3.5 ABBOTT, EM*; AZIZI, E; Univ. of California, Irvine; abbotte@uci.edu

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 recoil stretches 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. Plantaris muscles of Rana catesbeiana (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.

130.4 ACKERLY, KL*; WARD, AB; Adelphi University, Adelphi University; kerrackerly@yahoo.com

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 the 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.

23.1 ADDIS, E.A.*; REDING, D.M.; SCHWARTZ, T.S.; PALACIOS, M.G.; BRONIKOWSKI, A.S.; Gonzaga University, Iowa State University, CENPAT–CONICAT; addis@gonzaga.edu

Insulin–like signaling and life history trade–offs in garter snakes with divergent life histories

Life history theory, and specifically of the pace of life hypothesis, postulates the existence of trade–offs with organisms falling at the slow end of the continuum exhibiting low annual reproduction, slow growth and long lifespan while organisms at the fast end have higher reproduction, faster growth and shorter lifespans. While the existence of the pace of life continuum has been documented in a myriad of species, from nematodes to mammals, little is known about the physiological mechanisms underlying these demographic and physiological trade–offs. The insulin–like signaling (IIS) pathway is an evolutionarily conserved molecular network that has been involved in the pace of life trade–offs in model organisms. Key components of the IIS pathway include insulin–like growth factor 1 and 2 (IGF–1, IGF–2) and associated receptors (IGF–1R, IGF–2R). In this study, we explore the role of these components of the IIS pathway in growth of two genetically divergent ecotypes of the western terrestrial garter snake. Thamnophis elegans, which exhibit these slow and fast paces of life. We used a common–garden design in which snakes from each ecotype were placed in one of two daily temperature treatments from birth: 16 hours of voluntary heat exposure with eight hours at 20°C or eight hours of voluntary heat exposure with 16 hours at 20°C. We compare growth rates with plasma levels of IGF–1 and IGF–2 at three time points during rapid juvenile growth and gene expression levels of IGF–1, IGF–2, IGF–1R, and IGF–2R at 1.2 years of age. Lastly, we discuss the relevance of these results in relation to the life history and environmental differences in these divergent ecotypes of the garter snakes.
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 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 first hypothesis, then, is that this systems natural frequency, $f_0$, (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) $f_0$. 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 $f_0$, is achievable with a squat maneuver, and a stutter jump, which is optimal below $f_0$, 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 situations–appropriate tradeoffs between time–to–takeoff and internal power.

A reaction norm perspective on sex and mate choice
Sex is often seen as an essentially discrete trait, ensuing certain characteristics and "roles". However, sex and sexual characters and behaviors can exist in reaction norms, that is all phenotypes emerge out of environmental interactions with pre–existing phenotypes. For example, sex–change may be induced by temperature, body size or social environment. Sex allocation in hermaphrodites is influenced by environmental factors. Though sex is not completely plastic, Reaction norms may be reversible or non–reversible, differ in their amount of plasticity, the rapidity of response to environmental factors and in the responsive time–frame. Also, sex (determination, characters and behavior) changes over evolutionary time, and so does the relative importance of genetic and environmental influence on the expression of a trait. Females are traditionally expected to be generally choosy in their mate choice and males to be indiscriminate. However, accumulating empirical evidence shows that mate choice is flexible in response to environmental, social and internal factors. Both males and females have been shown to shift between choosy and random mating in response to a number of environmental, demographic, social and internal factors. Empirical studies have investigated diverse factors (such as predation risk, density, OSR, encounter rate, chooser condition) causing mate choice flexibility, often as deviations from a general female and male pattern. In contrast, Gowaty and Hubbell (2005, 2009) argued that all individuals are flexible. The dynamic view of sex opens up new directions for future research. We suggest that we need to pay more attention to phenotypes – morphological, physiological, and behavior – as developmentally plastic and/or individually flexible in relation to sex and sex–linked traits.
An analysis of neuromuscular control in the pelvic fin of African lungfish (Protopterus annectens).

African lungfish (Protopterus annectens) and tetrapods share fundamental features of their limbed locomotion. Previous study of pelvic fin kinematics emphasized the fish's 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, undeterred by the lack of a sacrum and digitized 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.
88.3 ALLEN, V.; NYAKATURA, J.; Univ. of Jena; jdallen@wm.edu
Joint contributions to locomotor velocity and power in Iguana iguana
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 Lepidosauria. 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.

37.4 ALUPAY, J/S.; CALDWELL, R/L; Univ. of California, Berkeley; jsalupay@berkeley.edu
The costs and benefits of losing an arm: autotomy in the octopus Abdopus aculeatus
Animals have evolved a diversity of defense mechanisms including cryptic and startle displays and flight responses to escape their predators. Arguably one of the most interesting tactics 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.

146.3 ALWARD, B.A.; ROWND, K.R.; BALL, G.F.; Johns Hopkins University; balward@jhu.edu
Time–course of expression of ZENK in auditory brain regions and gonadotropin–releasing hormone1 cells in starlings in response to song playback
Cues such as day length or social context modulate activity of the hypothalamic–pituitary–gonadotropin (HPG) axis, but it is not clear at what circadian timing system or time–courses of expression of ZENK in auditory brain regions and gonadotropin–releasing hormone1 cells in starlings in response to song playback

Many species have the potential to produce multiple (twins, triplets and quadruplets). For echinoderms, this is only the second report of the production of multiples under conditions embryo experience in the real world; the first described briefly by Mortensen 75 years ago. Multiple production is much more frequent in E. parma than in the other nearshore echinoids examined: Strongylocentrotus droebachiensis and Lytechinus variegatus. We hypothesize that the differences we observed in the propensity to produce multiples are due to differences among echinoids in the strength of the hyaline layer that surrounds blastomeres during early development. We plan to test this hypothesis in other echinoids known to have frail hyaline layers, notably Eucladis tribuloides. Whether the