Long-term Effects of Early-Life Stress on Metabolic Rates, Body Composition, and Body Size in Song Sparrows

The recent completion of a draft genome assembly of the ctenophore Mnemiopsis leidyi, a representative of the earliest branch of animals that emit light, has provided an excellent opportunity to examine the genome of an organism that uses photoproteins for bioluminescence. Interestingly, we found that photoprotein transcripts are co-expressed with two putative opsin genes in developing ctenophores. Opsin expression was also found in four small groups of neural cells in the floor of the apical sensory organ that coincides with structures described as ciliated lamellate bodies; these structures were suggested to be photoreceptors over 130 years ago. We present evidence that one of the opsin genes functions in vitro, absorbing light at wavelengths that overlap with peak photoprotein light emission. We also present genomic evidence of a complete ciliary phototransduction cascade in Mnemiopsis. These findings led us to hypothesize a novel dual role for ctenophore photocytes in both bioluminescence and opsin-mediated phototransduction. This work provides a foundation for further studies aimed at determining how the bioluminescence cascade operates in Mnemiopsis, as well as whether opsin and other phototransduction pathway genes play a role in either promoting or inhibiting luminescence production under different environmental conditions.
In the last decade of the 20th century some rumors occurred in internet discussion groups of hobby aquarists dealing with an enigmatic crayfish with strange reproductive behavior and of unknown origin. In 2003 this crayfish, popularly named Marmorkrebs (marbled crayfish), was introduced to science. In the publication the parthenogenetic reproduction mode and the affinity to American Cambaridae could be revealed. These results made the Marmorkrebs a highly interesting candidate for further studies. Over the last decade numerous papers have been published addressing aspects of the biology of this crayfish. These related to the mode of parthenogenesis, embryonic and postembryonic development, species identity, geographical origin, epigenetic variation, ecology, conservation issues, etc. Despite this progress in knowledge about the Marmorkrebs, a number of its riddles are still unresolved. Our presentation provides a summary of the research activities of the last ten years and develops a perspective for future investigations.

S9−2.4 SCHULTE, PM; University of British Columbia; pschulte@zoology.ubc.ca
Evolution of tolerance to multiple interacting stressors in fish
Anthropogenic environmental change, which involves changes in multiple interacting environmental stressors, is having important effects on animals living in aquatic environments. Although we have a fairly good understanding of the effects of abiotic stressors in isolation, our understanding of the effects of these stressors in combination is limited, which limits our ability to make predictions about the responses of fish to anthropogenic environmental change. Here, I review the available literature on the responses to interacting abiotic stressors such as temperature, hypoxia and salinity in fishes, with a focus on work from my laboratory on killifish (Fundulus heteroclitus), threespine stickleback (Gasterosteus aculeatus) and Atlantic salmon (Salmo salar). These data suggest that these stressors may act synergistically such that small shifts in multiple stressors could result in large effects on organismal performance. There is substantial intraspecific variation in tolerance to individual stressors in many species of fish that could act as the raw material for evolution of improved tolerance. However, the potential for adaptive evolution in the face of multiple interacting stressors will depend, in part, on the genetic correlations among tolerance traits. For example, negative genetic correlations (or trade−offs) between temperature and hypoxia tolerance could limit the potential for adaptation, while positive genetic correlations might be of benefit. The limited data currently available suggests that hypoxia and high temperature tolerance may be positively correlated in at least some species of fish suggesting the possibility for adaptive evolution in these traits in response to anthropogenic environmental change.

68.1 SCHULTZ, EM*; HAHN, TP; Univ. of California, Davis; emschultz@ucdavis.edu
The environmental and physiological factors modulating immunity in an opportunistic breeder
In order to be optimally suited to the current environment, organisms must choose when and how to allocate limited energy resources to the most essential physiological process. This conflict often results in a trade−off between investing in future survival (e.g., immune function) or current reproduction. Much research on these tradeoffs has focused on seasonally breeding organisms that constrain reproduction to times of year when environmental conditions are benign. In contrast, organisms such as the red crossbill Loxia curvirostra specialize on conifer seeds which are unpredictably available in space and time, and so have evolved temporally flexible reproductive schedules allowing them to reproduce 10 months a year if seeds are abundant. In this study we examined variation in allocation to three measures of constitutive innate immunity: differential white blood cell counts, hemolysis−hemagglutination and microbial killing assays. We compared those results between breeding and non−breeding individuals across seasons (summer, winter) and years of high and low food availability. In general, crossbills are able to invest more in both reproduction and immunity if environmental conditions are benign (summer, good cone crop). However, if environmental conditions are harsh (winter, poor cone crop), immunity tends to be lower, even in good cone years. Data collected from this summer (a poor cone year) will be used to augment prior data. Results from this study will provide novel information regarding environmental and physiological modulators of immunity in free−living animals, as well as providing a unique opportunity to investigate how harsh environmental conditions and reproductive effort may interact to shape investment patterns and life history evolution.
SICB 2013 Annual Meeting Abstracts

59.6 SCHWAB, D.B.*; KIJIMOTO, T.; MOCZEK, A.P.; Indiana University – Bloomington; schwab@indiana.edu
Contribution, developmental, and ecological determinants of resource allocation tradeoffs in the horned beetle, Onthophagus taurus
During ontogeny, growing structures may compete for a shared pool of limited resources to sustain their development. Such interactions may lead to tradeoffs, where the elaboration of one structure must come at the expense of another. Tradeoffs have the potential to constrain the production of phenotypic variation and to bias evolutionary trajectories. In Onthophagus beetles, large males produce extravagant horns used to secure matings. Previous studies suggest tradeoffs between horns and body proportions. We examine the nature of tradeoffs between head horns and eyes in the horned beetle O. taurus. We investigate (a) relative investment into horns and eyes among discrete populations and find that tradeoffs are absent in established populations, but may be present in populations at the edge of an invasion front. Using common garden rearing, we show that (b) relative investment into horns and eyes changes under laboratory conditions. We then (c) contrast exotic populations that have diverged heritably in horn investment. We find that reduced horn investment results in reduced investment into horns, opposite to predictions based on tradeoffs. Lastly, we (d) altered horn investment via RNAi of the somatic sex–determination gene doublesex, which results in greatly reduced horns in males. Again, we find that horn reduction also results in reduced investment into eyes. These results suggest that resource allocation tradeoffs between developing structures may depend greatly on genetic, developmental, and environmental contexts. This context–dependency may therefore limit the degree to which tradeoffs can be detected in natural populations or constrain their evolutionary trajectories.

38.5 SCHWALBE, M.A.B.*; WEBB, J.F.; University of Rhode Island; mbergstrom@riu.edu
The Contributions of Sensory Morphology and Prey Detection Behavior to Trophic Niche Differentiation in Two Sand–Feeding Lake Malawi Cichlids
The adaptive radiations of African cichlids resulted in a diverse set of feeding morphologies and strategies, but the role of sensory biology in niche partitioning remains largely unexplored. Fishes in the Lake Malawi genera Aulonocara and Tramitichromis both feed on benthic invertebrates, but differ in sensory morphology and foraging strategies. Aulonocara slowly swims just above the sand and detects flows generated by prey with neuromasts in its widened lateral line canals. In contrast, Tramitichromis fills its mouth with sand and sifts out prey, but the role of the narrow lateral line system (less sensitive than widened canals) in prey detection is unknown. We hypothesized that Aulonocara and Tramitichromis use their visual and mechanosensory capabilities differently while foraging. To test this, we evaluated the ability of Aulonocara stuartgranti and Tramitichromissp. to feed on live and dead adult brine shrimp under light and dark conditions. Prey detection behavior (# prey strikes, detection distance and angle, prey preference [live vs. dead]) was analyzed. Both species ate vigorously in the light, but Tramitichromis detected prey at longer distances and with a narrower range of detection angles than Aulonocara, suggesting a particular dependence on vision. In the dark, Tramitichromis tended not to feed while Aulonocara successfully captured prey and preferred live prey (that produced hydrodynamic stimuli to which the lateral line system responds). Thus, Aulonocara and Tramitichromis, which differ in lateral line morphology, employ distinct foraging and prey detection capabilities, and we hypothesize that these factors are important for trophic niche differentiation in these sand–feeding taxa. Supported by NSF grant IOS–0843307 to JFW. NSF EPS-CoR contract EPS–1004057.

141.1 SCHWARTZ, T.*; BRONIKOWSKI, AM; Iowa State University; schwartz@iastate.edu
Plasticity and evolution of stress response networks in divergent life–history phenotypes
The complex molecular network that underlies physiological stress response is comprised of nodes (proteins, metabolites, mRNAs) whose expression and activity evolve in concert. The fate of sensory biology in life–history evolution. We utilize natural populations of garter snakes (Thamnophis elegans) that have diverged along the pace–of–life continuum; the slow–living phenotype has slower growth, smaller reproductive bouts, and extended median lifespan relative to the fast–living phenotype. We take a multifaceted approach to test whether these phenotypes vary concomitantly at candidate nodes of the stress response network under unstressed and induced–stress conditions. In response to heat stress, some measures increased in both life–history phenotypes: plasma corticosterone; State III mitochondrial respiration; expression of heat shock proteins; and mitochondrial transcription; State IV mitochondrial respiration; circulating levels of ROS; and DNA damage. Additionally, mitochondrial haplotypes were unique to each phenotype. Our results indicate these evolutionarily divergent life–history phenotypes have diverged in their molecular stress response networks; and we identified specific nodes involved in oxidative stress and mitochondrial function at which selection appears to be acting. Further, these results support the prediction of tightly integrated molecular interactions between stress networks and life–history traits.
109.4 SCOBELL, S.K.*; JAQUES, J.T.; JONES, A.G.; Texas A&M University; Texas A&M Veterinary Medical Diagnostic Laboratory, Texas A&M University; skscobell@tamu.edu

Androgen profiles across the male pregnancy cycle in the sex–role reversed Gulf pipefish

Male pregnancy is a phenomenon found only in the teleost fish family Syngnathidae (seahorses, seadragons, and pipefish). The male accepts eggs from the female into a ventral brood pouch where they are fertilized and brooded until birth. Recent studies in syngnathids have shown that males aerate and osmoregulate the brood pouch fluid, and likely provide nutrients and immunity to embryos during the pregnancy. However, few studies have examined the hormonal regulation of male pregnancy in syngnathids. Hormones are well established in teleost fish as primary regulators of puberty, gonadal development, mating, and reproductive behaviors, and thus are likely candidates for mediating male pregnancy in seahorses and pipefish. Previous work on syngnathids suggests an important role of androgens in development of the brood pouch, maintenance of the testes, and spermatogenesis. However, to our knowledge there have not been any studies that correlate circulating plasma androgens with these traits across the reproductive cycle. We conducted a field study of circulating testosterone and 11-ketotestosterone levels in male and female Gulf pipefish, Syngnathus scovelli. We first asked whether there was a reversal of plasma androgen levels in the sexes of this polyandrous, sex–role reversed species. We then examined whether androgens correlated with gonadal mass or body size in both sexes. Finally, we compared testes mass and circulating androgen levels across various stages of the male reproductive cycle. Our data show no reversal of plasma androgen levels between the sexes, but they do suggest that male Gulf pipefish modulate androgens across the reproductive cycle to regulate alternating cycles of spermatogenesis and pregnancy.

24.1 SEARS, MW; Clemson; sears3@clemson.edu

Toward a spatially–explicit thermal ecology: predicting activity from the dispersal of individuals through thermally–structured landscapes

An ongoing challenge for ecologists is to predict the responses of organisms to changing climates. Process–based modeling approaches that incorporate physiological and behavioral mechanisms are rapidly becoming powerful tools to make such predictions. Key to these approaches are understanding the biophysical constraints on activity budgets. Typically, models assume an all–or–nothing approach where, as long as environmental temperatures overlap individual preferences, all individuals in a population are active and accrue (or lose) energy from the environment. Due to the thermal heterogeneity of many environments, such responses of activity by all individuals are not possible. Here, I demonstrate how activity patterns can be generated by the movements of individuals under thermoregulatory constraint and how these models predict activity similar to that observed in natural populations. Further, results will be contrasted with those predicted by other modeling approaches to note the potential pitfalls when small scale environmental heterogeneity is not considered.

1.4 SECOR, S.M.; University of Alabama, Tuscaloosa; ssecor@biology.as.ua.edu

From field metabolic rates to genomics, the integrative digestive physiology of snakes

Snakes feed across a continuum of feeding habits, however little is known regarding the frequency at which snakes feed. Following a 3–year field study on their feeding habits and field metabolic rates, Ken Nagy and I calculated that active foraging coachwhips (Masticophis flagellum) feed on average at 10−day intervals, whereas sit–and–wait foraging sidewinders (Crotalus cerastes) feed at 40–day intervals. These findings sparked the question: might snakes exhibit variation in their digestive physiology given differences in natural fasting durations? Our studies on nearly two dozen species revealed that snakes which feed relatively frequently in the wild narrowly regulate intestinal performance, whereas species which routinely experience long fasting episodes widely regulate intestinal form and function with each meal. The evolutionary rationale for this dichotomous response resides in energy conservation. The mechanistic bases for the two modes of regulation stems from whether intestinal microvilli maintain length with fasting (narrow regulation) or dramatically shorten with fasting and then length with feeding (wide regulation). For infrequently feeding Burmese pythons, the increased expression of more than 2400 genes underlie the rapid postprandial transformation of their intestinal morphology and function. I have had the good fortune to gain from Ken and my other mentors that in order to decipher the evolutionary and proximate mechanisms of adaptation, work needs to start in the field before continuing with approaches in the laboratory that can transcend multiple levels of design.

235.4 SEFTON, E.M.*; PIEKARSKI, N.; HANKEN, J.; Harvard University; eesftor@eob.harvard.edu

A dual embryonic origin of the vertebrate pharyngeal skeleton

The pharyngeal–arch skeleton is a hallmark of vertebrates. In basal taxa, it supports the gills and muscles of the pharynx, whereas in more derived groups it surrounds the larynx and trachea. That most of the pharyngeal–arch skeleton is derived from embryonic neural crest was first demonstrated in the mudpuppy in the late 19th century, and this result has since been confirmed in additional species. Yet, the evolution and extent of neural crest contributions to the pharyngeal skeleton is incompletely understood. In this study, we fated map neural crest in the axolotl, Ambystoma mexicanum, using transplantations from GFP–transgenic donors into wild–type hosts. We found that neural crest does not contribute to all elements of the pharyngeal skeleton: the ventral midline element basibranchial 2 was never labeled. Based on this result we also constructed a fate map of cranial mesoderm. Our results positively demonstrate for the first time a mesodermal contribution to the pharyngeal skeleton. Cranial mesoderm contributes to basibranchial 2, suggesting distinct patterning mechanisms in this region. Our results demonstrate a dual embryonic origin of the pharyngeal skeleton, from both neural crest and cranial mesoderm, and shed new light on its development and evolution.
**12.5 SELF, CJ*; HERRING, SW; University of Washington, Seattle; cjself@uw.edu**  
*Morphology of the rabbit periodontal ligament and the effect of reduced bite force*  
The periodontal ligament (PDL) transmits occlusal loads from the teeth. This study was undertaken to describe the morphology of rabbit molar PDL as an example of an evergrowing cheek tooth and to determine the effect of reduced loading on the PDL. Under reduced loading, decreased architectural uniformity and collagen amount were expected. To achieve partial unloading rabbits received a single dose of either botulinum toxin (BTX) or saline into one masseter muscle (n=7–8). After 4 weeks specimens were sectioned horizontally or coronally and stained with picrosirius red. Linearly polarized light was used on coronal sections to measure fiber orientation. Horizontal sections were evaluated under circularly polarized light to quantify collagen content. Values from the left and right sides were averaged. In control PDLs collagen content was 21.6±8%, lower than 35% reported in murine molars, which are not evergrowing and thus have relatively short, stable roots (Beertsen et al 1975). Average angle of fiber attachment was 61°, more obtuse than the reported 30° for humans (Raspani et al, 2000) but similar to rats (61°, Komatsu and Chiba 1997), mice (51°, unpublished), and cows (50°, Pini et al. 2004). Although more comparative data are needed, these findings suggest that relative root length can compensate for low collagen content and that obtuse PDL orientation correlates with horizontal–plane chewing. Nonparametric comparisons of reduced vs. normal bite force groups showed slight reductions in collagen and attachment angle, but these were non–significant, reflecting the small sample size and modest decrease in force. However, there was no trend for variability to increase. PDL uniformity may be related to chewing direction rather than occlusal force. Supported by PHS DE018142.

**S10–2.3 SERB, J.M.*; KRAUSE, A.J.; Iowa State University; serb@iastate.edu**  
*Uncovering gene family expansion and molecular convergence of the photoreceptive protein opsin in scallop (Bivalvia: Pectinidae)*  
Gene duplication is one of the key factors driving genetic diversification and innovation, and may play an important role in phenotypic novelty. We investigated how small–scale, gene–specific duplications in invertebrate visual systems affect function and how diametrically opposed processes of divergence and constraint act on the underlying molecular system by studying the diversity of visual pigments in the mirror–eye type of the scallop. These bivalves inhabit an array of photic environments and exhibit a diverse set of species–specific behaviors ranging from sessile attachers to mobile long–distance swimmers. Using a comparative transcriptomic and gene–targeting approaches, we identified an expansion of the photoreceptive protein opsin, a member of the G–protein coupled receptor family. Focusing on the Gq–coupled (rhodobin or r−) opsins, we generated a gene phylogeny from 530 sequences of 33 species across the Pectinidae. Scallop opsins segregated into two major clades, A and B, that differ by 45% in amino acid sequence, yet retain the functional motifs required for chromophore binding. Within each major clade, there was evidence for additional gene duplication events, but the number of duplication events, degree of divergence, and gene loss varied. We then tested the hypothesis that gene duplication events are associated with the spectrum of visible light available in the species habitat or with particular behaviors. We found multiple gene loss associated with sedentary lineages, while more mobile species had a suite of opsin copies. Interestingly, we identified molecular convergence in opsin within long–distance swimming lineages, which presumably rely more heavily on visual information. Our results suggest that both the retention and diversification of opsin copies in scallops are correlated with visual–mediated behaviors.

**128.3 SETTE, CM*; VREDENBURG, VT; ZINK, AG; San Francisco State University; carla.sette@gmail.com**  
*Temporal and spatial variation of crytiomycosis across Batrachoseps attenuatus populations*  
*Batrachochytrium dendrobatidis* (Bd) is a highly virulent fungal pathogen which causes chytridiomycosis in amphibians. This rapidly–spreading disease is implicated in the decline and extirpation of amphibian populations throughout the world. Because the fungus’ flagellated zoospores spread by swimming through water or on along amphibians’ moist skin, it is considered an aquatic disease. However, it has recently been detected in completely terrestrial salamanders, such as the California slender salamander, *Batrachoseps attenuatus*. We used quantitative PCR to detect the presence of Bd in up to 20 randomly–selected individuals from seven decades and across twelve counties within *B. attenuatus’* range. Results from these 1300 samples reveal temporal and spatial variation in the presence and infection intensity of Bd across populations. Because *B. attenuatus* is highly gregarious in its nesting behavior, we propose that social behavior may provide an opportunity for transmission of Bd.

**105.4 SYMEoure, B. M.*; MCMILLAN, W. O.; RUTOWSKI, R. L.; Arizona State University, Smithsonian Tropical Research Institute; brett.symeoure@gmail.com**  
*Convergence and Divergence of Eye Morphology in Mimetic Butterflies*  
Within the animal kingdom there are many groups of mimetic organisms that have converged on phenotypes. Within the tropical butterfly genus of *Heliconius*, the amounts of mimetic groups are astounding. In the former canal zone of Panama, there are at least five different mimetic groups of *Heliconius* that have converged on the same wing color and shape, flight pattern, and ecological niches. Previous research has shown that these different mimetic groups occupy different microhabitats within the forest and that these microhabitats differ in light environment. We asked whether co–mimics have converged on eye morphology. We hypothesized that eye morphology has converged within co–mimics because certain eye morphologies are more adaptive in certain light environments. In darker light environments, compound eyes should be structured to heighten sensitivity while in brighter environments, compound eyes should be structured to heighten acuity. We performed three separate studies to test the hypothesis. We measured interommatidial angles, eye size, and facet diameters for two different mimetic groups: *postmna* and blue–white. The postman group consisted of *H. erato* and *H. melpomene*, the blue–white consisted of *H. cydno* and *H. sapho*. We predicted that the three parameters: eye size, interommatidial angle, and facet diameters will be similar within the mimetic groups but different between mimetic groups. We show similarities and differences in eye morphology for the different mimetic groups and conclude that convergence and divergence has occurred in eye morphology within this mimicry complex.
Shadwick, R.E.*; Goldbogen, J.A.; Potvin, J.; Pyenson, N.D.; Vogl, A.W.; Univ of British Columbia, Cascadia Research Collective, St. Louis University, Smithsonian Inst., Univ. of British Columbia, shadwick@zoology.ubc.ca

**Novel muscle and connective tissue design controls engulfment volume in lunge−feeding whales**

Rorqual whales feed by engulfing and filtering large volumes of water containing schooling prey. The ability to engulf a mass of water on the order of the entire body mass is facilitated by highly compliant ventral groove blubber (VGB) and underlying muscle that make up the buccal cavity outer wall. Muscle fibres are in two strata, one is parallel to the body long axis (LS), the other is oblique (OS), at 45° to the LS. Based on a geometric model of engulfment we estimated the maximal circumferential VGB strain. For comparison we measured VGB strain from the relative separation of adjacent ridges seen in photos of lunging fin, blue, sei, Brydes and minke whales. In both cases we found that at full engulfment the VGB experiences circumferential strain of up to 160%. But how can the VGB muscles accommodate apparent strains as high as 160%? Histological examination showed that LS fibres are loosely connected and readily separate laterally with increasing VGB circumferential strain. OS fibres are embedded in a dense matrix of elastic tissue quite unlike other skeletal muscle. In the unloaded state we found that retraction of the elastin actually compresses the muscles by about 30%. The combination of re−orientation of the OS muscle fibres with VGB expansion, and their straightening as elastin is stretched, together allow for VGB strains of 160% to occur with only a 55% stretch in the muscle fibres. These results support the hypothesis that the VGB muscles play an active role in controlling the size and filling rate of the ventral cavity during engulfment feeding (J. Potvin et al. 2009, J. Royal Soc. Interface).

16.4 Sharma, P.P*; Schwager, E/E; Giribet, G; Jockusch, E/L; Extavour, C/G; Harvard University; psharma@post.harvard.edu, Giribet@fas.harvard.edu

**Distal−less and dachshund pattern both plesiomorphic and apomorphic structures in chelicerates: RNA interference in the harvestman Phalangium opilio (Opiliones)**

The discovery of genetic mechanisms whereby a morphological structure is transformed from a plesiomorphic (=primitive) state to an apomorphic (=derived) one is a cardinal objective of evolutionary developmental biology. However, this objective is often encumbered for many lineages of interest by limitations in taxonomic sampling or in genomic resources for the few available laboratory model organisms. In order to investigate the evolution of appendages within Chelicerata, the putative sister group of the remaining arthropods, we sequenced a developmental transcriptome of the harvestman Phalangium opilio. Concomitantly, we developed an RNA interference protocol for this species. We silenced the leg gap genes Distal−less (Dil) and dachshund (dac) in the harvestman via zygotic injections of double−stranded RNA. Consistent with the conserved roles of these genes in patterning the proximo−distal axis, we observe that embryos injected with Dil dsRNA lack distal parts of appendages or appendage−like structures, such as the labrum, the chelicerae, the pedipalps, and the walking legs; whereas embryos injected with dac dsRNA lack the medial podomeres femur and patella in the pedipalps and walking legs. In addition, we observe the involvement of these genes in patterning structures that do not occur in well−established chelicerate models (spiders and mites). Embryos injected with Dil dsRNA additionally do not develop the preoral chamber formed from pedipalpal and leg coxopophyses, or the ocularium, a dorsal outgrowth that bears the eyes. A single embryo injected with dac dsRNA was observed to lack the proximal segment of the chelicerae, a plesiomorphic podomere wherein dac is expressed in wildtype embryos.
97.1 SHARPE, S.S.*; MASSE, A.; TAZ, H.; GOLDMAN, D.I.; Georgia Tech, Wesleyan College; ssharpe@gatech.edu
Limb Use During Burial of the Sandfish Lizard
Desert dwelling animals like the sandfish lizard (Scincus scincus) dive into sand to escape heat and predators. The sandfish swims subsurface using a traveling wave along its body with little movement of the limbs. However, above surface, limbs are used during initial burial into the substrate and burial occurs in approximately 1.5 body undulations (< 1 s). To investigate the role of limbs during burial, we track limb movements during burial in 0.3 mm diameter glass particles using high-speed visible-light video and x-ray imaging. Sandfish (N = 5 animals, mass = 16.2 ± 1.4 g) use a stereotyped limb pattern and body undulation during burial. During the first undulation cycle the forelimbs are pressed against the body sequentially just before each side of the body becomes convex and stay there for the remainder of swimming. Hindlimbs adduct sequentially during the first undulation cycle, just after forelimb adduction and when the body is maximally convex. We hypothesize that since the hindlimbs are the last to adduct, these limbs are important for burial. To test this, we examine burial performance while restraining limbs using adhesive tape. Each animal was given 10 minutes to bury subsurface with limb restraints, and trials were accepted when animals attempted to bury. Animals readily buried when hindlimbs were bound but took a larger number of undulations (4 ± 2, P < 0.01) to bury than unbound animals. When forelimbs were bound, animals buried in 7 of 15 trials (N = 5 animals, n = 3 trials each), and all trials except one took over 4 undulations. When all limbs were bound, burial occurred in only 1 of 15 trials. These results imply that appropriately timed limb–ground interactions are critical to facilitate rapid burial.

S6−1.7 SHELDON, B.C.; University of Oxford;
ben.sheeldon@zoo.ox.ac.uk
Constraints and the importance of adaptive plasticity to climate change
Phenotypic plasticity is regarded as a key mechanism by which populations adapt to changing climates, but we know little about the importance of plasticity for population persistence, or what limits the scope of adaptive plasticity. In this talk I will present two different strands of work, derived from long-term studies of a temperate songbird (the great tit), which assess the limits on, and importance of, adaptive plasticity in response to phenology of the environment. First, I will argue that the evolution of population-level responses to adaptive plasticity in response to phenology of the environment. Second, I will present an analysis of a mechanistic model developed by Chevin et al. that predicts the critical rate of temperature change above which populations are inviable. Parameterisation of this model suggests that the importance of phenotypic plasticity for adaptation to climate change is strongly life-history dependent.

20.4 SHELDON, R.M*; JACKSON, BE; HEDRICK, TL; Univ. of North Carolina, Chapel Hill; rmshelto@email.unc.edu
High speed pursuit in barn and cliff swallows
Birds require visually guided interception techniques to catch prey in flight, to track down potential mates, and to chase off competitors. While the visually guided tracking strategies of various insects including butterflies, hoverflies and dragonflies have been well documented through lab experiments, birds only exhibit these behaviors in natural settings. Here we used a set of three high-speed cameras to capture a series of barn and cliff swallow chase sequences where one bird follows the other through a series of turns, sprints, dives and climbs. From these recordings we extracted 3D body and wing kinematics including the instantaneous velocity, acceleration, angular velocity, and angular acceleration of each bird, and various distances and angles between the two birds. We found a strong correlation between the total accelerations, angular accelerations, and angular velocities of the two birds with phase lags of approximately 89 ms, 71 ms, and 87 ms, respectively. These phase lags are slightly larger than the mean wingbeat period of the chasing bird (~70ms) suggesting that these birds may only be able to initiate a major flight maneuver once per flapping cycle, and that the response latency of the trailing bird is the sum of neurosensory and biomechanical lags. No simple visual targeting model precisely fits the response of the trailing bird suggesting that swallows may use a combination of sensory cues in planning pursuits. When comparing the flapping latency between the lead and chasing birds we observed a non-random distribution which could contribute to a complex chasing algorithm.

SICB 2013 Annual Meeting Abstracts
January 3–7, 2013, San Francisco, CA
Maternal stress as a driver of adaptive phenotypic responses in offspring

Maternal stress has become widely recognized as a driving factor affecting offspring phenotypes, and evolutionary biologists and medical practitioners are investing great effort in determining the role of maternally-derived stress (MDS) as a significant inducer of trans-generational phenotypic plasticity in offspring. Given the large contribution by the medical community to the literature, many of the phenotypic responses of prenatal stress are viewed as unavoidable negative outcomes by the ecological community. However, these studies offer a biased underestimate of the potential advantages of MDS-induced phenotypic plasticity as they are not designed to recognize, or experimentally test, the evolutionary history and ecological relevance of the maternal stress—offspring phenotype relationship. Here I will present emerging evidence from free-living systems that are beginning to show how and why MDS may act as a translator between the quality of the maternal or ecological environment and the potentially adaptive phenotypic responses in offspring. A recurring finding is the necessity to examine MDS-induced phenotypic adjustments within the evolutionary life-history context of the species as well as both the immediate environmental context in which they occur and the longer-term environmental context that offspring face as reproductive adults. As such, maternal stress effects can be considered adaptive or maladaptive depending upon whether they reliably translate the maternal environment into an appropriate offspring response (i.e., dependent upon the degree of maternal-offspring environmental matching).
Mechanisms of Metamorphic Remodeling in Hydroides elegans (Polychaeta).

Larvae of the serpulid polychaete *Hydroides elegans* are competent to settle and metamorphose five days after fertilization. At that stage, they are classical 3-setiger nectochaete larvae that are propelled by a well-developed ciliary prototroch that also provides their filter-feeding current. On contact with an appropriate bacterial biofilm, the larvae transform into a tube-dwelling, tentacle-feeding juveniles within 10 hrs. During the process, ciliated trochal bands and apical sensory organ disappear, the mouth is relocated from a ventral to an anterior-terminal position, and the feeding tentacles differentiate and elongate. We employed laser-scanning confocal microscopy and (1) acridine orange and TUNEL labeling to detect cell-death processes, and (2) Click-IT EdU labeling to detect cell proliferation, during and following metamorphosis in larvae of *H. elegans*. Apoptosis accounts for the loss of the prototroch and metatroch cells, the apical sensory organ and large numbers of epidermal cells on the larval episphere, especially at the anterior tip of the larva where the mouth will be positioned. Rapid cell proliferation produces the tentacles. After the tentacles are sufficiently developed for feeding, groups of apparent stem cells remain at their bases to accomplish tentacle elongation as the worm grows.

Elasmobranch fishes use electroreception to detect cryptic prey at close range. Behavioral assays demonstrate that they respond to prey-simulating dipole electric fields by sharply turning and biting at the electrodes. However, it is unknown whether they are able to discriminate between positive and negative poles, and, if they can, whether they prefer to bite at one pole or the other. To address these questions, and hence to better understand the mechanisms underlying elasmobranch electroreception, we employed behavioral assays to test whether the yellow stingray (*Urobatis jamaicensis*) can distinguish between the positive and negative charges of an electric dipole in a saltwater tank. We used positive food rewards to train rays to only bite at one pole of a dipole electric field. We trained two groups of animals: one group (N=6) was trained to feed from the positive pole and the other group (N=7) was trained to feed from the negative pole. After training daily for 4 weeks, yellow rays were scored based on their responses to polarity. We found that rays preferred to bite at the pole to which they were trained. This successful training is the first evidence that elasmobranch fishes may be able to resolve the orientation of a localized electrical field. This perceptual ability may have consequences not only for detecting prey, but also for short and long range navigation, since the geomagnetic field varies locally and globally. In addition, elasmobranch fishes may perceive underwater cables and power supplies with unknown biological consequences.

Consensus and confusion in molluscan phylogeny

Molluscs are the second largest and morphologically most disparate animal phylum, they are ubiquitous, and have a formidable fossil record. Monophyly of the eight Recent molluscan classes is undisputed, but relationships between these groups and patterns of early molluscan radiation have remained elusive. Molecular, fossil and anatomical data show apparently contradictory evidence for branching patterns within Mollusca. The traditional reductionist model of the hypothetical molluscan ancestor has hampered the resolution of molluscan topology; some hypotheses rejected as artifacts (e.g. Serialia) continue to find additional support and cannot be dismissed conclusively. Derived conditions in major body plan modifications, such as shell-loss, have occurred repeatedly in most groups. Rather than interesting sidelines, these anomalies, and evidence for rampant reversals, apparently represent the true norm of molluscan evolution. Based on new molecular clock results the first to include multiple exemplars of all 8 classes, diversification of molluscs started immediately in the early Cambrian and was far more rapid and complex than previously appreciated. Extensive evolutionary plasticity by heterochronic shifts in development and multiple convergent adaptations, as demonstrated in extant molluscs, were already within the evolutionary potential of their Cambrian forebears, and continue today.

Kidney mass of passerine birds in relation to diet, habitat, and phylogeny

The kidney plays an important role in electrolyte homeostasis, acid-base balance, osmoregulation, water conservation, and waste removal (in particular nitrogenous waste). Diversity in such factors as diet (e.g., protein content) and habitat (e.g., water availability) may cause variation in the selective regime and, ultimately, lead to evolutionary changes in kidney size and/or structure. A previous interspecific comparative study (Barceló et al. 2012) found no relationship between kidney mass (corrected for body mass) and the % invertebrates in the diet of passerine birds, but suffered from a relatively small sample size (n=16). In this study, data for kidney and body mass were collected for 100 species of passerine birds, along with corresponding diet and habitat data. Conventional and phylogenetically informed (multiple) regressions were performed with log kidney mass as the dependent variable, log body mass as a covariate, and all possible combinations of diet (% invertebrates in 5 categories, treated as a continuous variable), habitat (categorical: aquatic, mesic, semi-xeric, xeric), and clade (categorical: 6 superfamilies). Phylogenetic signal (Blomberg et al. 2003) in relative kidney mass was statistically non-significant, and conventional statistical methods consistently produced the best-fitting models. Diet was included as a variable in all top-performing models, and greater dietary consumption of invertebrates was a significant positive predictor of kidney mass. Neither habitat nor clade was a significant predictor of kidney mass. Our results suggest that the amount of dietary nitrogen consumed may be one factor that led to diversification of kidney size (and possibly structure) in passerine birds.
Behavioral responses to human−induced rapid environmental change (HIREC)
A key issue in animal behavior is the need to understand variation in behavioral responses to human−induced rapid environmental change (habitat loss, exotic species, pollution, human harvesting, and climate change). Why do some individuals exhibit maladaptive behaviors, while others show adaptive responses to evolutionary novel situations? At present, we lack a unified conceptual framework for generating predictions and guiding empirical and theoretical work on this critical question. Drawing from the concept of ecological traps, I suggest that a conceptual framework for explaining this variation should include 4 main points: 1) behavioral responses (adaptive or not) are the result of cue−response systems, or behavioral rules of thumb; 2) limited or imprecise, unreliable information often underlies suboptimal behavior; 3) the organisms' behavioral flexibility affects its response to novel situations, and 4) evolution (and development) in past environments has shaped cue−response systems, responses to imperfect information, and degree of behavioral flexibility to be adaptive in past environments, but not necessarily in novel environments. The degree of match/mismatch between past environments and novel environments altered by HIREC is thus a key to explaining adaptive vs maladaptive behaviors. I discuss several existing frameworks that address these 4 points, and that are thus potentially useful for explaining behavioral responses to HIREC: signal detection theory, adaptive plasticity theory, extended reaction norms, and cost−benefit theory on variation in learning. I further discuss more complex aspects of reality that it would be useful to add to these existing frameworks.

Behavioral responses to human−induced rapid environmental change (HIREC)

Systemic responses to ionizing irradiation−induced imaginal discs in the larval hornworm, Manduca sexta
The imaginal discs are progenitor cells in holometabolous insects such as Manduca sexta and Drosophila melanogaster, which are destined to become adult structures such as wings or antennae. Damage can be induced by the administration of high doses of x−ray irradiation during larval development, due to the highly proliferative nature of the discs. But these tissues are extremely resilient and are repaired extremely efficiently when damaged. It has been proposed that imaginal disc repair is facilitated by an endocrine−induced delay in puation via the inhibition of the developmental hormones Prothoracicotropic Hormone (PTTH) and the ecdysteroids, to accommodate repair of the damaged tissue. This delay is suggested to arise from the actions of secreted blood−borne factors from the damaged discs acting on the endocrine system. We therefore assessed the ability of a putative factor, adenosine, to delay development when injected into control M. sexta by assessing pupation rates. We further measured changes in the stain intensity of PPTH in cells of brains from x−rayed and control larvae, using immunohistochemistry with a PTTH−specific antibody, as a gauge of PTTH abundance. Our preliminary results showed that while adenosine induced developmental delays in M. sexta, this appeared to be through altered growth rates, a phenomenon not noted after irradiation. Furthermore, the continuous increase in PTTH stain intensity noted in control brains over a three−day test period was not noted in irradiated larvae. By the third day of development, PTTH levels appeared to plateau, suggesting that production was inhibited in irradiated larvae at this time. Experiments are currently underway to assess the effects of a second putative factor, Dilp−8 (an insulin−like peptide), in delaying development.

Restoration of anterior regeneration in a planarian species with limited regenerative potential
Why can some animals, but not others, regenerate missing tissues? Based on their amazing regenerative abilities, planarians have become important models for understanding the molecular basis of regeneration. However, some planarian species exhibit limited regenerative abilities. To understand this loss of regenerative potential, we examine Prostyla flaviscylla, a planarian with restricted ability to replace missing tissues. Although these animals heal wounds and initiate a proliferative response to wounding, they fail to re−establish axial polarity in regeneration−deficient regions. Using next−generation sequencing we defined the gene expression programs active in regeneration−permissive and regeneration−deficient tissues. We found that Wnt signaling is aberrantly activated in regeneration−deficient tissues. Remarkably, down−regulation of canonical Wnt signaling in regeneration−deficient regions restores regenerative abilities: blastemas form and new heads regenerate in tissues that normally never regenerate. This work reveals that manipulating a single signaling pathway can reverse the evolutionary loss of regenerative potential.

The Effect of Loss of Sensory Input from the Tegula on the Flight Behavior and Muscle Activation Patterns of the moth Manduca sexta
The tegula is a sensory structure at the base of each of an insects' wings. It provides the central nervous system with feedback about the movement of the wing during flight. To understand the role of the tegula in moth flight we measured the effects of the loss of tegulae inputs on the flight behavior and underlying activation patterns of elevator and depressor flight muscles in the tobacco hornworm moth Manduca sexta. We predicted that, as previously seen in locusts, removal of tegula input would affect the activation of the wing elevator muscles and thus the ability of the insect to fly. M. sexta males were challenged to track a female pheromone plume upwind in a wind tunnel and the flight behavior was recorded using high speed video cameras. Flight muscle activation data was collected by inserting electrodes into wing elevator and depressor muscles and synchronized with the video recordings. Initial analyses show that the onset time of the elevator muscle activation is inconsistent in moths without tegulae compared to intact moths. Moths without tegulae fly for shorter periods of time and, in extreme cases, will not fly at all. So far, our analyses show that the effects of removing the tegulae on moth flight are not exactly consistent with that seen in locusts, but there is a clear effect of loss of tegulae input. We thank Jennifer Avondet for her assistance in managing the insect colony and help with all aspects of this project. G.M.S. was supported by the Howard Hughes Medical Institute funded Summer Program in Undergraduate Research. M.A.W. was supported by an Air Force Office of Scientific Research grant FA9550−07−0149.
Insects are the most successful group of terrestrial animals, having overcome the challenges of variable temperatures and desiccating conditions. Overwintering temperate, polar and alpine insects are exposed simultaneously to a range of stressors, among which low temperature, desiccation, and starvation are the most important in determining insect success. Molecular and physiological evidence suggests that physiological responses to these stresses are often shared or co-activated. In addition, multiple lines of evidence suggest that exposure to low temperature activates the insect immune system, likely resulting in important consequences for insect-parasite interactions and overwintering success. How biotic and abiotic stressors, and the responses to them, may interact in the face of climate change is unclear, partly due to the poorly understood effects of climate change on microhabitat. Both synergistic and antagonistic interactions among these stressors are possible, and there is potential for the cold-stress–immune response axis to mediate significant impacts of climate change on overwintering insects via enhancement of biotic interactions caused by responses to abiotic stress.

The costs of current reproduction are not traded against maternal survival or subsequent reproductive performance in the Columbian Ground Squirrel

Life history evolution is contingent upon proximate and ultimate costs of reproductive effort. Allocating a greater amount of limited resources, such as energy, to current reproduction can reduce the amount of energy available for somatic maintenance and in turn ultimately impair future breeding success or maternal survival (i.e. cost of reproduction hypothesis). Although there is some support for the cost of reproduction hypothesis in birds, few empirical studies of mammals have demonstrated a tradeoff between current and future reproduction. Furthermore, most studies testing ultimate costs neglect to confirm that the proximate costs of reproduction are high. We experimentally manipulated litter size in a wild population of Columbian ground squirrels for 2 years to examine the proximate energetic and ultimate fitness (i.e. survival and breeding) costs of reproduction. Although females raising augmented litters had field metabolic rates that were almost 1.5 times greater than females raising control or reduced litters, there were no negative impacts on metabolic rates that were almost 1.5 times greater than females raising augmented litters. Pups from augmented litters grew more slowly during the lactation period, were smaller at weaning and had a lower probability of survival over–winter. Thus, although females are capable of raising more young than they give birth to, our observations suggest that it is not an energy allocation tradeoff that restricts litter size, but rather the reduced offspring survival associated with raising larger litters.

Where should we expect to find Early bursts of trait evolution? A case study using Carnivora

George Gaylord Simpson famously postulated that higher taxa originated as adaptive radiations - early bursts of lineage and phenotypic evolution that slowed through time as niches became saturated. Simpson was a paleontologist, and his ideas were based, in large part, on his reading of the mammalian fossil record. Yet recently developed phylogenetic methods have failed to find broad support for early burst type models in phenotypic datasets of extant taxa. Here, we assemble a comparative ecomorphological dataset for extant Carnivora and use a series of phylogenetic comparative methods to investigate tempo and mode of phenotypic evolution. We find strong support for an early burst of evolution in the dominant axis of ecomorphological evolution in carnivores, with different models supported for other axes. Significantly, an early burst is not supported for body size data, even though body size is often held to correlate with ecology. Simpsons observations, which were based largely on ecomorphological traits, appear to hold for carnivores. The pervasive use in comparative methods of body size data as a surrogate for species ecology may obscure the underlying mode of evolution of higher taxa.
Anemia amplifies postprandial cardiac hypertrophy in Burmese pythons

Burmese pythons (Python molarus) are intermittent feeders, capable of surviving prolonged fasts punctuated by periods of voracious feeding. The postprandial period in P. molarus is characterized by a rapid and significant increase in metabolic rate and a several-fold increase in oxygen consumption. Tasked with meeting elevated O\textsubscript{2} demand during digestion, the heart may enlarge by as much as 40% within 48 hours, though the trigger and universality of this response remain unclear. We hypothesize that this postprandial cardiac hypertrophy is triggered by a mismatch between oxygen demands and oxygen delivery. To test this hypothesis, we reduced the oxygen transport capacity of pythons by halving arterial blood oxygen levels (anemia). Animals were then fed meals equivalent to 25% body mass. 48 hours after feeding occurred, heart rate and blood pressure data were collected, all animals were sacrificed, and visceral organs were dissected. Fed anemic snakes experienced a 125% increase in heart rate and fed control snakes exhibited a 78% increase above fasted controls. Gastrointestinal hypertrophies occurred in both controls and anemic animals, however only fed anemic animals exhibited a significant postprandial cardiac hypertrophy (a 38% increase in ventricular mass over fasted controls). These results support our hypothesis that a mismatch between oxygen demand and oxygen delivery may serve as the upstream stimulus for postprandial cardiac hypertrophy in Burmese pythons. Funding was provided by the Danish Research Council to TW and NSF grant IOS 0922756 to JWH. CES would like to acknowledge support from an NSF Graduate Research Fellowship and a SICB FGST.

Population Structure and Life History of Western Pond Turtles, Actinemys marmorata, in Lentic Habitats in the Trinity River Basin

As populations of a species decline, an understanding of the regional variation in population health can contribute to successful conservation efforts. Over the past century Western Pond Turtle (Actinemys marmorata) populations have declined throughout much of their range (Baja California through Washington) as a result of habitat loss, overexploitation, introduced species, and water course alterations. The Trinity River, in northwestern California, has been modified from its natural state by damming and flow regulations; these alterations have decreased river quality for turtles. We investigated the health of Western Pond Turtle populations in alternative, lentic habitats adjacent to the Trinity River and its tributaries using four indicators of population health: 1) age structure, 2) size structure, 3) adult size, and 4) growth rate of young turtles. Of six lentic habitats sampled, four were biased towards large, old turtles. These habitats had prolific Bullfrog populations, while the other two sites lacked Bullfrogs. Given that Bullfrogs will eat hatching turtles, it appears that Bullfrogs are inhibiting turtle recruitment. The same four lentic habitats also had turtles with faster growth rates and larger adult sizes, likely a result of warmer water temperatures. Overall, conservation efforts should focus on creating or preserving ephemeral lentic habitats that are dry in late summer; turtles and native anurans do not require permanent water, but Bullfrog larvae usually take two years to metamorphose.

Invariant feeding kinematics of trophically distinct nonnative Florida fishes, Belonesox belizanus and Cichlasoma urophthalmus across environmental temperature regimes

Nonnative fishes have the ability to adapt to environmental conditions in the invaded ecosystem and utilize resources that may have been absent in their native ecosystem. Belonesox belizanus and Cichlasoma urophthalmus are both invasive fishes in Florida. Ecomorphological studies conclude that C. urophthalmus is a trophic generalist while B. belizanus is a trophic specialist. The current Florida distribution of these species indicates that C. urophthalmus spreads northerly into the colder regions of Florida at a faster rate than B. belizanus. Is it conceivable that this variation in rate of spread is due to difference in temperature response between this ecomorphologically distinct nonnative fishes? This study was designed to test the hypothesis that the prey-capture kinematics and behavior differ between C. urophthalmus and B. belizanus at a given temperature and across temperatures. Two-Way Repeated Measures Multivariate Analysis of Covariance (MANCOVAR) revealed that 1) at a given temperature, excursion and timing variables differed between species and 2) the kinematics of prey-capture did not vary across temperatures in both species. This interspecific comparison suggests that both species have the same temperature tolerance and that any difference in their rate of spread across Florida may be driven by factors other than species-specific physiological tolerance to temperature.

Food supplementation of Florida Scrub-Jay (Aphelocoma coerulescens) nestlings: long-term effects on hypothalamic–pituitary–adrenal axis responsiveness

In a wide variety of animals, plasma glucocorticoid levels rapidly increase in response to a stressor. In Florida Scrub-Jays (Aphelocoma coerulescens), the magnitude and time course of increased corticosterone (CORT) during a restraint stress can vary greatly between individuals. These differences can be detected within a few months post-fledging, and are repeatable throughout the life of the animal, suggesting that these differences are a persistent aspect of the individual's phenotype. Further, the differences in stress responses are correlated with life history and behavioral traits, such as an individual's life span and degree of neophobia. The CORT phenotypes of offspring are correlated with parental CORT phenotype, but it is currently unknown if this similarity is due to genetic inheritance or other factors, such as differences in parental care, early life nutrition, or other environmental conditions. To investigate which factors are important in the development of the CORT stress response, we used a novel SmartFeeder design that utilizes radio-frequency identification (RFID) technology to food supplement specific individuals within a population of free-living Florida Scrub-Jays. With these feeders we delivered live mealworms to specific adult jays caring for nestlings, and thereby supplement their nestlings. Behavioral observations at supplemented and control nests confirm adult feed mealworms to nestlings. Supplemented nestlings were not larger than control nestlings and nestling baseline CORT did not differ between treatments; however, supplemented nestlings had lower stress-induced CORT levels at approximately 50 days post-fledging. Continuing research will determine if these differences persist into adulthood and if they are correlated with behavioral differences and individual success.
27.5 SMITH, A. M.; Ithaca College, NY; asmith@ithaca.edu
Double network gels and biological glues: a powerful new toughening mechanism
Limpets, marsh periwinkles and some terrestrial slugs produce remarkable glues that are gels. A key question has been how they can achieve tenacities on the order of several hundred kilopascals using only a dilute gel that is a modified lubricating mucus. Previous work has shown that the essential change is the addition of relatively small, cross-linked proteins. Nevertheless, highly cross-linked gels are typically brittle and fail easily. Molluscs may avoid this through the use of a double network. Recent work in materials science has found that combining two highly dissimilar, interpenetrating gel networks can increase gel strength by a factor of 100 to 1000 over the strength of the two gels separately. A prototypical double network gel combines a deformable network of very large polymers and a highly cross-linked network of much smaller polymers. Initial fracture occurs in the stiffer, highly cross-linked network. Fracturing the soft network as well, though, requires extensive deformation. This deformation damages the rigid network in a large volume surrounding the crack. This can increase the energy required to propagate the crack by several orders of magnitude. Such a mechanism is likely at play in molluscan adhesive gels given their structure. In fact, any biological gel containing proteoglycans or similarly large polymers in combination with smaller cross-linked proteins has the potential to operate this way. This talk will outline the structural and mechanical criteria for double network gels and consider the applicability of this mechanism to different biological materials.

67.3 SMITH, A.J.*; ROSARIO, MV; EITING, TP; DUMONT, ER; UMass, Amherst; ajsmith@cns.umass.edu
A conundrum of covariation: The effects of missing data on disparity analysis
Disparity, or morphological diversity, is an important metric of biodiversity used to analyze evolutionary trends in form over geological timescales. Although missing data are common in fossil datasets, we do not fully understand how different disparity metrics respond to increasing levels of missing data. Past research investigated this by randomly removing morphological characters from simulated taxa. However, the loss of anatomical characters is not a random process; characters in close physical proximity to one another are likely to be correlated in presence or absence. First we calculated covariation in character loss from 12 extinct taxa coded for 196 characters, then used that covariance structure to remove characters from a data-rich matrix of 49 extant taxa coded for the same characters. Starting from a maximum of all characters present, we sequentially removed characters in every taxon from the extant matrix such that the average character loss across taxa represented 0% to 75% loss. At each character loss step, we calculated morphospace range and variance (average spread and dissimilarity among taxa respectively). We then repeated this process without character covariation (i.e., randomly removing characters). With covariation, our range metrics exhibited inverse exponential declines whereby the slope changes at ~40% missing characters before declining rapidly. Our variance metrics declined linearly with confidence intervals narrowing as loss increased. Without covariation, range metrics displayed linear declines, while variance metrics exhibited exponential declines. Our results show that character covariation has important consequences for disparity metrics, and should be taken into consideration in future disparity studies.

47.1 SMITH, K. A.*; DUNNE, J. P.; SARMIENTO, J. L.; Princeton University, NOAA Geophysical Fluid Dynamics Laboratory; kas3@princeton.edu
Predicting the effect of multiple stressors on respiratory niches in the pelagic ocean over the next century
Global climate change is rapidly altering temperature, oxygen, and acidity in the ocean environment and the effect that these changes will have on pelagic fisheries and ecosystems is an increasing concern. Oxygen availability is one of the most important factors for determining the distribution of fish in the pelagic ocean environment. Oxygen is extracted from the ocean environment in the gills. The extraction process requires oxygen to diffuse through the gill membrane and into the red blood cell where it binds with hemoglobin. The rate of hemoglobin oxygenation is sensitive to both temperature and acidity and is highly variable among species. A fish is unlikely to use habitat where aerobic metabolism is impeded by low rates of hemoglobin oxygenation. We use the Po2, the oxygen tension at 50% hemoglobin oxygen saturation, as a proxy to determine available habitat in the ocean. The effects of temperature and acidity on Po2 are incorporated into the analysis. Habitat thickness is predicted for a range of physiological traits in the global ocean using temperature, oxygen and pH data from NOAA’s Geophysical Fluid Dynamics Laboratory Earth System Models. Results indicate that there will be habitat compression in the next century.

87.4 SMOOT, S.C.*; PLANTE, C.J.; PODOLSKY, R.D.; College of Charleston; scsmoot@gmail.com
Separating the effects of the deposition substrate and habitat on the anti-microbial properties of egg masses of Homionea vesicula
Several marine invertebrates reproduce by encapsulating embryos inside gelatinous egg masses until hatching. Previous studies have shown that the anti-microbial activity of egg masses of a given species can vary among field locations. This observation suggests that anti-microbial activity may be affected by the nature of the deposition substrate or by other aspects of between-site variation. If differences in anti-microbial activity across habitats depend strongly on the deposition substrate, then adults provided different substrates in a common garden should produce egg masses with different levels of anti-microbial activity. We compared anti-microbial activity in egg masses of the opisthobranch mollusc Homionea vesicula in two ways: when laid on different macrophyte substrates at a single field site, and on the same substrate (the green alga Ulva lactuca) at different field sites. Methanol (MeOH) and ethyl acetate (EtOAc) extracts were then tested for anti-microbial activity against marine type cultures and several environmental strains using a 96-well plate bacterial growth assay. The level of anti-microbial activity depended strongly on the substrate the egg mass was laid on and minimally on the field site. These results suggest that chemicals produced by macrophytes or their associated microbial communities could be influencing the level of anti-microbial activity of deposited egg masses, suggesting that these differences may play a role in oviposition preference of H. vesicula adults.
The role of learning in mediating transgenerational responses to nutrition
Understanding how organisms cope with variation in the quantity and quality of nutrition is relevant to predicting their responses to changing nutritional environments and may have implications for human health. In many species, parents gain both direct and indirect information about the future nutritional environment of their offspring. How does such information impact parental investment and offspring survival? This talk discusses how different life cycles may determine whether parental experience can result in adaptive transgenerational responses to nutritional variation. I present data from butterflies suggesting that adult learning experiences may prepare offspring for novel nutritional environments through effects on energy allocation to eggs. Finally, I will discuss developmental mechanisms, such as gene expression stochasticity and DNA methylation, which may underlie such transgenerational responses to nutrition.

Thermal Physiology of albacore tuna, , as revealed through archival tagging data
Juvenile albacore, Thunnus alalunga, were tagged with archival tags in two regions of the Northeast Pacific: (i) off Northern Baja California, and (ii) off Washington and Oregon between 2001 and 2006 with the objective of describing seasonal movements, migration patterns, vertical distribution, and thermal physiology. Twenty tags were recovered with times at liberty ranging from 63 to 697 days. The tags sensors recorded depth, ambient temperature, relative light levels, and the temperature of the tunas peritoneal cavity every minute for the duration of the deployment. Analysis of this data revealed diel diving behavior, with repeated dives below the thermocline during the day and restriction to the mixed layer throughout the night. As temperatures below and above the thermocline are fairly homogeneous, the vertical movements of the albacore resulted in a cycling between relatively stable cold and warm thermal regimes. These cold and warm regimes were used as in situ incubation treatments. By calculating the change in internal temperature during in situ incubation treatments, the rate of heat loss due to the thermal gradient between the tuna and the surrounding water temperature was estimated. Incorporating this parameter into a heat budget model, the predicted body temperature given only the water temperature was estimated. Change in body temperature due to metabolic heat input was then estimated as the difference between the predicted temperature and the observed temperature. Preliminary results suggest that the diving behavior and the thermal structure of the water column affect the juvenile albacore's ability to regulate and maintain their internal temperature.

The effects of changing nutrient inputs on sexual selection dynamics and life history evolution
Discussions of rapid human-induced environmental change often focus on the loss or disruption of critical resources, such as habitat destruction, pesticide contamination or drought in the face of climate change. However, humans are also significantly increasing the availability of crucial nutrients or resources that were once limited. For instance, salt, nitrogen, phosphorus and lipid availability have increased in certain habitats or regions due to human activity. In some cases, such changes may have positive impacts on the growth and development of individuals. This talk discusses the longer term evolutionary consequences of such changes in nutrient availability. In particular, increased availability of once limited nutrients may relax sexual selection intensity and shift selection to novel traits. Changing nutrient dynamics may also alter patterns of energy allocation that are relevant to life history evolution. We present data from a butterfly system illustrating the potential impacts of altered nitrogen availability on mating systems and conclude with suggestions for future research in this area.
Lessons from cold–adapted enzymes: Can protein adaptation to temperature be simple and quick?

Fascination with how proteins manage to work well at near−freezing temperatures has led to detailed study of enzymatic and structural properties of Antarctic notothroid fishes. Discovery that lactate dehydrogenase (LDH) orthologs of notothroidi have extremely high intrinsic rates of activity (kcat values) and appropriate substrate binding affinities (Km) for function in the cold has prompted investigation of the underlying changes in amino acid sequence that generate these adaptations. One key finding of these comparative studies is that adaptation to cold can be achieved by only one or two amino acid substitutions and need not involve a wholesale redesign of protein structure. This discovery has prompted wide−ranging studies of other proteins and other taxa, to see if such a simple solution to temperature adaptation is prevalent. Indeed, studies of orthologous malate dehydrogenases (cMDHs) of several invertebrate lineages have shown that (i) a single amino acid substitution can suffice to achieve adaptation, (ii) a number of sites in the sequence are candidates for adaptive change, and (iii) the primary effect of these amino acid substitutions is to modify the conformational mobility of regions of the enzyme that move during function. Active (catalytic) sites themselves are fully conserved. Importantly, studies of different proteins suggest that not all proteins are as thermally sensitive as LDH and cMDH. Thus, temperature adaptation may not involve modification of the entire proteome. These findings have implications for rates of protein evolution, notably in the context of a rapidly warming planet.

Energy homeostasis as a tool to integrate the effects of multiple stressors in animals

Energy balance plays a key role in survival and stress tolerance of all organisms due to the need to balance energy demand with sufficient energy supply for survival. In animals, both the amount of available energy (through food uptake and assimilation), as well as the capacity of metabolic energy conversions and ATP synthesis are limited resulting in the trade−offs between the energy fluxes that support different fitness−related processes. Environmental stress can result in the negative shifts of energy balance due to the increased metabolic demand for stress protection and damage repair, stress−induced damage to the organismal functions such as food and oxygen uptake and delivery and/or impaired cellular metabolic capacity. These shifts have direct consequences for the organisms fitness due to the reduced aerobic scope available for growth, reproduction and/or survival. Thus, studies of the energy balance provide a common yardstick to compare and integrate the effects of multiple stressors regardless of their nature and molecular mechanisms, and to predict the ecological consequences of these effects. Bioenergetic thresholds can also be used to distinguish between the moderate stress when the long−term survival of the organisms and their populations is possible albeit at the expense of the reduced growth and reproduction, and the extreme stress incompatible with the long−term survival. Here I present the general concept of energy−limited stress tolerance in animals, describe the bioenergetic markers useful in distinguishing between the moderate and extreme stress exposures and illustrate the applicability of this concept to integrate of the interactive effects of multiple stressors using an example of marine bivalves exposed to trace metals, temperature, salinity stress and ocean acidification. Supported by NSF IOS−0921367 and IOS−0951079.

The physiological response to captive stress varies among species, with some adapting quickly to captive environments, but others adjusting slowly or exhibiting long−term deviation from baseline patterns in the wild. To evaluate the effects of captive stress on any given species, it is essential to compare captive measures with measures taken in the wild. We tested for hematological indicators of captive stress in juvenile and adult western terrestrial garter snakes, Thamnophis elegans. We measured baseline plasma corticosterone and heterophil to lymphocyte (H:L) ratios in both juvenile and adult snakes upon capture in the field, and in adult females after one and three months in captivity. Corticosterone and H:L ratios were also measured at three and thirteen months of age in captive−born offspring of wild−caught females. Interestingly, while corticosterone levels were strongly positively correlated to H:L ratios in the field, the relationship between the two disappeared over time spent in captivity, and was not present in juveniles born in captivity. Longitudinal samples of adult females showed higher levels of both corticosterone and H:L ratios in captivity than in the field; both variables were at their highest levels after three months in captivity. Offspring corticosterone and H:L ratios were also significantly higher than a mixed−age sample of animals in the field. Our findings suggest that captivity has long−term consequences for physiological indices of stress in Thamnophis elegans, and that these consequences are manifest in both wild−born and captive−born individuals.
The doubly-labeled water method has been a valuable tool to quantify human energy expenditures over a range of daily energy demands. With the increase in a more sedentary lifestyle over the past half century, human daily energy expenditure (DEE) relative to resting metabolic rates (RMR) had become relative modest compared to that of wild animals. Humans are spending a majority of their metabolic expenditure on rest, whereas wild animals spend most of their expenditure on activities. This reduced DEE/RMR relationship for humans is evident in the increase incidence of obesity in Western societies. Described in this talk will be the determinants of human energy flux, the interplay between changes in daily expenditure and levels of nutrition in altering body composition and activity, and the insights gained from animal studies on the human physical condition.

The molecular evolution of chiton shell eyes

Understanding the evolution of complex traits has been a major goal of biologists for generations. When studying the origin of a particular complex trait, it is useful to first ask about the separate evolutionary histories of its components. In the case of an image–forming eye, for example, these components likely include sets of genes involved with phototransduction, pigment synthesis, and organogenesis. Chitons (Phylum Mollusca; Class Polyplacophora) are a promising system in which to study the process of eye evolution. All chitons have aesthetes, small sensory tentacles that fill narrow channels in the dorsal shell plates. In certain chiton species, some of the aesthetes terminate in a shell eye with a pigment layer, retina, and aragonite lens. From a phylogenetic perspective, these eyes are clearly a derived trait; further, from a historical standpoint, they may be the most recently evolved animal eyes the chiton fossil record extends back to the Cambrian, but eyed chitons have only diversified within the last 25 million years. Using immunohistochemistry we find that the aesthetes, but not the eyes, of the chiton Acanthopleura granulata express an r-type opsin similar to those expressed by the cephalic eyes of many other invertebrates. Next, through transcriptome sequencing, we find that chiton aesthetes generally express a wide range of vision-related genes, including opsins and arrestins, pigment synthesis genes, and canonical eye development transcription factors such as Pax6. We hypothesize that both A. granulata aesthetes and eyes are light-sensitive, but that they operate via different phototransduction pathways and mediate different photo-behaviors. Further, our work suggests that the extra-ocular expression of vision-related genes may be a widespread trait in mollusks.

New insights into the position of the metazoan root from multi-criterion outgroup selection and microRNAs

There are several phylogenetic hypotheses relating the different sponge classes, but all agree on the same unrooted tree. Most studies place the metazoan root between the sponges and all other animals (Porifera monophyletic), or between the Silicea and all other animals, (Porifera paraphyletic). The nature of outgroup sequences can strongly affect the position of the root, especially if outgroup taxa are long-branched or compositionally-heterogeneous. Here, we conducted multi-criterion outgroup selection (Rota–Stabeli and Telford, 2008, MPE 48:103) on three different datasets. Analyses with outgroups that were ranked objected better by the selection process, as well as analyses designed to alleviate compositional heterogeneity, found support for sponge paraphyly. Analyses with outgroups ranked worse found decreased support for sponge paraphyly or support for sponge monophyly, suggesting that sponge monophyly may be an artifact driven by compositionally-heterogeneous choanoflagellate outgroups. These results were tested by examining the presence/absence of microRNA genes, which have given insight into the phylogeny of other metazoan clades, from all major lineages of sponges. Comparison of microRNAs in calcareans and homoscleromorphs with those previously described from siliceans and eumetazoans reveals that these newly described genes are novel, with each metazoan lineage (Silicea, Calcarea, Homoscleromorpha and Eumetazoa) characterized by a non-overlapping repertoire of microRNAs. Thus while microRNAs cannot resolve between sponge mono- vs. paraphyly, these data suggest the intriguing possibility that microRNAs may have evolved multiple times independently within animals, with important implications for the evolution of gene-regulatory networks.
Evident, whereas PO is compromised by poor protein nutrition. A direct compromise between migratory and anti-bacterial activities is indicated. To investigate the relationship between diet, anti-bacterial activity, whereas those deficient in carbohydrates have less and enhances specific aspects of their immune systems. Migrants deficient in proteins have less spontaneous phenoloxidase (PO) activity, whereas those deficient in carbohydrates have less anti-bacterial activity. To investigate the relationship between diet, movement, and immunity further, we removed Mormon crickets from a migratory band and offered each cricket one of five diet treatments: high protein, high carbohydrate, equal weight proteins and carbohydrates (P+C), vitamins only, or water only for one hour. We then attached a radio, returned each to the migratory band, and recaptured them 18–24h later. Crickets fed protein moved furthest, those without diet or only vitamins moved less, and those fed carbohydrates or P+C moved the least. Standard intake trials also demonstrated that the Mormon crickets were deficient in carbohydrates. We then attached a radio, returned each to the migratory band, and offered each cricket one of five diet treatments: high protein, high carbohydrate, equal weight proteins and carbohydrates (P+C), vitamins only, or water only for one hour. We then attached a radio, returned each to the migratory band, and recaptured them 18–24h later. Crickets fed protein moved furthest, those without diet or only vitamins moved less, and those fed carbohydrates or P+C moved the least. Standard intake trials also demonstrated that the Mormon crickets were deficient in carbohydrates. We then attached a radio, returned each to the migratory band, and offered each cricket one of five diet treatments: high protein, high carbohydrate, equal weight proteins and carbohydrates (P+C), vitamins only, or water only for one hour. We then attached a radio, returned each to the migratory band, and recaptured them 18–24h later. Crickets fed protein moved furthest, those without diet or only vitamins moved less, and those fed carbohydrates or P+C moved the least. Standard intake trials also demonstrated that the Mormon crickets were deficient in carbohydrates.
The Effect of Water on the Gecko Adhesive System

Although we now have thousands of studies focused on the nanoscale micro and recently whole animal mechanics of gecko adhesion on clean, dry substrates, we know very little about the effects of water on gecko adhesion. For many species of gecko however, rainfall frequently wets the natural surfaces they navigate. We investigated the performance of the gecko adhesive system on surfaces fully submerged in water as well as those that were misted with water droplets (as might occur after rain). Although we found distinct limitations of the gecko adhesive system related to surface water and wetting of the adhesive toe pads, we also found that in certain conditions gecko adhesion is not significantly affected by water. While this result is not surprising based on the native environments many geckos inhabit, such as the tropics, anecdotal observations of geckos slipping on wet laboratory surfaces has been noted for years. The loss of adhesion on wet surfaces can be affected by a number of variables including interspecific variation, orientation of the surface, surface chemistry and surface utilization (e.g., clinging vs. running). To test these variables we compared locomotor performance on wet and dry surfaces at different orientations and with multiple species endemic to different environments. We also considered the effect of substrate surface chemistry, noting that geckos often perch and move on plant surfaces such as leaves. While loss of adhesive capability could be detrimental, it is possible that limitations on wet glass surfaces are not necessarily predictive of adhesive system performance on surfaces that are more similar to those in their native environment.

Comparative analyses can extract information from the now readily available genome sequence data of organisms in order to study how gene and genome content change over time. Connecting these genomic changes to the evolution of traits or lifestyles can help determine the molecular basis for adaptations. Several existing tools exist for the comparison of fungal genome sequences including the new database platform FungiDB – http://fungidb.org. The application of this system to discover patterns in gene families, gene content, and inference of gene function from model systems to less tractable system studies will be demonstrated. These approaches are useful in both studies of recently emerged pathogens and evolution of traits across the fungal Kingdom. Comparisons to identify factors underlying pathogenesis in the amphibian killing chytrid fungus Batrachochytrium dendrobatidis (Bd) revealed potentially important gene family changes. These families included a large number of protease and metabolism related functions. Gene families of some potential cell wall proteins are highly expanded when comparing Bd to a closely related non-pathogenic species. In addition, comparisons of the early diverging chytrid fungi and with the Dikarya group of fungi revealed changes in gene content that suggest changes that underly the transition from single-celled aquatic chytrid fungi to the multicellular filamentous mushrooms and molds.
119.3 STEFFENSON, M.M.; FORMANOWICZ, D.R.; University of Texas at Arlington; mmsteff@uta.edu
Adaptation and foraging effects on wolf spider foraging success
Autotomy, or voluntary loss of various body parts, has been shown as an effective predator escape mechanism in many different taxa. The autotomy of a limb has the short-term benefit of escaping a predator. This defensive mechanism has associated costs: decreased mating success, diminished locomotive proficiency, and reduced territory size. Autotomy has also been hypothesized to negative effect foraging ability. However, few studies have actually tested this theory, particularly in spiders. The objectives of this study were to identify whether losing specific limbs through autotomy had different effects on foraging success. Mature Rabidosa rabida were captured from a creek bed in the Chiricahua mountains. R. santrita were separated into three groups: control (missing no legs), 1st leg (in which the 1st walking leg was autotomized), and 4th (in which the 4th walking leg was autotomized). The running speed of each individual was recorded both pre and post-autotomy. Each individual was introduced into an experimental chamber with five Pardosa valens (a local spider that is frequently preyed upon by R. santrita). Spiders were observed for 1 hour and the number of prey items captured was recorded every 15 minutes. Preliminary data analysis indicates that the running speed of spiders did not differ when any limb was removed. Additionally, the number of prey items consumed by the predator did not differ significantly, though a trend was observed of intact spiders consuming the highest proportion of available prey items, those missing a 1st walking leg consuming somewhat less, and individuals missing their 4th walking leg consuming the lowest proportion of available prey. Results indicate that while missing specific legs may affect a predator's ability to forage, it does not do so significantly.

SI3-3 STEWART, WJ*; NAIR, AM; MCHENRY, MJ; Univ. of California, Irvine; wstewart@uci.edu
The sensory cues for predator evasion in fish
Prey fish can survive an encounter with a predator fish by detecting the predators approach and quickly responding with an evasive maneuver. While the ability to detect predator attacks is critical for prey, the sensory signals that trigger prey responses are unclear. Predator fish produce both fluid and visual stimuli during approaches, but identifying the specific cues sensed by prey fish has been unfeasible due to the variable nature of predator–prey encounters. To simplify this behavioral variability and reveal the sensory cues that alert prey fish to predator attacks, we controlled the sensory signals and recorded the resultant escape responses of prey in detail. This was achieved with a high-precision linear motor that translated a preserved predator (zebrafish adult, Danio rerio) towards live prey (zebrafish larvae, Danio rerio) over a range of repeatable and realistic approach speeds. Two high-speed cameras attached to the motor recorded prey escape responses in 3D from the predator frame of reference. The flow field around the approaching predator was quantified in 3D with particle image velocimetry, which allowed us to determine the fluid signals experienced by prey when startled. Video recordings and flow measurements showed that, in dark conditions, nearly all prey responded rapidly after encountering the disturbed flow ahead of the approaching predator. However, when approached slowly in light conditions, the prey behaved differently by swimming away from the predator at lower speeds before encountering the disturbed flow. These results suggest that flow sensing is critical for rapid prey responses to predators approaching at high speed or in the dark, while vision mediates more gradual responses when conditions permit.

32.1 STEWART, TA; Univ. of Chicago; tomstewart@uchicago.edu
Multiple origins of the adipose fin and the morphological diversification of novel vertebrate appendages
Adipose fins are appendages found between the dorsal and caudal fins of some teleost fishes. Their evolutionary history is poorly understood, as is their function. These fins are often regarded as vestigial in the literature, and adipose fins are clipped off by the millions by fishery agencies as a means of tracking salmon. Using a recent phylogeny of actinopterygian fishes I demonstrate that adipose fins have evolved independently at least twice, once in the Otophysi clade excluding Cyprinidae (i.e.: Characiformes, Siluriformes, and Gymnotidae), and again within the Euteleostei. Thus, as convergent novel appendages, I argue for their functionality and explore the diversity of adipose fin anatomies that have evolved within these two groups by comparing their variation in shape and composition. From these surveys I identify muscles that insert upon the adipose fins of several families of catfishes (Siluriformes). This implies the repeated innovation of musculoskeletal linkage systems among adipose fins. This study highlights these structures as an emerging model system by which to study the evolution of structural complexity and function in vertebrate appendages.

7.4 STOCKING, J.B.; RIPPE, J.P.; REIDENBACH, M.A.; University of Virginia; jbs4yq@virginia.edu
Boundary layer flow effects on dissolved oxygen exchange and photosynthesis in scleractinian corals
To investigate the interaction between flow environment and coral photosynthesis, in−situ field measurements of boundary layer flow, photosynthetic quantum yield, and dissolved oxygen levels were obtained over the scleractinian corals Porites furcata and Siderastrea siderea in the coastal ocean of Bocas del Toro, Panama. A vertical profile of three−dimensional velocity structure was obtained using a high−resolution profiling acoustic Doppler velocimeter. Estimates of Reynolds stress, turbulent kinetic energy, and wave orbital motion were derived from these velocity measurements. Local rates of coral photosynthesis were measured using a pulse−amplitude modulated (PAM) underwater fluorometer, and dissolved oxygen (DO) concentrations were measured at the same location using a fluorescence−based optical needle probe. Results show that periods of higher root−mean square (RMS) velocity in the free water column correlate to higher maxima of turbulent kinetic energy (TKE) in the momentum boundary layer directly above the coral−water interface. Larger TKE values also correlate with higher levels of photosynthetic quantum yield and with increases in dissolved oxygen concentration at the coral−water interface. The combined measurements suggest that turbulent eddies act to break down the diffusional boundary layer at the coral surface, thereby promoting DO exchange out of the coral polyp and driving the reaction kinetics of photosynthesis. The results provide in−situ evidence for flow−induced physical control over coral physiology and for consideration of flow as a key parameter in coral health.
Mechanisms of hemoglobin adaptation in high-altitude vertebrates: insights from protein engineering
Is it possible to predict which molecular mechanisms are most likely to contribute to biochemical adaptation? Can we predict which mutations – or which types of mutation – are most likely to contribute to adaptive changes in protein function? To address these questions about the inherent predictability of adaptive evolution at the molecular level, III present results of recent research on molecular mechanisms of hemoglobin adaptation to high-altitude hypoxia in birds and small mammals. These studies integrate evolutionary analyses of sequence variation with experimental studies of hemoglobin function using site-directed mutagenesis.

Color vision in coral larvae? Insights into settlement behavior and possible function of fluorescent proteins
Corals express multiple GFP-like fluorescent proteins (FPs) that result in an array of phenotypes within and between species. The suggested functions of fluorescent proteins range from visual communication with fish to innate immunity, but thus far the support for any of these hypotheses has been scarce. In Acropora millepora larvae, red fluorescent protein (RFP) is expressed in epidermal cells located on the aboral pole, which is the region with which the larva probes the substrate prior to settlement metamorphosis. We hypothesize that RFP serves a sensory function involved in this behavior. We set up an experiment to see if light field modifications would affect the process of larval settlement and also whether this response would correlate with the fluorescent phenotype of the larva. We monitored settlement of individual larvae of two species, A. millepora and Diploria strigosa, under light of different color equalized for total photon flux (intensity) over 3 days. A. millepora exhibits red/green fluorescent polymorphism between full sibs, while D. strigosa expresses only green. In A. millepora, green light strongly enhanced settlement while red light reduced settlement, compared to the settlement rate in the dark. The larvae that settled in the dark were almost exclusively red–fluorescent. In D. strigosa, both green and red light strongly reduced settlement compared to the blue light and darkness. The correlations between fluorescence of the larvae and settlement rate, as well as specific response to green light in A.millepora both agree with our hypothesis of the sensory function of the RFP. It is reasonable to expect that coral larvae would need to avoid light of longer wavelengths since in situ its abundance would indicate direct downwelling light and therefore exposed nature of the location.
53.3 SUMMERS, M.M.*; ROUSE, G.W.; Scripps Institution of Oceanography, UCSD; msummers@ucsd.edu

Understanding the trees of obligate symbionts: myzostomes and echinoderms

The obligate association of myzostome worms (Myzostomida) with echinoderms, in particular with crinoids, is an ideal system in which the evolution of symbiotic lifestyles and body plans can be investigated using phylogenetic inference. An association that has persisted since before the Jurassic, the body plans of myzostomes vary considerably and are consistent with four prominent symbiotic lifestyles (free-living, gall-forming, cyst-forming, and internal) in which the myzostome steals food from or directly consumes the host. Those living freely are mainly disk-shaped and tend to mimic the host by adapting similar colors and/or appendages that resemble the host, traits which are lacking in those that live internally or form cysts and galls. This variety of life histories and dependence on an echinoderm host over long time-scales presents the opportunity to compare the evolutionary histories of myzostomes and their hosts, as well as investigate the evolution of character traits related to this symbiosis. In this study we combine new and previously published sequence and morphological data to present a systematic revision of Myzostomida and their echinoderm hosts, assess congruence between host and symbiont phylogenies, and infer possible evolutionary events leading to the current diversity of myzostome species, lifestyles, and body plans.

25.4 SUNDAY, J.M.*; BATES, A.E.; DULVY, N.K.; Department of Biological Sciences, Simon Fraser University, Institute for Marine and Antarctic Studies, University of Tasmania; sunday@sfs.ca

Global patterns of thermal tolerance and range limits predict climate change responses in ectotherms

How species ranges are shaped by environmental gradients is a central goal of ecology and has come under renewed relevance given the new challenges posed by global climate change. Here we present a comparative analysis of thermal tolerance limits in ectotherms on land in the ocean, and test the hypothesis that species occupy latitudes that correspond to their thermal tolerance windows. We find that marine and terrestrial ectotherms differ in the degree to which they fill their potential thermal ranges. Terrestrial ectotherms are excluded from the warmest regions of their latitudinal range, while marine species more fully occupy the extent of latitudes tolerable within their thermal niche. These findings suggest that terrestrial species may be less sensitive to climate warming at their warm range boundaries. We test this hypothesis by collecting global observations of climate-induced range shifts at poleward and equatorward range boundaries in systematic assemblage surveys. We find that in the ocean, shifts at both range boundaries have been equally responsive, while on land, equatorward range boundaries have lagged in their responses to climate warming, matching predictions. These results indicate that marine species ranges conform more closely to their limits of thermal tolerance, while terrestrial species’ ranges do not. Understanding the relative contribution of other factors in controlling warm range boundaries on land is necessary for predicting the rate of local extinction at trailing range boundaries.

35.2 SUSTAITA, D.*; RUBEGA, M; HARTMAN, G; University of Connecticut, Dept. of Ecol. and Evol. Biology, University of Connecticut, Dept. of Anthropology; diego.sustaita@uconn.edu

When biomechanics meets biogeochemistry: functional correlates of Loggerhead Shrike (Passeriformes: Laniidae) feeding ecology based on stable isotopes analysis

Loggerhead Shrikes are medium-sized (~50 g) passerines that feed on arthropods and vertebrates. Differences in the physical and behavioral attributes of their prey are likely to impose disparate demands on their beaks and jaws. For instance, capturing and dispatching vertebrate prey may select for greater length and curvature of the bill hook, as well as greater bite force capabilities. These features, however, might trade-off against one another, because longer hooked tips may be more susceptible to fracture under greater loads. Previously, we reported a significant negative relationship between a bill shape characterized by increasing hook tip length and curvature, and bite force, in a wild population of Loggerhead Shrikes. Furthermore, we found that bite pressure (force/area) is unrelated to bill tip shape, suggesting that, across individuals and populations, shrikes of different bill tip shapes can achieve functional equivalence in terms of force/area by modulating bite force. Here we use analysis of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotopes of feathers and prey items to place shrike morphology and performance in the context of their feeding ecology. Upper bill shape variables are uncorrelated with isotopic values, but bite performance is negatively related to $\delta^{13}C$ and quadratically related to $\delta^{15}N$. It is as yet unclear specifically how these isotope values relate to prey use, however these results suggest that bite performance might not only mitigate the effects of variation in bill tip shape, but might also mediate the relationship between bill morphology and a dynamically changing prey base.

37.2 SWEENEY, A.M.*; JOHNSON, S; GAGNON, Y; MORSE, D.E.; STRAMSKI, D.; University of Pennsylvania, Duke University, Scripps Institution of Oceanography, UCSD; alisonsw@physics.upenn.edu

Jurassic marine photonics: Squid dynamic iridescence and predation by large extinct marine reptiles

Dynamic iridescence in Loliginid squids has been fascinating and well-studied from an ultrastructural and biochemical point of view. However, its function has remained mysterious, especially the fact that the predominant color of the dynamic iridescence has a peak in the far-red, at 670 nm, which is counter-intuitive for a marine organism. Here we demonstrate that the dynamic red reflectance of the Loligo dorsal surface is likely an adaptation for camouflage against upwelling long wavelength Raman-scattered ocean light, and that this camouflage likely originated at the time of the Jurassic origin of this group in response to predation by large marine reptiles. At the time of origin of the Loliginidae, several major groups of apex marine predators such as Ichthyosaurs, Metriorhynchids, Mosasaurs and Teleosaurs included squids as major portions of their diets. An evolutionary analysis demonstrates that all these groups were likely to have a tetrachromatic visual system with oil droplet filters to increase wavelength specificity of the four cone types. Visual system modeling of an extant squid-eating member of this lineage, the Shearwater Puffinus pacificus, demonstrates that Raman-scattered light is easily visible to these animals, and that prey without an ability to camouflage against this phenomenon will be more visible to these birds. Our findings are an intriguing insight into the visual world of large Jurassic reptiles and suggest other possibilities for reconstructing the visual ecology of these extinct animals.
One of the fundamental physical forces shaping life on earth is light from the sun. My work so far has sought to elucidate the photonic sophistication of evolved structures in animals, and I have tried to not only describe novel light−resonant structures but also to place those structures in an environmental, behavioral context to better understand the nuances of their structural/optical function. I will discuss the evolution of the graded index lenses required for cephalopod vision, the photonic structures underlying deep−sea squid camouflage, and the optical structure of photosymbiosis in giant clams and demonstrate how keeping the animals in their environmental context shows the way to understanding these systems.

---

**33.6 SWORE, J.J.*; KOHN, A.B.; KOCOT, K.M.; SWALLA, B.J.; NOREKIAN, T; MÓROZ, L.L.; Univ of Florida, Auburn Univ, Univ of Washington; jjswore@students.nwc.edu**

**On the Origins of Glutamatergic Signaling: Insights from the ctenophore genome (Pleurobrachia bachei )**

Ctenophores are extant representatives of one of the earliest animal lineages. Yet, as pelagic predators, they developed remarkable behavioral complexity with true neurons and muscles. Here, we performed a genome−wide survey of neurotransmitters in the ctenophore Pleurobrachia bachei focusing on the characterization of glutamate (Glu) mediated signaling. Specifically, we identified and characterized the molecular organization and expression of 14 ionotropic Glu receptors (iGluR), and associated components of Glu synthesis and uptake. In Pleurobrachia, we discovered an unprecedented molecular diversity of Glu signaling; a diversity that far exceeds the situation observed in other animals including humans. There is also an extremely unusual genomic organization of many iGluRs. All cloned receptors showed remarkable cell−type specific expression both in development and in adults, but only a small subset of receptors is associated with neuronal−type elements, suggesting pre−neuronal origins of Glu−mediated transmission. In summary, we revealed the presence of well−developed Glu signaling in Ctenophores. However, this type of signaling is substantially different from other animals and can be explained in terms of extensive parallel evolution. On the other hand, Ctenophores might preserve one of the earliest designs of neural organization among animals, with a number of unique innovations absent or lost in other animal lineages.

---

**110.5 SWIDERSKI, D. L.*; ZELDITCH, M. L.; Univ of Michigan, Ann Arbor; dwidder@umich.edu**

**Mouse Jaw Ontogeny in Tres Partes Divisa Est**

The mouse mandible is a popular model system that continues to be the focus of studies in evo−devo and other fields. Yet, little attention has been given to the role of postnatal growth in producing the adult form. Using cleared and stained specimens, we describe the timing of tooth and jaw development and changes in jaw size and shape from postnatal day 1 (p1) through weaning (c. p21) to adulthood (c. p35). We found that tooth development is relatively advanced at birth, and that the functional adult dentition is in place by p15 (just before the start of weaning). Shape analysis showed that the trajectory of jaw shape changes direction at least twice between birth and adulthood, with the first change around p7 and the second around p15. Before p7, the tooth bearing horizontal ramus deepens more than it elongates while the bone keeps pace with the growing molar crowns; the posterior processes also expand rapidly, increasing space for muscle attachment well in advance of the shift from nursing to chewing. After p7, the ramus deepens more slowly, with the teeth erupting while the roots are still growing; and the posterior processes widen more than elongate. After p15, the ramus increases curvature with the incisor, while the main changes in the posterior processes are deepening of the angular and elongation of the coronoid. Thus, at each stage there are changes in shape to all tooth and muscle bearing regions, and at each change of direction, all regions change their pattern of growth. In each interval (p1−7, 7−15, 15−35), the amount of shape change is nearly the same, as is the amount of size change. So although the jaw and teeth are close to adult form at the end of weaning, this last phase still affords ample opportunity for the environment to exert a direct effect on jaw size and on the shapes of all parts of the jaw.
TARRANT, AM*; MCCORKLE, DC; DEPUTRON, SJ; settled them on tiles and reared them for two weeks under controlled conditions. In laboratory experiments, decreased aragonite saturation state can lead to decreases in skeletal growth of both adult and juvenile corals. In experiments conducted with corals and other animals, individuals vary in their apparent resistance or sensitivity to the effects of acidification. To investigate possible maternal effects on coral growth and sensitivity to ocean acidification, we collected brooded larvae released by nine maternal colonies of Porites astreoides, settled them on tiles and reared them for two weeks under conditions of ambient or elevated carbon dioxide (targeting aragonite saturation states of 3.6 and 1.6, respectively). The maternal colonies produced larvae that varied substantially in settlement success, ranging from 2−54%. After two weeks, polyp diameter and weight varied significantly among maternal colonies, but little to no difference was observed in response to CO2. These experiments demonstrate that over a short time period, P. astreoides juveniles appear to be relatively insensitive to moderate acidification. Under controlled conditions, maternal colonies produce offspring that vary dramatically in their settlement rates and size, which may lead to differential survival and eventual recruitment. Further experiments are needed to identify the environmental and/or genetic factors that contribute to these differences.

53.1 TEICHHOLTZ, P.J.: University of Michigan; pteich@umich.edu
Developmental mode, poecilology, and population structure of the pyramidalid snail Boorea impressa
Poecilology, the expression of more than one developmental mode in a single species, is usually not viewed as an evolutionarily stable strategy. Poecilognous species are typically considered transitional states between discrete developmental modes. However, poecilology may also represent a successful bet-hedging strategy that maximizes fitness under unpredictable conditions. Although species with this condition offer promising systems for illuminating the evolution of life histories, aspects of larval ecology and implications of different developmental modes on population dynamics, poecilology is difficult to confirm in many cases, and only a few poecilognous species are known. Many suspected poecilognous species turn out to be cryptic species complexes. Proper recognition of cryptic speciation is thus necessary for determining the actual prevalence of this condition and identifying appropriate systems for further study. Here I investigated a potential case of poecilology among Gulf coast populations of the marine snail Boorea impressa. Populations of B. impressa from Galveston Bay and Aransas Bay have been reported as exhibiting direct development and lecithotrophy, respectively. To determine whether cryptic speciation was present in, I utilized molecular phylogenetic and population genetic approaches based on analyses of mitochondrial (COI) and nuclear (ITS2) gene sequences to assess reproductive isolation and genetic structure of three Gulf coast populations of B. impressa. While no clear evidence of cryptic species was found, significant population structure was evident both within and between populations. This pattern is similar to the substantial population structure observed among other confirmed poecilognous species. Together these results show that intraspecific variation in developmental mode contributes to the diversification of marine invertebrates.

42.2 TAYLOR, KR*; NISHIKAWA, KC; Northern Arizona University; kst757@nau.edu
The effects of a titin mutation on tremor frequency during shivering thermogenesis
Muscular springs, such as titin, play an important role in determining muscle properties. The muscular dystrophy with myostis (mdm) mouse model is characterized by a deletion in the N2A region of titin. Previous work suggests that muscles from mdm mutants are stiffer when passive and more compliant when activated than wild type muscles. Shivering frequency is an ideal way to measure the in vivo consequences of muscle stiffness because frequency of tremor (f) should be directly proportional to (k/m)^1/2 where k is stiffness and m is body mass. Because mutants have more compliant active muscles (i.e., decreased k), we expected that mutant mice would exhibit lower frequency tremors during shivering than predicted based on body mass. Further, we predicted that wild type and heterozygous mice would exhibit tremor frequencies expected based on body mass. Shivering was elicited by reducing ambient temperature, and tremor frequency was measured using an accelerometer attached dorsally to the trunk. The predicted tremor frequencies and the observed frequencies were not significantly different for wild type (expected: 41.5 Hz +/- 0.5 Hz; observed: 40.5 Hz +/- 0.3 Hz) and heterozygous mice (expected: 40.8 Hz +/- 0.8 Hz; observed: 39.5 Hz +/- 3.0 Hz). However, the observed tremor frequency for mutant mice (19.2 Hz +/- 4.1 Hz) was significantly lower than predicted by body mass (50.5 Hz +/- 0.7 Hz). These results support the hypothesis that the mdm mutation results in reduced active muscle stiffness in vivo. Thus, the results of this study demonstrate the important role that muscle stiffness, provided by titin, has in setting shivering frequency. Supported by NSF IOS−1025806.
44.5 THAWLEY, C.J.*; ROBBINS, T.R.; LANGKILDE, T.; Pennsylvania State University; cjt177@psu.edu

Survival at what cost?: Consequences of a native lizards adaptations to invasive fire ants

Anthropogenic environmental change, including introductions of non-native species, imposes novel selective pressures on native species. A populations ability to persist under these threats can depend on its capacity to adapt accordingly. However, responses to an altered fitness landscape may not be optimal across all environments or life stages. We conducted a field transplant experiment using Eastern Fence Lizards, (Sceloporus undulatus) to investigate how a populations history of coexistence with predatory red imported fire ants (Solenopsis invicta) affects fitness (survival). Fence lizards in fire ant invaded sites have altered behavior and morphology, which are assumed to increase survival under this novel threat. We show that both adult and juvenile lizards from populations historically invaded by fire ants have higher survival in the presence of fire ants than do lizards from uninvaded populations. Adult lizards from invaded populations, however, appear maladapted when fire ants are absent, having lower survival than naïve lizards under these conditions. Juvenile lizards show an advantage associated with exposure to fire ants but do not experience the same costs as adults. These ontogenetic differences in the consequences of adaptation to fire ants may derive from the specific outcomes associated with each adaptation. Adults from fire ant invaded sites exhibit behaviors that promote escape from fire ants but expose them to mortality via native predators; whereas juveniles demonstrate innate avoidance of eating fire ants, which protects them from envenomation. Studying the downstream effects of pressures imposed by invasive species can provide insights into the longer-term consequences of environmental change on community interactions and the persistence of biodiversity.
THOMAS, W H*; FUNG, J K; THOMAS, F; University of Hawai'i–Windward Community College; hoaka.thomas@me.com
Weed Quality of Kne'ohe Bay Using Indicator Species Trinereustes_gratilla
Over the years the populations of the sea urchin Trinereustes_gratilla have decreased drastically in Kne'ohe Bay, Hawaii. The loss of this opportunistic grazer from its waters has coincided with an increase in invasive algal species like Gracilaria salicornia that impact the coral reef ecosystem. The goal of this study was to measure the water quality of Kne'ohe Bay by tracking the effect of naturally occurring waters from off shore and near shore sites on early development in T. gratilla. The results of these experiments were compared to a reference toxicant (copper) over a range of concentrations. A gamete-extraction protocol was performed to produce fertilized urchin eggs. The urchin embryos were allowed to grow in 20 mL beakers of onshore, offshore, and control seawater, and seawater containing varying concentrations of copper. Concentrations ranged from 5 μg per liter to 200 μg per liter. Larvae were allowed to develop for three days. After which tallies were taken to see how the larvae developed. The larvae were categorized as normal, abnormal or underdeveloped. In the copper-toxicity test, urchin larvae showed sensitivity to copper above concentration of 20 μg per liter, with normal development dropping to 30% normal development at this concentration. In naturally occurring water, samples from onshore had more underdeveloped and abnormal larvae than those developing in offshore water samples. The onshore samples had similar levels of abnormal and underdeveloped larvae to concentrations of copper ranging from 20 μg per liter to 200 μg per liter. This could mean that chemicals with properties similar to those of copper are in high concentration along the shores of Kne'ohe Bay.

THOMETZ, N.M.*; WILLIAMS, T.M.; University of California, Santa Cruz; nthometz@ucsc.edu
Ontogeny of oxygen storage capacity and diving ability in southern sea otters (Enhydra lutris nereis)
As the smallest members of the smallest marine mammal species, immature sea otters face extraordinary physiological challenges as they transition from dependent pups to independent foragers. High energetic demands and limited oxygen stores severely limit the diving ability of a variety of immature marine mammals, potentially impacting their ability to respond to changes in prey distribution and abundance. We examined the ontogeny of blood and muscle oxygen stores and calculated aerobic dive limit (cADL) in southern sea otters. Key blood and muscle parameters, including hemoglobin (Hb), hematocrit (HCT), red blood cell (RBC) count, mean corpuscular hemoglobin content (MCHC), and myoglobin (Mb) content were determined for pups, juveniles in their first year post-weaning, and adults. Pups had oxygen stores between 69–89% of adult values depending on size and age, while juveniles had oxygen stores similar to adults. Neonates displayed minimal Hb levels (11.76±0.36 g/dL) which increased in large pups (15.78±0.32 g/dL) and juveniles (18.13±0.35 g/dL). Mb levels were particularly low in neonates (0.31±0.15 g/100g tissue) and medium pups (1.24±0.30 g/100 g tissue) but reached adult levels in juveniles (3.42±0.14 g/100 g tissue). Small and medium pup cADL was between 1.0–1.9 minutes, while large pup cADL ranged from 2.1–2.9 minutes. Despite similar oxygen storage capacity, juvenile cADL was only 2.7–3.6 minutes compared to 3.0–4.1 minutes for adults, due to increased metabolic demands. As benthic foragers, limited aerobic capacity will likely impact the ability of young otters to compete with adults for limited food resources.

THOMPSON, D. M.*; LIGON, D. B.; Missouri State University; denise.thompson17@gmail.com
Rocky Raccoon Must Die: Nest Predation Patterns in a Population of Reintroduced Alligator Snapping Turtles Predation of turtle nests is the primary cause of egg mortality and can be as high as 100% in some populations. In North America, raccoons (Procyon lotor) are significant predators of turtle nests; however, the importance of different sensory cues to nest detection and predation by raccoons has not been investigated. We experimentally tested the importance of visual and olfactory cues by measuring raccoons' response to artificially constructed nests composed of: a) visual cues alone; b) olfactory cues alone; c) both visual and olfactory cues; and d) controls with no sensory cues. Research was conducted in southern Oklahoma at Tishomingo National Wildlife Refuge at ponds containing reintroduced alligator snapping turtles (Macrocrystis temminckii). Artificial alligator snapping turtle nests were created to represent the three aforementioned nest treatments. A total of 16 trials were run from 26 July, 2011 and monitored with time-lapse, infrared game cameras. Initial raccoon detection of nests in each trial resulted in 9 (56%) of the 16 visitations occurring at the visual treatment, 7 (44%) at the visual–olfactory treatment, and none occurring at the olfactory or control treatments. Similarly, predation events were evenly distributed between visual and visual–olfactory treatments, with each being the first to be predated 7 times, while olfactory nests were the first nest predated only once. In 85% of trials the olfactory nest was the last nest to be predated, and on one occasion was not predated at all for an entire 3–day trial. We conclude that visual cues play a far more important role in raccoon detection and predation of alligator snapping turtle nests than do olfactory cues.

BOYLES, J.G.*; MCKECHNIE, A.E.; T. Thompson, A.B.; BOYLES, J.G.*; MCKECHNIE, A.E.; T. Thompson, A.B.; MCKECHNIE, A.E.; jgboyles@siu.edu
Patterns in mammals using two scales (Thermoregulatory Scope, TS; and Heterothermy Index, HI). Similarly, body mass, season, latitude, and boarding were important predictors of TS, a proxy of the variation in Ta a species is capable of displaying. Similarly, body mass, latitude, and average environmental temperature were important predictors of HI, a measure of the variation in Ta displayed under natural conditions. During winter, there was a strong positive relationship between latitude and heterothermy, suggesting species at high latitudes are more likely to display large fluctuations in Ta. However, during summer, HI values were negatively related to latitude, suggesting that factors other than temperature (e.g. water or food availability) more strongly affect Ta patterns. Phylogenetically older taxa exhibited high TS values, suggesting they are capable of allowing Ta to fluctuate more than phylogenetically young taxa. However, the phylogenetic pattern was less clear in HI values, suggesting that although older taxa may be more capable of displaying heterothermy, Ta patterns in the wild are strongly controlled by ecological factors.

119.2 THOMPSON, D. M.*; LIGON, D. B.; Missouri State University; denise.thompson17@gmail.com
Ontogeny of oxygen storage capacity and diving ability in southern sea otters (Enhydra lutris nereis)
As the smallest members of the smallest marine mammal species, immature sea otters face extraordinary physiological challenges as they transition from dependent pups to independent foragers. High energetic demands and limited oxygen stores severely limit the diving ability of a variety of immature marine mammals, potentially impacting their ability to respond to changes in prey distribution and abundance. We examined the ontogeny of blood and muscle oxygen stores and calculated aerobic dive limit (cADL) in southern sea otters. Key blood and muscle parameters, including hemoglobin (Hb), hematocrit (HCT), red blood cell (RBC) count, mean corpuscular hemoglobin content (MCHC), and myoglobin (Mb) content were determined for pups, juveniles in their first year post-weaning, and adults. Pups had oxygen stores between 69–89% of adult values depending on size and age, while juveniles had oxygen stores similar to adults. Neonates displayed minimal Hb levels (11.76±0.36 g/dL) which increased in large pups (15.78±0.32 g/dL) and juveniles (18.13±0.35 g/dL). Mb levels were particularly low in neonates (0.31±0.15 g/100g tissue) and medium pups (1.24±0.30 g/100 g tissue) but reached adult levels in juveniles (3.42±0.14 g/100 g tissue). Small and medium pup cADL was between 1.0–1.9 minutes, while large pup cADL ranged from 2.1–2.9 minutes. Despite similar oxygen storage capacity, juvenile cADL was only 2.7–3.6 minutes compared to 3.0–4.1 minutes for adults, due to increased metabolic demands. As benthic foragers, limited aerobic capacity will likely impact the ability of young otters to compete with adults for limited food resources.

19.2 THOMPSON, A.B.; BOYLES, J.G.*; MCKECHNIE, A.E.; MALAN, E.; HUMPHRIES, M.M.; CAREAU, V.; McGill Univ., Southern Illinois Univ., Univ. of Pretoria, Univ. of California, Riverside; jgboyles@siu.edu
Resource needs and climate means contributing to a global heterothermic continuum in mammals
Thermoregulatory patterns are a defining characteristic of all animals, but endotherms have garnered special attention in this area, presumably because of the ecological and evolutionary success these species have gained from their ability to control body temperature (Ta) via metabolic thermogenesis. We evaluated ecological and evolutionary factors that affect Ta patterns in mammals using two complementary metrics that place variation in Ta on continuous scales (Thermoregulatory Scope, TS; and Heterothermy Index, HI). Body mass, season, latitude, and boarding were important predictors of TS, a proxy of the variation in Ta a species is capable of displaying. Similarly, body mass, latitude, and average environmental temperature were important predictors of HI, a measure of the variation in Ta displayed under natural conditions. During winter, there was a strong positive relationship between latitude and heterothermy, suggesting species at high latitudes are more likely to display large fluctuations in Ta. However, during summer, HI values were negatively related to latitude, suggesting that factors other than temperature (e.g. water or food availability) more strongly affect Ta patterns. Phylogenetically older taxa exhibited high TS values, suggesting they are capable of allowing Ta to fluctuate more than phylogenetically young taxa. However, the phylogenetic pattern was less clear in HI values, suggesting that although older taxa may be more capable of displaying heterothermy, Ta patterns in the wild are strongly controlled by ecological factors.
The warm–adapted Mediterranean blue mussel species *Mytilus galloprovincialis* invaded southern California during the last century and since replaced the cold–adapted native *M. trossulus* from its southern range, possibly due to climate change. Furthermore, *M. galloprovincialis* is more sensitive to lower salinity levels than the native. Both, temperature and salinity changes have been hypothesized to contribute to the range shifts and limits. Using proteomics, we characterized the underpinnings of interspecific differences in thermal and salinity tolerance limits. We conducted several experiments: an acute heat stress experiments to 24°C, 28°C and 32°C, followed by a 24 h recovery at 13°C; a 4−week long temperature acclimation (7°C, 13°C and 19°C) experiment and an acute hyposaline (35, 29.8 and 24.5 psu seawater) exposure for 4 h followed by a 24 h recovery. Using gill tissue, we applied 2D gel electrophoresis and mass spectrometry to separate and identify proteins. The results suggest that acute heat stress triggers a shift from pro−oxidant NADH− to anti−oxidant NADPH−producing pathways to reduce the production of reactive oxygen species (ROS) and increase the cells capacity for ROS scavenging. Temperature acclimation showed that *M. trossulus* induces molecular chaperones at 19°C. Cold acclimation increased oxidative stress proteins and molecular chaperones in both congeners, although more so in *M. galloprovincialis*, suggesting a ROS−induced challenge to protein homeostasis at lower temperatures. The responses to hypo−salinity stress suggest that *M. galloprovincialis* is able to respond to 29.8 psu but not to 24.5 psu, in contrast to the native *M. trossulus*, which can respond to both. The results suggest that increased ROS production correlates with metabolic depression and reduced protein synthesis in all three treatments.
**40.1 TYTPELL, E.D.; Tufts Univ.; eric.tytell@tufts.edu**

*The intrinsic dynamical properties of muscle are self–stabilizing for physiological gaiting.*

Animal locomotion is a rhythmic behavior that requires the effective coupling of multiple feedback loops, including mechanical coupling between the animal's body and the environment, coupling between muscular force production and body movement, and sensory feedback. Computational models were used to analyze how the intrinsic dynamical properties of neural and mechanical systems interact to produce stable, but adaptable locomotion. Fluctuation theory, a branch of nonlinear dynamics, includes ways to analyze how such rhythmic systems respond to perturbations. We analyzed the dynamical mathematics of a mathematical model of lamprey muscle and developed several robust ways of estimating the Fluctuation modes of a rhythmic system, which are canonical patterns of activity after a perturbation. We found that when a block of muscle is forced to change length sinusoidally and is cyclically activated, at the standard work–loop protocol, it is strongly self–stabilizing, even with no sensory feedback. When two muscles act antagonistically, as they do around most vertebrate joints, then the system is less stable naturally. However, if the animal has sensory input regarding the joint position, it can be stabilized very easily.

---

**6.1 USHERWOOD, JR; The Royal Veterinary College; jusherwood@rvc.ac.uk**

*The basic mechanics of pronking, bounding or frog–hopping: the costs of pitching accounts for much of the diversity of fast quadrupedal gaits.*

Quadrupeds show a fascinating range of gaits, both between species and across speeds. Accounting for the selection of these gaits, and understanding them within the context of mechanics, body form and locomotory requirements remains challenging. Current extreme reductionist models provide a range of insights, but fail to account for many aspects of gait selection. Here, I build on the principles of collisional mechanics developed for quadrupedal locomotion pioneered by Ruina, Bertram and Srinivasan, and develop a numerical pseudo–impulsive approach to account for the energetic requirements of pronking, bounding and frog–hopping, including the consequences of pitching. This allows two complications to the point–mass model to be considered: points of force application on the ground being distributed (because of a finite back length); and the forces are allowed to apply torques about the centre of mass (because of a finite pitch moment of inertia). In effect, this model treats a quadruped as a stiff table. This approach successfully accounts for why horses gallop with only a gathered aerial phase (and frogs extended). However, if the body geometry does not vary with speed, no account is made for a transition from pronking to pitching gaits (or trotting to galloping) with increasing speed. Indeed, the energetic costs of non–pitching gaits (pronking, trotting and pacing) are predicted to be independent of speed, while pitching gaits (bounding, frog–hopping, galloping etc.) are predicted to increase with speed. So, while the model provides novel and, in retrospect, intuitive insight into the footfall timing and direction of forces during pitching gaits, it also predicts a gallop to trot transition with increasing speed. Likely limitations of the model assumptions will be considered.
Feeding and swallowing on land

An important step towards understanding the evolution of terrestriality in vertebrates is to identify how the aquatic ancestors of tetrapods were able to access ground-based prey. Since several lineages of modern bony fishes show a number of transitional feeding lifestyles, these fishes can be used to study the biomechanical requirements of successful aquatic to terrestrial transitions to capture and transport prey in their buccopharyngeal cavity. We analyzed the functional morphology and kinematics of two morphologically distinct and distantly related species that are both successful terrestrial feeders: the mudskipper (Periophthalmus barbarus) and the eel–catfish (Channallabes apus). During prey capture, the mudskipper pivots over its strong pectoral fins, and uses its complex system of oral jaws to pick up pieces of food on land. Notably, we found that this species still makes use of water carried along in the buccopharyngeal cavity to assist prey capture, and to provide intra–oral transport of food towards the esophagus by performing suction movements. This mechanism is markedly different from the eel–catfish, which curls towards the esophagus by performing suction movements. This still makes use of water carried along in the buccopharyngeal cavity to transport the necessary food to its physical source, and whether or not they decide to land on it. To answer these questions we built an experimental rig capable of delivering predictable pulses of odor into a wind tunnel with minimal turbulence. We used a mini PID to characterize the odor pulses and build an accurate model, allowing us to predict the time varying odor landscape in the wind tunnel. To study how the flies integrate this olfactory cue with their visual sense we added a vertical black post near the plume. Using a 9-camera tracking system we were able to track the flies in 3D as they flew through the wind tunnel with different olfactory and visual scenarios. Preliminary results suggest that flies that recently passed through an odor plume are 3 times more likely to land on a nearby object (N=699), compared to flies who have not experienced any odor, yet flew within the same general area (N=879). Furthermore, the effect of the odor stimulus appears to persist – flies that have experienced odor, but less recently, are 7 times more likely to land than in the control case (N=679, 686, resp.). In summary, our unique experimental paradigm has allowed us to begin probing the roles of olfaction, vision, and memory, in food finding behavior in freely flying fruit flies.

Body dynamics of larval fish – implications for the mechanics of large–amplitude swimming

Body and center–of–mass dynamics are fundamental to the mechanics of locomotion. Experimental studies have shown that small swimmers and flyers are relatively strong, since they generate forces and torques that are large compared with their body weight. However, small organisms must overcome relatively high drag forces, so their locomotion is characterized by high thrust and low efficiency. In this study, we quantify the center–of–mass kinematics of zebrafish larvae from video recordings of C starts and cyclic swimming. During cyclic swimming, the larval tail produces high torques as part of thrust generation: torque correlates with tail velocity (rather than tail acceleration, or velocity of anterior body sections). Torque increases with swimming speed, as do kinetic energy and power output. A maximum power output of 20 W/kg is observed at swimming speeds of 0.2 m/s at tail beat frequencies of 100 Hz. This value approaches the maximum power of fast and superfast muscles. Strouhal number decreases with increasing speed and Reynolds number, from values above 2 at Re 100 to 1 at Re 1000, indicating that swimming efficiency increases with speed. Previous studies on C starts suggested that fish begin to translate in the preparatory phase (stage 1, formation of the C). Our data show that the center of mass moves outside the body during stage 1, but does not translate in the earth–bound frame of reference. Translation begins during the propulsive phase (stage 2). Translational kinetic energy during stage 1 is near zero; rotational kinetic energy is high during stages 1 and 2, indicating that the change of heading during a C start is the net result of the large torques generated during both stages. We did not find the previously reported inverse relationship between forward speed and turning angle.

Fluctuations in Historical Oxygen Levels Impacted Insect Body Size and Physiology

Fluctuations in atmospheric oxygen over the last 500 million years have been hypothesized to have driven a number of evolutionary changes, including Paleozoic insect gigantism. However, the fact that not all insect groups exhibited gigantism coupled with the paucity of the fossil record and the complex interactions between oxygen, organisms and communities makes it difficult to definitively accept or reject the oxygen–size link. Yet, evidence from a series of modern insect rearing experiments does support this link: 1) dragonflies and other insects develop larger body sizes in hyperoxia, 2) almost all insects develop smaller body sizes in hypoxia, 3) tracheal system investment is inversely correlated with rearing oxygen, and 4) rearing oxygen affects insect physiology including growth, development, and fecundity even in insects that show no increase in body size. These results point to not just an effect of oxygen on maximum size, but a strong effect on average body size and insect physiology. Therefore, we have carried out a series of fossil studies focused on average body size across geologic times of both high and low oxygen levels. The results of these studies further support the link between fluctuations in oxygen and insect evolution: 1) the maximal and average size of Protodonata and Paleodictyoptera fossils correlate positively with modeled atmospheric oxygen, 2) Blattodea fossils showed little variation in maximum size, but average size was correlated with atmospheric oxygen, and 3) the Triassic hypoxic event appears to have a larger impact on insect body size than the Paleozoic hypoxic event. The results from this combination of modern and fossil studies suggest that historical fluctuations in atmospheric oxygen would have influenced insect size, physiology and fitness. Supported by NSF EAR 0746352.
**Effects of testosterone on spring nocturnal migratory restlessness and body composition in Zonotrichia albicollis**

Testosterone influences a number of hormonal cascades that modulate seasonal changes in behaviour and physiology. In the spring, many bird species migrate to breeding grounds, where androgens and estrogens promote courtship and territory defence behaviours. Testosterone also increases muscle mass and fat deposition rates via hyperphagia, supplying migrating birds with additional fuel. Captive birds exposed to photoperiod cycles display migratory restlessness in the form of nocturnal hopping activity (Zugunruhe). Precise endocrine modulation of this migratory behaviour and physiology is unclear, however castrations decreased the rate of spring Zugunruhe in prior experiments. Our study compared Zugunruhe and body composition in castrated and intact white-throated sparrows (Zonotrichia albicollis) following photoperiod and hormone manipulation. Intact sham-operated males kept on short days (non-migratory) did not exhibit Zugunruhe behaviour, while those switched to long days did. Long-day castrates implanted with androgen blockers (flutamide) and an aromatase inhibitor (ATD) displayed minimal nocturnal activity intermediate to that of short-day and long-day intact males. Long-day castrates given testosterone replacement exhibited higher levels of nocturnal activity than the three other groups. Flight muscle, heart and liver mass differed among the four treatment groups, generally showing greater size in the testosterone replacement group. Our results indicate that long day exposure in spring will elicit Zugunruhe, but that testosterone enhances photoperiod-induced migratory restlessness and organ changes.

**Multiple stressor interactions delay horseshoe crab embryo development**

Fertilized eggs of the American horseshoe crab, Limulus polyphemus, are exposed in shallow nests above the high tide line, where they are exposed to variations in abiotic conditions during early development. We examined whether the rate of embryonic development is affected by exposure to environmentally–relevant combinations of three factors: temperature (T; 25°, 30° and 35° C), salinity (S; 5, 15 and 34 ppt), and dissolved O2 (DO; 5%, 13% and 21% O₂). Newly fertilized eggs collected from nests of individual mating pairs were returned to the lab and incubated under fully-factorial stressor combinations for 14 d, then placed in control conditions (30° C, 34 ppt, 21% O₂) for an additional 14 d. Growth rate was measured every 2 d throughout the experiment. We assessed 8 embryos from each of 6 mating pairs at each of the 27 treatment combinations (1296 eggs). We found that although the effect of isolated stressors (high T, low S or low DO) on development was minimal, stressor combinations showed stronger effects with evidence of complex interactions. For example, whereas high T and low S in isolation each had no effect, they were lethal in combination, and although low T in isolation slightly decreased the rate of development, it reduced the negative effects of low S and/or low DO. Furthermore, low DO increased the effect of high T, but it did not affect the response to low S. Low DO also appeared to pause development, which then resumed upon return to control conditions, but only after a 4 d lag. These data demonstrate that complex, synergistic interactions among environmentally–relevant levels of abiotic stressors can substantially alter the development of a coastal invertebrate in ways that may not be predicted from the effects of the stressors in isolation.
A phylogenomic approach to the evolution of the coral reef fish fauna

Coral reefs, while only making up a mere 1% of the oceans area, are home to over a third of all the marine fish species. The reef-associated fish fauna is polyphyletic. Approximately 160 out of 450 families of ray–finned fishes include coral reef associated species. Nearly all of the major reef fish families fall within Percomorpha, a group comprising ~16,000 species. Due to the poor phylogenetic resolution of the percomorph tree of life, major questions regarding the evolution of the reef fish fauna remain unanswered. For example, the number of transitions to reef habitats, the timing of radiations of reef families, and the influence of geo–historical events such as changing sea levels and temperatures on the reef fish fauna are poorly understood. To begin to address the evolution of the percomorph reef fish fauna, we sampled 10 major reef–associated families as well as other non–percomorph lineages. We employed a new phylogenomic approach using targeted enrichment and massively parallel sequencing of >1300 ultraconserved DNA elements (UCEs). Our sampling strategy is designed to recover the crown ages of these 10 families to begin evaluating hypotheses regarding the timing of their colonizations and occurrence of concurrent radiations. Our long term goals include increasing the density of sampling within these groups as well as generating UCE–based phylogenies for 22 additional poorly studied reef clades.

Rapid Burrowing by the Mantis Shrimp Squilla empusa

Mantis shrimp rely on their burrows for shelter, protection from predators, reproduction efforts, and food manipulation. While some species incur great costs during burrow construction and consequently maintain a robust burrow for a long time, Squilla empusa can create simple burrows very rapidly. We investigated S. empusa burrowing by collecting nine animals and filming their burrowing motions in the laboratory using high speed video and particle image velocimetry. We also released captive animals back into their native habitat and filmed the resulting burrow excavation in situ. In both in the laboratory and in the field, S. empusa employed two methods of moving sediment: pleopod fanning, which directed stirred–up sediment posteriorly, and bulldozing, in which the animals carried sediment forward in a basket made of their maxillipeds. Pleopod fanning occurred in short bursts: S. empusa formed depressions deep enough to accommodate their body in about two minutes. After this stage, maxilliped bulldozing became the dominant excavation method. Video analysis suggested that pleopod fanning effectiveness was improved by rotational movements of the pleopods that directed the resultant current medially. Scanning electron micrographs indicated that the extremely setose nature of the pleopods greatly increased their surface area, facilitating current generation. The formation of the maxilliped basket was enhanced by a complex arrangement of setae, especially on maxilliped pairs 3−5, that interlocked to form a robust chamber able to carry substantial amounts of varied substrate. Together, the morphology of the appendages and the dynamics of their movement made it possible for S. empusa to make completely new burrows in less than thirty minutes, and to carry out daily adjustments to already existing burrows.
How the pilidium larva feeds

The nemertean pilidium is a novel larval type that is difficult to relate to other invertebrate larval forms, except inasmuch as the pilidium—like the actinotroch, the mitraria, the endolarva of Polygodius, or the dipleurulas—consists of an inflated, transparent larval body bearing ciliated bands by which it swims and feeds, and within which a juvenile develops from growing rudiments. Like those superficially-similar larval forms, the pilidium feeds on small phytoplankters. The heteronemertean Micrura alaskensis can be raised in the lab from egg to metamorphosis when fed solely with Edible cells, but rarely inert particles, trigger rapid flicks of the pilidial lobes and lappets, re-directing a food particle and surrounding parcel of water into an atrial chamber. Non-beating cilia within the band are the likely sensors that detect edible cells. Once a parcel of food-containing water is engulfed, a secondary ciliated band beats in reverse, as if to barricade the exits while expelling excess water. Slow flow within the esophagus gently moves the cell toward the stomach entrance. Most captured Rhodomonas make repeated attempts to escape by firing ejectosomes, but the size of the chamber and the persistent flow within it seem to defeat the captured cells’ efforts, until, their ammunition exhausted, they are drawn defenseless toward the gastric sphincter. This feeding mechanism is striking both for its novelty—it’s not like any other larva—and for its familiarity: in inventing something original using fundamental biological principles.

VOLTZOW, J.; Univ. of Scranton; voltzowj2@scranton.edu

An exchange of countercurrents: Models, demos, and raps

Many students learn better when they are actively involved in manipulations or other hands-on exercises. In content-rich courses like introductory biology, these exercises can be especially effective to help students make connections between seemingly diverse topics. Countercurrent exchange is a basic mechanism used by animals to enhance the diffusion of respiratory gases across their gills, to reduce heat lost to the environment through the surfaces of extremities, and to concentrate excretory products. This important concept arises several times over the semester in units on respiration, homeostasis, and excretion. I wanted students to appreciate that these functions depend upon the same underlying basic mechanism. Towards the end of the course, therefore, I ask students to build models or present demonstrations of countercurrents to the class. I give them a large amount of leeway, but they are required to do something that is three-dimensional or involves an activity. The assignment has resulted in games, skits, and even a rap video with thousands of hits on YouTube. The exercise helps students appreciate the shared principles that permit these multiple applications and gives them the opportunity to share their understanding with their peers. Most importantly, they have fun doing it and appear to remember it longer because they created something original using fundamental biological principles.

VON DASSOW, G*; EMLET, RB; MASLAKOVA, SA; University of Oregon; dassow@uoregon.edu

How the pilidium larva feeds

SWARTZ, S.M.; Brown University; rheg_vonbusse@brown.edu

Kinematics of swimming and flying big brown bats, Eptesicus fuscus—a comparative study

Bats are extremely maneuverable and versatile fliers. Although there has been substantial research concerning the kinematics of bat flight, it is less widely appreciated that bats are also good swimmers. Here, we ask: how do bats modify the basic movements of the wing when encountering a fluid of much greater density and viscosity than air? To explore this question, we carried out a comparison of 3D wing, hindlimb, and body kinematics in swimming and flight in the big brown bat, Eptesicus fuscus. We videographed swimming in a water tank, from above and below the water surface, carried out flight trials in a variable-speed wind tunnel, and reconstructed 3D kinematics. Two propulsion phases could be identified in the swimming stroke, and the data suggests that both forelimbs and hindlimbs contribute to the thrust production. However, the three individuals used in this study differed greatly in the timing of the propulsion and in the swimming speed. The comparison between swimming and flight data revealed that wing beat frequency is similar during swimming and slow flying. While swimming, the wrist amplitude in the stroke plane and the stroke plane angle was lower, while the span ratio and the downstroke ratio was higher than in flying, which reflects the greater importance for thrust than lift production in swimming.

VON BUSSE, J.R.S.*; MOSTOWY, M.; BRUCE, H.; SWARTZ, S.M.; Brown University; rheg_vonbusse@brown.edu

How the pilidium larva feeds

59.2 VON DASSOW, G*; EMLET, RB; MASLAKOVA, SA; University of Oregon; dassow@uoregon.edu

92.2 VON WETTBERG, E.J.B.; Florida International University; ericvonwettberg@yahoo.com

An exchange of countercurrents: Models, demos, and raps

92.4 VOLTZOW, J.; Univ. of Scranton; voltzowj2@scranton.edu

Successes and pitfalls in the inversion of a large enrollment majors Evolutionary Biology course

Creating learner-centered classrooms through the inversion of instruction has the potential to create more engaged students and improve student achievement at a time of rising enrollments and cutbacks. I examine the deployment of several strategies, including Peer-Led Team Learning (PLTL) and peer Learning Assistants (LA), research-focused case-studies, and electronic clickers in a large enrollment upper-division majors course in Evolutionary Biology at a minority serving university. Although I find some improvement in student performance on test materials following the adaption of PLTL, LAs, case studies, and iclickers, the gains are limited. Student feedback suggests that improved PLTL leader and LA training, and better web-based materials may further improve student performance.
Focusing on survivors: Understanding how some amphibian populations persist beyond chytridiomycosis outbreaks

Mountain yellow–legged frogs (Rana muscosa) are among the most imperiled of all amphibian species. Over the past few decades, these frogs have disappeared from >93% of their historic range. One of the most pressing threats to Mountain yellow–legged frogs is chytridiomycosis, a disease implicated in the decline of amphibians around the world. Chytridiomycosis is caused by a fungal pathogen, Batrachochytrium dendrobatidis (Bd), which can spread rapidly into naïve amphibian populations and cause high rates of mortality. In the Sierra Nevada mountains, a chytridiomycosis epidemic has been linked to mass mortality events and resulted in catastrophic losses of frog populations. Here we present results from exposure experiments that indicate Rana muscosa survive with Bd–infection and from field resurveys in populations that have survived initial chytridiomycosis outbreaks. The mechanisms by which some populations survive while other die out have not been fully resolved, but we propose that investigating evolutionary shifts in both host and pathogen responses to infection may reveal how some populations persist with a tolerance for the disease. Investigating the mechanisms of population persistence through epidemic outbreaks (i.e., focusing on survivors) is critical to amphibian conservation because many species are being bred in captivity with the idea of one day reintroducing them to the wild. Because Bd is now ubiquitous in many parts of the world, characterizing survival traits will facilitate population recovery and the repatriation of captive amphibians where devastating losses of amphibian biodiversity have occurred.

Corticosterone and fitness: effects of incubation temperature

In the recent years, there has been growing interest in how glucocorticoids mediate fitness. Two non–mutually exclusive hypotheses, the Cort–fitness hypothesis by Bonier et al and the Cort–condition hypothesis by Breuner and Hahn, posit that baseline corticosterone and/or the amplitude of adrenocortical responses should relate to fitness. However, such relationships between corticosterone and fitness–related traits will likely depend on the developmental environment and context. To explore how developmental stress and context alter this relationship, we manipulated egg incubation temperature (36.2, 37.4, 38.4°C) and examined the effect of prenatal stress and mates behavior on the relationships between stress physiology (adrenocortical responses, responses to ACTH and dexamethasone), reproductive performance, and survival in captive zebra finches (Taeniopygia guttata). Suboptimal incubation temperature had no effect on reproductive performance but lowered survival. Stress physiology did not correlate with survival but significantly correlated with several measures of reproductive performance. However, this relationship depended on incubation temperature. Days to first egg was negatively correlated with adult adrenocortical responses but only in 37.4°C. Egg viability was linked to nestling baseline corticosterone but the direction depended on the incubation temperature. Parental behavior was not affected by stress physiology but affected mostly by the mates behavior. The results suggest a complex relationship between corticosterone and fitness altered by developmental stress.

Impact of hydroelectric operations on the physiology of songbirds during Fall migration

Habitat quality in migratory zones used by Neotropical passerine migrants, important during migration, will vary with changes in water level. This is an important management consideration for operation of hydroelectric facilities. We conducted a three–year study monitoring physiological condition of Fall migrants in relation to variation in water levels in four passerine species (Geothlypis trichas, Setophaga petechia, Oreothlypis celata, & Cardellina pusilla) in Revelstoke, British Columbia. Birds were blood–sampled during migration and we measured plasma metabolites (triglyceride, glycerol, & 4–hydroxybutyrate) and corticosterone (CORT) as indicators of fattening rate and environmental stress, respectively. Individuals had low baseline CORT and showed a robust stress response following capture, contradicting the Migration–Modulation Hypothesis, which proposes that baseline CORT levels are elevated response following capture, contradicting the Migration–Modulation Hypothesis. Additionally, there was significant annual variation in timing of the stress–induced increase in CORT, and individual variation in the rate of increase in CORT was correlated with Julian day, being higher later in the migration period. Estimated fattening rate (triglyceride) increased with time of day and date, reflecting diurnal and seasonal variation in fattening, and among species. However, fattening rate did not vary among years despite marked annual variation in water levels. Plasma glycerol and 4–hydroxybutyrate also varied among years, but this was not consistently associated with high or low water levels.
The signature of natural selection shaping genome sequences can be detected through the statistical analysis of the pattern and distribution of mutations in DNA. At times, they can have a positive effect and allow organisms to survive by adapting to their environment; however, more often mutations have a negative or deleterious effect. Because of the negative effects of mutations on cell machinery, and ultimately the fitness of the organisms, the mechanisms eukaryotic organisms use for efficient and reliable DNA replication have evolved for stability. In this study, we survey the presence and evolution of long mononucleotide repeats in coding DNA. Previous research has indicated that natural selection will act against runs of monomeric nucleotide repeats because of their increased likelihood of slippage and the introduction of frameshift mutations into gene sequences. In order to examine the structure of genes, we maintained the integrity of the amino acid sequence and created sequences with the expected number of mononucleotide repeats that we then compared to the number of mononucleotide repeats actually observed. We also examined the hypothesis that long runs of monomers lead to frameshift mutations. By comparing the genomes of closely related species, we were able to determine whether the genes that have a long mononucleotide repeat in one species led to a frameshift mutation in the same gene of a closely related species. We found that almost all eukaryotic species have a strong resistance to long mononucleotide repeats; this remains true across the entire tree of life with the exception of two lineages. We present data with the following goals: 1) to expound on the role of monomers contributing to frameshift mutations and 2) to discuss how natural selection acts to maintain genome stability in most eukaryotic lineages.

Environmental induced stress is thought to be a key driver of emerging disease in wildlife populations, however, the mechanistic links between stress, vertebrate immune function and epidemic outbreaks are not well tested. The physiological stress response regulated by the hypothalamus–pituitary–interrenal (HPI) axis and the expression of glucocorticoid hormones is likely central to disease dynamics. While chronic stress and activation of the HPI axis is often immunosuppressive, acute stress can have a positive effect on immune function by stimulating the inflammatory response and lymphocyte production. In this experiment, we tested the effects of experimentally induced physiological stress on the immune response and susceptibility of wood frog larvae (Lithobates [Rana] sylvaticus) to Ranavirus. Ranavirus (family Iridoviridae) are directly transmitted, often lethal viruses of ectothermic vertebrates that cause mass die-offs and may contribute to the risk of extinction in amphibians throughout the United States and the globe. Through experimental acute or chronic exposure to exogenous corticosterone and immunohistochemistry staining for splenocyte proliferation we explore the effects of stress on amphibian immune responses, susceptibility and survival to ranavirus infection.

Sex and dormancy are directly connected in organisms that engage in sexual and sexual reproduction. The transition between asexual and sexual reproduction typically results in a dormant stage that provides a mechanism to persist under harsh environmental conditions. For example, many species of Daphnia engage in sexual reproduction when environmental conditions deteriorate and produce resting eggs (ephippia) that remain viable for decades. It has long been assumed that observed variation in the timing and magnitude of sexual investment among populations or species reflects local environmental conditions. Yet, the importance of sex to the persistence of a given population of Daphnia can differ dramatically among habitats (i.e., permanent vs. seasonal ponds). As a result, environmental conditions have the potential to exert selection on sexual investment in Daphnia. In this presentation, I will highlight a growing body of research illustrating an important link between environmental conditions and divergent reproductive strategies in zooplankton. I will specifically: (1) discuss the environmental cues that initiate a transition between asexual and sexual reproduction in Daphnia, and (2) review recent work demonstrating an evolutionary consequence of ecological selective pressures, such as predation and competition, on plasticity in sexual investment in Daphnia.

Regional pressure changes in the digital cushion under vertical load in elephants and horses. It is difficult to determine how externally applied locomotor loads affect internal foot mechanics; however, the digital cushion (DC) in terrestrial animals is commonly associated with distributing and thus reducing pressures as a result of locomotion. Considering that the DC of horses is relatively small and rigidly confined compared to the DC of elephants, we used these two extreme, specialized morphologies to compare regional changes in (DC) pressure under load, focusing on forefeet. We hypothesized that under similar loads, pressures would vary with location and be greater in horse feet. We used standard invasive blood pressure monitoring equipment to measure cadaveric DC pressure in four locations under vertical loads representing 0%, 30%, 60% and 100% body weight (BW) in 6 adult specimens of mix-breed horses and 6 Asian elephants. We found that internal pressures increased under load and varied with location (p < 0.05). Surprisingly, under similar standing loads (mean ± SD: 27.8 ± 8.4 % BW and 29.6 ± 5.9 % BW), pressures were higher in the elephant DC (median ± IQR: 4.3 ± 4.8 mmHg) than in the horse DC (3.8 ± 1.5 mmHg), although these differences were not statistically significant. Regardless, the heterogeneous internal pressures we observed support the inference that the DC acts more like a compressible solid than an incompressible fluid under vertical loading conditions. Considering that high pressures may be related to the development of pathology, determining how internal structures such as the DC respond to locomotor loading is essential to understanding foot health and pathology.
The nonlinear relationship between animal metabolic rates and their body size is a many-splendored thing and the mechanistic basis for this relationship, if one exists, is highly controversial. One of the challenges in empirically testing the predictions of hypotheses regarding an organism's size is that the necessary manipulations are likely destructive. Colonial organisms, including marine ascidians, encrusting bryozoans, and terrestrial social insects, are composed of functionally integrated modular subunits, making them ideal systems to study across a range of artificial sizes. We investigated the relationship between metabolic rate and colony size for a set of laboratory reared *Pogonomyrmex californicus* seed harvester ant colonies. Repeated measures of metabolic rates and patterns of behavior were conducted with minimal disruption to the social milieu of the nests by maintaining entire colonies within enclosures designed for flow-through respirometry and video analysis. Same-aged colonies ranging in mass from 0.32–1.7 grams were measured before and after a manipulation of their size to include only half of their workers, larvae, and pupae. Both sets of measurements, before and after manipulation, revealed metabolic hypometabolism and moreover, there was a significant increase in the mass specific metabolic rate of the manipulated colonies. Investigating the scaling of locomotory activity and interaction network structure among the workers within these colonies may help to identify the mechanistic basis for the size-dependence of their metabolic rates.
Osteohistological differences between marsupials and placentals reflect both growth rates and life history strategies

Bone microstructure is influenced by many factors, including body size, growth rate, and phylogeny. The literature acknowledges no great differences between marsupial and placental bone histology, leading some to infer a common histological signature for therian mammals. Histological similarity is reasonable for small marsupials and placentals (< ~40g ), which have similar growth rates and durations, but larger marsupials grow at lower rates and delay epiphyseal fusion for several years compared to placentals of similar body size and ecology. Given these growth differences, larger marsupials should show histological evidence of extended slow growth, contrasting the fast−growing bone tissues described for placentals. However, the mammalian osteohistological sample is biased toward placentals of economic importance, and only two marsupials have been usefully described. I sampled the mid−diaphyseal femora of 42 extant and extinct marsupial species, as well as afrotherian, xenarthran, and laurasiatherian placentals. My marsupial sample encompasses all extant orders, spans a 10g−2500kg size range, and comprises mainly wild−caught animals. Small therians do show a common histology of nearly avascular lamellar bone. Marsupials >50g typically produce well−vascularized woven bone early in life, but after 1−2 years deposit poorly vascularized lamellar bone for several years. This pattern also occurs in afrotheres (except elephants), xenarthrans, Solenodon, and bats; but differs from those of the large−bodied ungulates (exclusively well−vascularized woven bone) and primates (heavily remodeled bone) that dominate the literature. I propose that the first condition is plesiomorphic for therians, and that sampling biases have obscured both size and phylogenetic signals in the distribution of mammalian bone growth patterns.

Integrative biological footprint of the Deepwater Horizon oil spill in the laboratory and field

Large populations of killifish inhabit Gulf−exposed marsh habitats that are at high risk of contamination from oil spilled from the Deepwater Horizon disaster, and are strategic models for assessing contaminating oil impacts. We conducted a field study spanning the year following the spill, integrated with controlled laboratory exposures, to characterize oil spill impacts by integrating genomic, analytical chemistry, showing a clear genomic footprint of oil exposure. Divergence in genome expression that coincided with damage to tissue morphology. Genome expression was most distinct at the peak of oil contamination documented by satellite imagery and across space and time. Genome expression in livers and gills of resident fish was tracked and physiological indicators of biological effects. In field studies genome expression in livers and gills of resident fish was tracked across space and time. Genome expression was most distinct at the only field site out of six that was clearly impacted by oil, and at the peak of oil contamination documented by satellite imagery and analytical chemistry, showing a clear genomic footprint of oil exposure. Divergence in genome expression that coincided with contaminating oil is consistent with genome responses that are predictive of exposure to hydrocarbon−like chemicals and suggestive of physiological and reproductive impairment, and coincide with significant impacts on tissue morphology. Genome expression responses following exposures to oil in the laboratory were predictive of the responses observed in the field, and coincided with damage to the DNA molecule. These data confirm that marsh fish were exposed to the toxic components of contaminating oil in the field, highlight mechanisms underlying exposure responses, and contribute to forming hypotheses about how other natural estuarine stressors may interact with oil to affect organismal resilience in nature.

Using energetics of sea urchin development to examine the temperature−size rule

Temperature is one of the most important environmental parameters that organisms experience. Physiological processes such as metabolism are strongly affected by temperature, and temperature−driven changes in metabolic processes can affect how an organism expends and stores energy. Most ectotherms grow to larger sizes when reared at lower temperatures, an effect known as the temperature−size rule (TSR); the TSR may be driven by differential effects of temperature on energy utilization and acquisition. To investigate this hypothesis, we reared larvae of the sea urchin Lytechinus variegatus through metamorphosis at 23, 27, and 30°C and measured size (body length), energy consumption (algal cells consumed), energy expenditure (respiration, ammonia excretion), and energy accumulation (changes in biochemical content) at multiple developmental stages. We found that larvae and juveniles reared at 23°C were larger and had more protein, lipid, and carbohydrate than larvae reared at higher temperatures. Animals reared at 23°C also had greater food intake and decreased energy expenditure. Together these data suggest that the TSR may be driven by increased food intake and decreased energy expenditure at lower temperatures. Also, juveniles which metamorphosed from larvae reared at 23°C had lower mortality rates; this suggests that increases in sea temperature may negatively affect marine invertebrates by lowering the quality of both larvae and juveniles, which in turn could affect recruitment into adult populations.
Handedness and predation success in the stone crab *Menippe mercenaria–adina*

The stone crab *Menippe mercenaria* possesses dimorphic claws, typically with a large, molar–tooth bearing, right crusher claw for breaking shelled prey and a smaller, left pincer or cutter claw for holding and stabilizing prey. While the majority of *M. mercenaria* hatch this way, molting errors, limb autotomization, and removal of crushing claws by fisheries can lead to reversed handedness after a number of subsequent molts. A major food source for *M. mercenaria* is the gastropod *Strombus alatus*, which has a right–handed or clockwise coiling direction. To investigate whether and how fisheries–induced handedness changes in stone crabs might influence feeding interactions with right–handed coiling gastropod prey, we assessed experimentally whether right versus left–handed *M. mercenaria–adina* hybrids differed in prey handling behaviors and predation success on *S. alatus*. Preliminary results indicate that left–handed crabs had similar feeding success than right–handed crabs as estimated by numbers of prey kills, but their attacks resulted in less damage to *S. alatus* shells and less access to prey tissues. Energy gain per successful attack may, therefore, be less in left–handed stone crabs relative to their right–handed counterparts. The prevalence of certain types of damage differed as well; right–handed crabs tended to damage the shell ornamentation and siphonal canal more often, while left–handed crabs clipped the spire more often.

Strain in the Hyomandibular Cartilage of Elasmobranchs

The main jaw suspensory element, the hyomandibula, determines jaw mobility in elasmobranchs and ranges from slender and posteriorly directed in wide gaped bite feeders, to block–like and laterally directed in smaller mouthed suction feeders, to slender and anteriorly directed in skates and rays, which have ventrally orientated mouths. This diversity in jaw suspension morphology and feeding style will impose different levels and type of mechanical strain in the hyomandibula when feeding. Here we measure biological load in vivo with the goal of understanding the performance of cartilaginous elements with clear morphological and kinematic differences. Sonomicrometry uses ultrasound to measure distance and is used to quantify applied biological load and function. Strain in spiny dogfish and little skates was quantified using sonometric transducers firmly glued to the ventral surface of the hyomandibular cartilage. Another transducer was sutured to cranium adjacent to the hyomandibula to record hyoid movements. Results show that strain is tensile in the hyomandibula when feeding. Here we measure biological load in the hyomandibula of dogfish and increases with mouth opening during suction feeding and ventilation. Strain is lowest in normal ventilation, intermediate in heavy ventilation, and highest in suction capture. Strain during processing can be as high as that during capture. In contrast, strain is compressive in the hyomandibula of skates during biting and ventilation, with greater strain when biting. It appears that major morphological shifts in the evolution of the jaw suspension and associated changes in kinematic patterns of the feeding apparatus also show related transformations in mechanical performance and feeding style. This also supports the theory that the jaw and hyoid arches evolved from branchial arches to increase ventilation performance and then became preadapted for feeding. This technique for measuring strain can be used on many biological structures for the broadest possible comparative content.

Bird feeding is a popular hobby for many Americans, with more than 55 million individuals participating in feeding annually. Though bird feeding remains a largely unregulated practice, the true value of commercial bird seed to the health of free–living birds remains unknown, although some studies have indirectly examined the influence of feeding on avian populations. Over an 18–month period, we completed a comprehensive study examining community dynamics, body condition, nutritional condition and measures of immune, reproductive, and stress physiology in twelve songbird species before, during, and after addition of bird feeders at feeder naïve sites. Comparisons were made to similar sites without feeders that were monitored simultaneously to address potential seasonal changes independent of the presence of supplemental food. Our results demonstrate that bird feeding greatly influences community dynamics and the general health state of birds, however, not all influences are positive.
Mid–winter temperatures, not Spring temperatures, predict breeding phenology and fecundity in the European starling

The current working model for control of timing of breeding suggests that day length provides reliable initial predictive information for general seasonal breeding but that supplemental factors, especially ambient temperature (Ta), fine–tune the actual timing of egg–laying. Furthermore, theory suggests that the greater the time–lag between an organism’s perception of a cue and the fitness consequences of their response, the less informative cues are likely to be. To date, most studies of timing of breeding in temperate avian species are highly correlated with onset of egg–laying is relatively close (< 1 month) to the population mean egg–laying date. Here I use an 11–year dataset on European starlings (Sturnus vulgaris) to show that mid–winter Ta, not Spring Ta, strongly predicts both breeding phenology and fecundity. Mean laying date was 10 April (range 5–13 April), and 80% of all nests were initiated over 2–8 days within–years. Despite this high degree of synchrony clutch size decreased significantly with date in most years. Sliding window analysis showed that a time period of 22 days from the 9 – 31 January provided the highest correlation between Ta and laying date (r = .87). Analysis of average monthly Ta data and mean laying date confirmed that laying date was independent of temperatures in February, March or April. However, January Ta was highly negatively correlated both with laying date and clutch size, i.e. when mean January Ta was colder starlings laid later, and laid larger clutches. Despite high synchrony of breeding starlings are exquisitely attuned to date, and they appear to use supplemental environmental cues, but in a very different way than predicted by our current models.

Navigating through confined spaces is one of the more impressive tasks flying animals can accomplish. We presented pigeons (C. livia) trained to navigate through a field of vertical obstacles with an evenly spaced array of vertical bars. The spacing between these bars was altered in successive trials; pigeons successfully navigated through gaps between 2 and 6 body widths (13 and 31 cm). At wider spacings body roll was used to pass between the obstacles. However, at spacings below 26 cm, one of two strategies was employed; the wings were either: 1) held at the top of the upstroke for the time required to pass through the gap, or 2) folded back at the wrist just before passing through the gap. This first strategy was employed in 71% of the trials (n=52 runs) and may provide greater control authority upon reaching the unobstructed space, as a new wingstroke may be immediately initiated. The second strategy was employed in the other 29% of trials, and may be a backup for when the timing of the wingstroke cycle relative to the approaching obstacles did not permit pausing at the top of the upstroke. (ONR N0014–10–1–0951)

Juvenile male blue crabs move into the freshwater James River during warmer months to feed and grow by undergoing molting. In crustaceans, growth and molting are hormonally controlled and the juvenile molting crab is a life stage sensitive to chemicals found in the James River benthos. This set of experiments looks at the effects of multiple stressors, including moderate hypoxia and sediment contaminants. The physiological effects of a multiple stressor environment are determined by comparing the blue crabs basal oxygen uptake to the oxygen uptake after exposure to pure sand, James River sediment, or Endosulfan–spiked sediments. The effect of these multiple stressors on molting is measured by activity of an enzyme in the epidermal tissue important to molting: N–acetyl–&beta–glucosaminidase.

The current working model for control of timing of breeding suggests that day length provides reliable initial predictive information for general seasonal breeding but that supplemental factors, especially ambient temperature (Ta), fine–tune the actual timing of egg–laying. Furthermore, theory suggests that the greater the time–lag between an organism’s perception of a cue and the fitness consequences of their response, the less informative cues are likely to be. To date, most studies of timing of breeding in temperate avian species are fully consistent with this model: the time period where Ta is most highly correlated with onset of egg–laying is relatively close (< 1 month) to the population mean egg–laying date. Here I use an 11–year dataset on European starlings (Sturnus vulgaris) to show that mid–winter Ta, not Spring Ta, strongly predicts both breeding phenology and fecundity. Mean laying date was 10 April (range 5–13 April), and 80% of all nests were initiated over 2–8 days within–years. Despite this high degree of synchrony clutch size decreased significantly with date in most years. Sliding window analysis showed that a time period of 22 days from the 9 – 31 January provided the highest correlation between Ta and laying date (r = .87). Analysis of average monthly Ta data and mean laying date confirmed that laying date was independent of temperatures in February, March or April. However, January Ta was highly negatively correlated both with laying date and clutch size, i.e. when mean January Ta was colder starlings laid later, and laid larger clutches. Despite high synchrony of breeding starlings are exquisitely attuned to date, and they appear to use supplemental environmental cues, but in a very different way than predicted by our current models.

The Effects of River Sediment Contaminants and Moderate Hypoxia on the Blue Crab (Callinectes sapidus) in the Tidal Freshwater James River

Juvenile male blue crabs move into the freshwater James River during warmer months to feed and grow by undergoing molting. In crustaceans, growth and molting are hormonally controlled and the juvenile molting crab is a life stage sensitive to chemicals found in the James River benthos. This set of experiments looks at the effects of multiple stressors, including moderate hypoxia and sediment contaminants. The physiological effects of a multiple stressor environment are determined by comparing the blue crabs basal oxygen uptake to the oxygen uptake after exposure to pure sand, James River sediment, or Endosulfan–spiked sediments. The effect of these multiple stressors on molting is measured by activity of an enzyme in the epidermal tissue important to molting: N–acetyl–&beta–glucosaminidase.
Environmental variation is known to induce trade-offs, which requires shifts in energy allocation among behaviors involved in reproduction, parental care and self-maintenance, thereby affecting reproductive success and survival. We examined behavioral plasticity in hooded warblers (Setophaga citrina) in response to alteration of habitat structure due to commercial logging and linked plasticity in behavior to reproductive success. A seven state Markov model was used to describe how birds move through the habitat, how they attack prey, prey handling behaviors, and reproductive behaviors. We found significant differences in the transition probabilities among males in the undisturbed stand compared to the disturbed stand including how they searched for and attacked prey. Males in the disturbed stand had higher transition probabilities from short flight to aerial attack while males in the undisturbed stand were more likely to transition from hop to surface attack. Males in the disturbed stand were more likely to transition from non feeding behaviors to short flight consistent with observations of opportunistic foraging while singing. This suite of behaviors suggests that aerial attacks may ameliorate time budget trade-offs. Significantly fewer young were fledged per nest in the disturbed stand compared to the undisturbed stand. In 2010, individuals that were more plastic also fledged more young. In 2011 this trend was reversed; however, the pattern may be driven by the high levels of brown headed cowbird nest parasitism in the disturbed stand which reduced brood size. This study demonstrates that behavioral plasticity varies between years and in relation to habitat disturbance. In addition, plasticity is associated with reproductive success thus providing support for the hypothesis that plasticity is adaptive.
Optimal Performance Theory: developing a framework for understanding whole–animal performance in the wild

Should an animal run as fast as it can when trying to escape a predator? What about when running to catch food or whilst displaying to a female? The simple answer should be no, of course not. After all, we would never run at full pace down a steep set of stairs or across an icy sidewalk, no matter how many predators were chasing us. It is surprising then that much of our focus on animal performance is concerned with quantifying an individuals maximal capabilities. In fact, when biologists have quantified whole–animal performance levels used in the wild, most species seem to rarely perform at speeds that approach maximal capacities, even when executing fitness–relevant tasks. This should not be surprising – whether its running on a slippery surface or on a thin branch, the actual performance used by an animal should be optimized to the prevailing environmental conditions. In this talk, we will explore the idea of optimal performance theory and attempt to develop a theoretical approach for studying whole–animal performance in nature. We believe that the concept of optimal performance will help shift the focus away from studies of only maximal capacity towards a more comprehensive understanding of the evolution of physical performance tasks. To do this, we will present a simple model of optimal performance and provide a discussion of the type of empirical studies that may help move this framework forward.

Utilizing algal communities as bioindicators for PPCP contamination

There is growing concern over the increased presence of personal and pharmaceutical care products (PPCPs) in the environment. Freshwater algal productivity and diversity are often used as biomarkers for freshwater systems under stress. A series of assays were performed to determine the individual impacts of Triclosan, Estradiol, Loratadine, and Ciprofloxacin on a natural algal community. Toxicological effects were measured as total productivity (chlorophyll a), total protein production (genera production), and relative genera abundance (biovolume). Total productivity was significantly reduced in the presence of and Estradiol or Ciprofloxacin (p < 0.05). The relative genera abundance was significantly reduced (p < 0.05) in communities exposed to Triclosan and Ciprofloxacin, including the loss of at least one genus. In both cases, the dominant genera present shifted from a high protein producing organism to one of lower protein content. Individual genera produce varying amounts of available protein ranging from 20–60% dry mass. For both Triclosan and Ciprofloxacin there was also a significant loss (p < 0.05) in total protein available due to the change in dominant genera. There was no significant loss in either relative genera abundance or protein content in the algal community exposed to Loratadine or Estradiol (p > 0.05). Productivity may not be a sufficient indicator for potentially compromised ecosystems; other measures of diversity and protein content may be required. Changes within the overall algal community not only represent a loss in potential food sources for preferentially grazing herbivores in freshwater systems, but may also result in herbivorous grazing on less valuable protein sources due to PPCP exposure.

Metabolic and osmoregulatory challenges of emersion in fishes

The climbing perch (Anabas testudineus), comboy blenny Lipophrys pholis, and weatherloach Misgurnus anguillicaudatus are three examples of teleost fishes that have adapted to terrestrial conditions. The gill in fishes, which is generally the main organ for aquatic respiration, is also the site of ion−regulation and excretion of metabolic (nitrogenous) waste primarily as ammonia. However, the typical teleost fish gill is designed to function in water and collapses in air and with the loss of ventilatory water flow to maintain favorable diffusion gradients combine to challenge metabolic waste elimination and osmoregulation. The climbing perch is a euryhaline, freshwater fish that is capable of surviving days out of water. It has a specialized labyrinth organ in the suprabranchial chamber that facilitates aerial gas exchange. The climbing perch is capable of maintaining aquatic rates of ammonia excretion while emersed in contrast to most other fishes, although we have made a similar observation in the intertidal blenny. As an indicator of iono regulatory status, plasma Na⁺ and Cl⁻ levels fell 10 and 5%, respectively, after 5d emersion. The expression levels of two key branchial ion pumps, Na⁺−/K⁺−/ATPase (NKA) and H⁺−/ATPase, were found not to be modulated under these conditions. This can be contrasted with the intertidal L. pholis in which branchial NKA activity increased during emersion. The facultative intestinal air−breathing weather loach has adapted to long periods of emersion during the dry season by vatilolizing ammonia through its intestine using facilitated NH₄⁺ excretion while in the gill NH₄⁺ excretion by a different Rhc−H⁺−ATPase coupled mechanism is up regulated. This work was partially supported by Instituto Science Fund (ISF) grant 65/39. A

Plants have developed a multitude of ways to defend themselves from insect herbivores. One recently discovered strategy is the release of airborne chemicals that signal the type of herbivore attacking the plant. In some systems, this information is used by predators and parasitoids to find their prey or host that is, the plant defends itself by calling in a third trophic–level. However, we still know little about these communication systems, and the ecological ramifications they have. Any type of communication system can be corrupted by noise. Here, we propose that variation in environmental factors can act as a source of noise in plant volatile communication systems. We focus on abiotic noise affecting the plant–transmitter, Datura wrightii after herbivory by larvae of the hawkmoth Manduca sexta based on field measurements from a population in southeastern Arizona. Among potential sources of noise in the natural world, temperature is likely to be particularly powerful, because it modifies the underlying biochemistry of signal reception and transmission, and is one of the few abiotic factors that can affect plants and insects simultaneously. However, air humidity and soil moisture vary widely (both spatially and temporally) in many habitats, including the desert southwest, and may also be important in modifying communication between plants and insect defenders. If environmental noise causes significant signal degradation, the effects of varying abiotic conditions on both transmitters (plants) and receivers (insect predators and parasitoids) may drive broad patterns of evolution and ecology in both parties.
89.2 WILSON, AM*; ROSKILLY, K; LOWE, J; HUDSON, P; 
GOLABEK, K; MCNUTT, J; RVC, London, BPCT, Botswana; 
awilson@rvc.ac.uk
Dynamics of high speed locomotion and hunting in free ranging 
cheetah
Studies of maximum performance are limited by subject motivation 
and attempts by ourselves and others to measure domestic cheetah 
performance show limited straight line and manoeuvring 
performance. We set out to describe the speed, acceleration and 
manoeuvring of wild cheetahs when hunting. We developed a collar 
powered by a combination of rechargeable, non rechargeable 
batteries and solar panels. Sensors comprise a 3Hz L1 pseudorange 
Doppler data GPS receiver, 3−axis MEMS accelerometer, 3 axis 
MEMS gyroscope, and a 3 axis magnetometer. Data were off loaded 
via a wireless link to an aircraft or vehicle. The sensors provide, at 
300 Hz, acceleration (force) and with integration velocity and 
polarity is inverted relative to other metazoa. position, angular velocity and with integration heading and 
orientation of the collar and (approximately) the cheetah. GPS and 
IMU data are fused using our own Kalman filtering optimised for 
sensor characteristics and animal dynamics to provide the data we 
require. The collar adapts its operation (and hence power 
consumption) across six states depending on the time of day, the 
animals activity level and battery voltage. This allows collection of 
finely grained information and movement data and therefore unbiased 
records of hunting behaviour data. Collars were attached to five 
cheetahs in the Okavango Delta area of Botswana. To date we have 
collected data for 169 runs from these five cheetahs and data 
collection is ongoing. Successful hunts involve rapid acceleration and 
deceleration indicating high muscle powers, relatively high speed 
galloping and a period of manoeuvring with high lateral 
accelerations. We have also deployed similar collars on other 
predators in the study area.

71.5 WINDSOR, P.J.*; LEYS, S.P.; Univ. Alberta; 
pwindor@ualberta.ca
Tracing cell identity through metamorphosis in a freshwater 
sponge larva
Sponges, like other animals, show anterior–posterior polarity 
especially in their larval stages. However whether larval polarity is 
carried over to the adult is not yet known. Nor is the fate of any of the 
cells from the larva. We used dil injection coupled with cell labelling 
using CMFDA and bisection experiments to determine the fates of 
different regions of the larva of the freshwater sponge, Eunapius 
fragilis. This larva has a distinct anterior end with a large larval 
cavity, and a posterior end that contains amoeboid cells, feeding 
chambers and spicules; the entire outer surface consists of columnar 
ciliated cells. We cultured anterior and posterior halves separately to 
determine the fates of each half. The anterior half of the larva settles 
and flattens into a thin sheet, but lacks adult structures such as canals 
and an osculum. Without the anterior half, the posterior half is not 
competent to settle. We tattooed the anterior and posterior poles with 
dil to define specific cells that arise from these regions. The anterior 
pole largely gives rise to basipinacocytes that adhere to the substrate 
during settling, while sclerocytes derive from the posterior pole. 
Interestingly, the osculum, the terminus of the aquiferous system axis 
in the adult, is also derived from posterior cells. We dyed the outer 
layer of columnar ciliated cells in swimming larvae with CMFDA. At 
metamorphosis these cells appear to be resorbed. Choanocyte 
chambers of the juvenile sponge arise from multinucleated cells very 
soon after settlement. Importantly, we show larval polarity is 
reversed in the adult the posterior pole gives rise distinctly to cells 
that form the osculum confirming a long held concept that sponge 
polarity is inverted relative to other metazoa.

101.2 WINDSOR, S.P.*; TAYLOR, G.K.; Univ. of Oxford; 
shane.windsor@zoo.ox.ac.uk
The role of head stabilization in the flight control system of 
hawkmoths
During flight many insects actively stabilize their head relative to 
their surroundings. Gaze stabilization acts to significantly simplify 
the processing and extraction of relevant visual information but in 
addition to this the act of stabilizing the head may also play a 
significant role in the flight control system of flying insects. Using a 
virtual reality flight simulator we measured the head motions of the 
hawkmoth Hyles lineata in response to complete wide−field visual 
motion. The moths responded strongly to visual motion, moving their 
heads to greatly reduce the dynamic range of the visual stimuli seen 
by the eyes. In addition to stabilizing the visual field the orientation 
of the head relative to the body potentially gives the insect 
information about the angular orientation of its body relative to the 
world around it. Using mathematical models the advantages and 
limitations of head stabilization and its role in the flight control 
system of a flying insect were investigated. These models indicate 
that head stabilization may play an important role in insect flight 
control.

S6–1.1 WINGFIELD, JC; University of California, Davis; 
jcwingfield@gmail.com
Allostasis, resilience and coping with a changing world
A potentially serious outcome of global climate change is the 
increase in frequency and intensity of extreme weather events. 
Additionally, environmental perturbations such as human 
disturbance, invasive species, social disruption and pollution indicate 
that bird populations world wide face major challenges in coping 
with stress. Responses to one or more environmental perturbations 
incure energetic costs in addition to those of the normal life cycle such 
as breeding, migrating etc. The concept of allostasis provides a 
framework to integrate energetic demand and wear and tear of daily 
and seasonal routines (the predictable life cycle) with perturbations 
of the environment including disease, aging and social status. The 
concept is particularly attractive because it allows a framework to 
assess the challenges faced in changing social and physical 
environments at the individual level because no single organism 
experiences the environment in exactly the same way as another. The 
reactive scope of the mediators of coping mechanisms, such as the 
adrenocortical response to acute stress, also vary on seasonal, daily, 
habitat and individual bases. Understanding these regulatory 
mechanisms will be critical to ameliorating the effects of global 
change in general.
89.3 WOFFORD, SJ*; MOORE, PA; Bowling Green State University; swwofford1@gmail.com

Sex and fighting: Male and female crayfish use different assessment strategies during agonistic behavior

Agonistic behavior is an important social aspect of animal behavior, and the outcome of agonistic interactions is critical to the acquisition of resources such as food, shelter, and mating opportunities. During agonistic interactions, individual participants make behavioral decisions based on energy and time investment such as escalating the intensity of the interaction and whether to end the interaction by retreating. Each of these decisions can be informed through self-assessment (i.e. energy reserves, fight capability, size) or through some form of mutual assessment (i.e. comparative energy reserve, size differential). Crayfish are ideal model organisms for the study of such behavior due to ritualized fighting and a well-established ethogram. In this study, we are examining the assessment strategies that crayfish employ during same and mixed sex fights. After a brief acclimation, two individuals (male–male, female–female, or male–female) were allowed to interact for 15 minutes. Video analysis was used to calculate fight duration and times spent at various intensity levels. Analysis indicates that males and females appear to be using two different assessment strategies. In male–male fights, agonistic decisions are based on a self-assessment strategy whereas in female–female fights, decisions are based on a mutual assessment strategy. In mixed sex bouts, a mixed strategy appears to underlie a crayfish decision.

82.6 WOERHEIDE, G; Ludwig–Maximilians–Universitaet Muenchen; woerheide@lmu.de

A networked Citizen Science monitoring system for estuarine environment and biota.

The Coastal and Estuarine Monitoring System (CEMS) addresses the spatial and temporal heterogeneity in estuaries, where events can be fully described only by dense monitoring arrays. Changes in many estuarine variables are large, and useful information can be obtained from instruments with modest accuracy. These cost far less than precision units and can be affordably deployed in large numbers. Our prototype system sits offshore in Chesapeake Bay but data uploading and control are via the Web. It logs solar panel and battery status; water depth; temperature, salinity, water clarity in four color bands at two depths; and biological observations correlated with the physical data (gape of 16 oysters). The datalogging module will be expanded to log currents, surge and waves, and can accommodate other sensors that provide serial data or voltage output. The same electronics could go into a mobile housing and be towed along transects by a small boat, when they would log the vessels GPS positions and compass headings as well. Logged data are stored in non-volatile memory. In fixed arrays, the datalogging module is polled by a single-board computer on a piling or buoy, which periodically uploads data via Wi-Fi to an on-shore access point and server. The data appear on the project website in nearly real time. We also are developing apps to allow the data and graphs to be downloaded by nearby visitors with smart phones. The sensors are simple and their housings, mainly of PVC and pipe fittings, are designed for easy assembly and maintenance. Citizen groups (e.g., high school classes) would be capable of taking ownership of an array, and seeing their data online as contributions to a national database.
A common view among physiologists is that homeostasis evolves to protect organisms from the damaging extremes of variation in physiological factors. Here we propose that homeostasis also evolves to minimize noise in physiological channels. Fluctuations in physiological factors constitute inescapable or global noise that corrupts the transfer of information through physiological systems. We apply information theory to homeostasis to develop three related ideas. First, because fluctuations of physiological factors are systemic and affect such basic cellular components, many common modes of noise cancellation (filtering, private channels) won’t work. Homeostasis and signal redundancy are the only options. Second, homeostatic regulation creates quiet physiological backgrounds for the transmission of all kinds of physiological information. Third, because homeostatic systems act as coupled pairs and in individual or large communities, should show strongly synergistic or emergent effects. This new view emphasizes that selection may work on subtle dysfunctions arising from disturbance to communication networks at all levels of sub-organismal organization, and it frames death as a kind of runaway physiological noise.

Sponge mortality associated with a dense phytoplankton bloom on the southern portions of the Belize Barrier Reef in late summer 2011 was extreme, with 70% of the sponge biomass abruptly lost. Context for this mortality event was provided by detailed records of community dynamics for the previous five years. Beginning in 2006, all sponges on a set of shallow patch reefs were mapped, identified, and measured for volume at yearly intervals, allowing sponge community dynamics to be quantified with respect to biomass, number of individuals, and species. These data revealed an earlier mortality event in the southern portions of the Belize Barrier Reef in late summer 2011. Here we report organic osmolytes in amphipods (Gammarus oceanicus) from the Mariana Trench. One hypothesis to explain how life adapts to the deep sea involves piezolytes, small organic solutes (first discovered as osmolytes) that counteract pressure effects on protein activity and stability in vitro, better than other osmolytes. 2) Muscle TMAO contents increase with depth in marine bony fishes (analyzed to 7 km depth). 3) In marine shallow species are dominated by the non–piezolyte glycine, but TMAO increases and glycine decreases with depth in species down to 3 km. 4) Muscle TMAO contents increase with depth (to 1.4 km) in freshwater Lake Baikal amphipods, which do not need osmolytes. Here we report organic osmolytes in amphipods (Hirondellea sp.) from 10.9 km in the Mariana Trench. They were caught with a lander with bait (tuna, chicken) inside a 30 L Niskin sampler that rested on the seafloor. On the ship, animals were deep–frozen and later shipped on dry ice to Whitman College, where metasomal muscles (n=5) were analyzed for osmolyte–type solutes. We found no glycine but instead a predominance of the methylamines TMAO, glycerophosphocholine and dimethylglycine, plus the polyol scylo–inositol (SI). Although only TMAO has been tested with pressure, all are potential osmolytes as each is a protein stabilizer (e.g., SI stabilizes the non–toxic form of beta amyloid). These results represent a record depth for such analyses of animals and support the piezolyte hypothesis. Funding by the National Science and Blue Planet Marine Research Foundations.
40.3 Yaniv, S; Elad, D; Holzman, R*; Tel Aviv University; holzman@post.tau.ac.il
Characterization of a computational model of aquatic feeding: Scaling of suction feeding dynamics from larval to adult fish
To capture prey, larval fishes swim towards their target while rapidly opening their mouth to generate a flow of water external to the mouth. This feeding mode, termed suction feeding, is thought to be the universal feeding mode in larval fishes. The suction flow is key to feeding success, because it draws the prey into the predator's mouth, countering possible escape response of the prey. Because of the difficulties inherent in making direct measurements and observations on small animals such as larval fishes, very little is known about these flows, how they translate to prey capture, and whether those flows change during early development. In this study, we used a Computational Fluid Dynamics model (CFD) to elucidate the flow dynamics inside and outside the mouth, from the scale of first feeding larva to adult fish. Our simulations reveal that size has strong effects on the patterns of flow inside and outside the mouth. Peak flow speed and Reynolds numbers increased with increasing mouth size. The radial symmetry that characterises suction flows in adult fishes dissipated as mouth length decreased. In adult fish, flow decays rapidly outside the mouth, and suction flows have a negligible effect on particles movement at a distance of ~2 mouth widths. However, in larval fish flow decayed much slower, and significant flows were observed at a distance of ~5 mouth widths. While invicid models are generally suitable to describe the flow in large mouth sizes, they fail at the size range that characterizes larval fish. The different flow regime in larval fish likely changes larval feeding performance, including their ability to exert forces on the prey, and lead to size-related changes in feeding efficiencies.

85.4 Young, V.KH.;*; Gifford, M.E.; Clemson Univ., Univ. Arkansas, Little Rock; skhill@clemson.edu
Limited thermal acclimation capacity in a salamander, Desmognathus brimleyorum
Temperature is a critical factor impacting the fitness of ectotherms. Previous studies have indicated that many ectotherms have the ability to adapt their physiological capabilities to cope with variation in their thermal environment. Theories of optimal acclimation predict that individuals experiencing thermal conditions that fluctuate widely will exhibit physiological traits that are less sensitive to temperature than those individuals experiencing stable thermal conditions. We tested this prediction by studying acclimation of swimming performance, metabolic rate, and critical thermal maximum in the salamander Desmognathus brimleyorum. Salamanders from each of five populations across the species range in Arkansas, USA were assigned to either a constant or variable temperature treatment in the lab. Following a two-month period of acclimation, each salamander was subjected to swimming speed trials at each of seven temperatures between 2 and 30°C. Each trial was recorded using a high-speed camera and velocity data were collected via video analysis. Metabolic rates for individuals were measured using flow-through respirometry and recorded over four temperatures between 5 and 20°C. Our results indicate that adult D. brimleyorum do not acclimate swimming performance to alternate thermal environments. However, limited capacity for thermal acclimation of metabolism and thermal tolerance was evident in this study. Interestingly, the majority of variance detected in this experiment resulted from differences among populations. We also discuss interpopulation variation in physiological traits and possible sources of this variation.

13.5 Yuge, S*; Honeyfield, D.C.; Saloka, S.K.; Li, W.; Michigan State Univ., E. Lansing; USGS–NARL, Wellsboro; shinya.yuge@gmail.com
Characterization and functional analyses of three thiamin related transporters and a thiamin pyrophosphokinase in rainbow trout, and examination of their expression alteration in thiamin deficiency
Thiamin (Th, vitamin B1) is a micronutrient essential for metabolism. Th deficiency (TD) has caused a lethal disease in salmonids. However, little is known about molecular mechanisms of the salmonid TD. In the rainbow trout, we identified Th metabolism related genes, two th transporters (thtr1, thtr2), a th derivative transporter (thde-trtfr) and th pyrophosphokinase with its seven splice variants (tpk_tv1–7). The transporters are critical for cellular Th uptake. mRNA expression of thtr1 and thtr2, but not Thde-trtfr, expressed in HEK cells exhibited H–Th uptake. mRNA expression of thtr1, thde-tr and tpk_tv1 with two-three tpk_tv were found in all examined tissues, while thtr2 transcripts were observed only in intestine and kidney. During embryonic development, total tpk_tv transcripts increased to a peak before hatch, thtr1 and thde-tr transcripts peaked in yolk-sac fry stage, while thtr2 transcripts gradually increased toward the swim-up stage. Notably, tpk_tv5 mRNA expression was abundant in ovary and in most of the embryonic stages. In trout with TD, the mRNA expression was reduced in the following tissues: thtr2, upper and lower intestine; thde-tr; all tissues examined; total tpk_tv, gill, liver, upper intestine and muscle. In contrast, no such changes occurred in thtr1 in any of those tissues. In summary, in rainbow trout, 1) thtr1, thde-tr and tpk are active genes within all tissues and most of embryonic stages, while thtr2 may be specific for intestinal and renal Th absorption; 2) tpk_tv5 mRNA expression might be important in ovary and in embryogenesis; and 3) in TD, thtr2, thde-tr and tpk appear to be down-regulated.
S11–1.4 YUSA, Yoichi*; SAWADA, Kota; YAMAGUCHI, Sachi; 2 Octolasmis warwickii in a darkened wind tunnel (1 m long, 0.33 m wide) in Aedes aegypti yusa@cc.nara−wu.ac.jp

We flew female mosquitoes and odor emission. They are also equipped with detection, suggesting convective tracking may require the our observations suggest that the distinction between hermaphrodites and dwarf males is sometimes obscure. We suggest that sexual expression of barnacles is more continuous and plastic than previously considered.

17.5 ZAMORO, S*; LAMARCA, E; DANIEL, TL; University of Washington, Roosevelt High School; sharri@uw.edu

Mosquitoes track host prey at large distances using windborne signals such as CO2 and odor emission. They are also equipped with a pair of thermosensory organs on the distal end of each antenna. The calculated radia- tionsensitivity and the biased landing on surfaces of varying radiative emissivity suggest they are not sensitive to radiative (black body) heat, making convective (windborne) heat a likely navigation signal. Experiments suggest that r orking on CO2 detection, suggesting convective tracking may require the presence of CO2. We seek to determine if mosquitoes can track a convective thermal signal, and how this behavior is modulated by a CO2 background. To test mosquitoes ability to navigate using convective heat in the absence of CO2, we flew female mosquitoes (Aedes aegypti) in a darkened wind tunnel (1 m long, 0.33 m wide) in clean air. Two gold–leafed stainless steel heating rods were placed upwind as a convective heat source with low radiative emissivity. Small changes in temperature (+2 C) were detectible in thermographic images. For all trials, one heater was kept at 40 ± 0.1 C. We used 200 fps video to track the flight path and landing selectivity between two heat sources. Our data suggest that, in the absence of CO2, A. aegypti do not exhibit bias toward the heated selectivity. Of the animals flights analyzed, 5 of 9 of the mosquitoes flew predominantly downwind of the heated element, while 2 trials showed no side preference. All exhibited search behaviors, but none landed on the heated rods. Given the low radiation of the heat source and the falloff of radiant heat, it remains unlikely that the mosquitoes detect radiant heat at these distances. Our observations suggest thermal tracking requires CO2 detection.

96.6 ZAKAS, C*; ROCKMAN, M.V.; New York University; christinzakas@gmail.com

Identifying genomic regions responsible for offspring dimorphism in Streblospio benedicti

Major transitions between development modes are a nearly ubiquitous feature in the evolutionary history of most animal phyla, with profound micro- and macroevolutionary consequences. However, the genetic changes that govern such transitions have yet to be characterized, impairing our understanding of how such shifts occur and shape metazoan evolution. Poecilogonous species, such as the marine polychaete Streblospio benedicti, produce two distinct offspring types and are ideal systems to study the evolutionary consequences of offspring dimorphism within a single species. Here, we use transcriptomic data to investigate how intraspecific genetic differences can produce morphologically distinct offspring modes. We compare expression and sequence differences between adults with contrasting developmental modes to establish markers for future genomic studies. Preliminary investigation of the S. benedicti transcriptome has revealed little differentiation between the two developmental modes in neutral SNP markers, suggesting that only a small portion of the genome underlies developmental differences. By using a comparative transcriptomic approach, we expect to identify a small number of key gene regions that are responsible for driving the distinct morphological differences in development mode that occurs in S. benedicti.

54.3 ZAMUDIO, S*; BRAMANTI, L; EDMUNDS, PJ; California State University, Northridge; sylvia.zamudio.69@my.csun.edu

Temperature−induced maternal effects on the phenotype of larvae released by the brooding coral Pocillopora damicornis

Maternal effects on offspring facilitated though environmental factors can provide insight to the response of organisms to global climate change. A maternal effect occurs when environmental factors affecting mothers influence offspring phenotype, independent of their genotype or the environment into which they are released. Such effects are referred to as transgenerational plasticity. In this study we examined maternal effects induced by temperature on the larvae of the scleractinian coral Pocillopora damicornis in Nanwan Bay, Taiwan. Specifically we tested the hypothesis that colonies exposed to high temperature displayed different reproductive traits and released dissimilar larvae compared to colonies at a lower temperature. Eight colonies were incubated for 16 d at ambient (27.13 C) and elevated (29.65 C) temperature and the outcome assessed as colony−level fecundity, timing of larva release, and energy content of larvae. Colony−level fecundity was affected significantly by temperature, with fecundity increasing 52 % at high compared to ambient temperature, and colonies in warmer conditions releasing larvae earlier (1 d) than colonies at ambient temperature. The energy content of larvae also was affected by the temperatures under which the parents were retained, with energy content 34 % lower in larvae released from colonies held at 29.65 C. Our results show for P. damicornis that the thermal environment affecting maternal colonies can influence reproduction and larval phenotypes in ways that could affect offspring success.

January 3−7, 2013, San Francisco, CA
72.1 ZARROUK, D.; PULLIN, A.; FEARING, R.; UC Berkeley; david.zarrouk@gmail.com

**Locomotion Analysis of Dynamic in–Plane Hexapod**

This research focuses on the velocity of in–plane dynamic hexapod robots. The velocity of the robot and the thrust forces are calculated as a function of robot geometry, leg compliance, static and dynamic friction coefficients, stride rate. In our model, the body of the robot is rigid and each of the robot has two compliant degrees of freedom, one along its length and the other, rotational, at the hip. We first formulate the velocity of the robot for the rigid legs case and then compare the influence of the leg compliance on the locomotion using a dynamic multi–body numeric simulation and analyze the influence of the kinetic coefficient of friction on the locomotion speed. During a stride, the robot experiences a varying thrust which results in decelerating at the beginning and the end of each stride while accelerating through the middle. The velocity decreases with surface incline and the advance ratio on inclined surfaces is a function of the step angle only. For experimental validation, a purpose built robot with high, nearly flat, sprawl angle, was developed to examine the in–plane mechanics model and simulation. The experimental robot was run on two different surfaces using rigid and flexible legs while changing the slope. For rigid legs, the running stall angle was ultimately limited by the minimum of the range of the kinetic COF values. For flexible legs, the advance ratio of the locomotion was reduced due to bending, but in certain cases such as running over acrylic, the stall angle was the maximum of the kinetic COF. The static COF was practically irrelevant to the locomotion for both rigid and compliant legs because the locomotion is dominated by slip. The results of the simulation, analysis and experiments were compared and found to be in excellent agreement.

64.1 ZENG, Y*; NUNNS, H; DUDLEY, H; Univ. of California, Berkeley; dreaoniz@berkeley.edu

**Flight with Winglets in Stick Insects**

The stick insects (Insecta: Phasmatodea) exhibit remarkable variation in wing size and flapping kinematics across a wide spectrum of aerial performance, from flapping flight to complete flightlessness. How species with intermediate–sized wings fly is thus key for understanding the transition between flapping flight and flightlessness in nature. We compared different forward flights in both transport efficiency and details of wing and body kinematics, and used conservative models to address the aerodynamic output of different wings. Our analyses showed that the average wing force production with respect to body weight is important for determining the incline angle of equilibrium flight. Incipient flapping in intermediate–sized wings show reduced lift generation and power efficiency than flapping of fully developed wings. For example, they allow computation of lift, thrust, and drag on wings and fins of a diversity of shapes and kinematics in a variety of flying and swimming animals. In contrast, we know little about how limb morphology and kinematics affect legged locomotion on natural substrates like sand and gravel which also flow in response to movement. This is largely because predictive models for such flowing ground have been unavailable. Our recently developed terradynamics (Li et al., in review)predictive force laws for legged locomotion on granular media (sand)allow us to begin to investigate the role of limb morphology in locomotor performance on granular media. Using terradynamics, we develop a multi–body dynamic simulation of a small six–legged robot (13 cm, 150 g) moving on granular media, and predict the speed of the robot for c–shaped legs of a range of curvatures (−1/R < 1/r < 1/R, where 2R = 4.1 cm is maximal leg length) and a range of stride frequencies (0 < f < 5 Hz). Our simulation reveals that the robot moves faster using positive curvature legs than negative curvature legs, because the former leg elements can access larger stresses and penetrate less deeply but generate larger thrust given the same average lift (robot weight). Further, our model predicts that using an optimal c–shaped leg of curvature 1/r = 0.86/R, the robot can achieve maximal speed of ~70 cm/s (~5 BL/s) at 5 Hz. Our study demonstrates the power of terradynamics in the design of bio–inspired devices and promises to aid understanding of the functional morphology of sand–dwelling organisms.

103.6 ZELDITCH, M. L.*; SWIDERSKI, D. L.; Univ. of Michigan, Ann Arbor; zelditch@umich.edu

**Plasticity of a complex, integrated structure: The impact of diet on mandibular form**

Plasticity may play a critical role in the persistence of populations threatened by climate change and even populations that track their thermal habitat are likely to be challenged by extreme or novel biotic environments. Phenotypes responsive to the biotic environment may be under intense selection, and, in the case of complex morphologies such as the mammalian jaw, adaptive evolution may be impeded by the (co)variance structure. If plasticity can produce a large enough change, in a direction specific to the environmental change, plasticity can circumvent both demographic and quantitative–genetic constraints. But large changes may incur other costs, e.g., disrupted developmental homeostasis. As a model system, we use mandibles of deer mouse, Peromyscus maniculatus bairdii, fed pellets, powder or gruel, to examine the impact of dietary consistency on size and shape. We find that plasticity has a moderate impact on size, shifting the mean of the gruel–fed mice by 0.6 standard deviations, but it has a large impact shape, shifting the means by 7.5 Mahalanobis distance units and in significantly different directions depending on diet. Despite those large changes, jaw development is not decanialized, destabilized or disintegrated. The covariance structure does change, however. Our results suggest that plasticity can modify trophic morphologies by more than is feasible by natural selection over by 10–100 generations at the maximal sustainable rate, incurring neither demographic nor developmental costs.

147.5 ZHANG, T*; LI, C; GOLDMAN, DI; Georgia Institute of Technology, University of California, Berkeley; tingnan1986@gatech.edu

**Using Terradynamics to Understand the Role of Limb Morphology in Legged Locomotion on Granular Media**

The theories of aero– and hydrodynamics form the bases for prediction of animal movement and device design in flowing air and water. For example, they allow computation of lift, thrust, and drag on wings and fins of a diversity of shapes and kinematics in a variety of flying and swimming animals. In contrast, we know little about how limb morphology and kinematics affect legged locomotion on natural substrates like sand and gravel which also flow in response to movement. This is largely because predictive models for such flowing ground have been unavailable. Our recently developed terradynamics (Li et al., in review)predictive force laws for legged locomotion on granular media (sand)allow us to begin to investigate the role of limb morphology in locomotor performance on granular media. Using terradynamics, we develop a multi–body dynamic simulation of a small six–legged robot (13 cm, 150 g) moving on granular media, and predict the speed of the robot for c–shaped legs of a range of curvatures (−1/R < 1/r < 1/R, where 2R = 4.1 cm is maximal leg length) and a range of stride frequencies (0 < f < 5 Hz). Our simulation reveals that the robot moves faster using positive curvature legs than negative curvature legs, because the former leg elements can access larger stresses and penetrate less deeply but generate larger thrust given the same average lift (robot weight). Further, our model predicts that using an optimal c–shaped leg of curvature 1/r = 0.86/R, the robot can achieve maximal speed of ~70 cm/s (~5 BL/s) at 5 Hz. Our study demonstrates the power of terradynamics in the design of bio–inspired devices and promises to aid understanding of the functional morphology of sand–dwelling organisms.
Of Lice and Lemurs: Personality Traits and Parasite Dynamics in Wild Brown Mouse Lemurs Microcebus rufus

Animal personality traits have the potential to influence exposure and susceptibility to parasites. Bold individuals may experience increased contact rates with conspecifics and aggressive behaviors which make them more vulnerable to parasites with direct transmission routes. To better understand whether bold individuals are at a higher risk of ectoparasite infestation than their shy conspecifics, we performed behavioral assays to qualitatively determine degrees of boldness and shyness, measured fecal testosterone levels, quantified louse infestations, and documented the exchange of lice between known individuals in a population of wild brown mouse lemurs (Microcebus rufus) in the eastern rainforests of Madagascar. We hypothesize that 1) bold individuals will have higher testosterone levels than shy individuals, 2) bold individuals will harbor more lice than shy individuals, and 3) bold individuals will play a larger role in spreading lice in the population than shy individuals. While we did find that bold individuals had the highest testosterone levels, we found no evidence to support the idea that bold individuals had more lice than shy individuals. However, when examining the patterns of louse exchange between individual lemurs, our results show that bold individuals act as superspreaders and are responsible for the widespread movement of lice in the population, while shy individuals act as supercollectors harboring higher louse infestations. Taken together, these results suggest that personality traits may underlie differences in host–parasite dynamics. Meanwhile, parasites also impact host condition, and thus may also play a role in the evolution of host personality traits such as boldness and shyness.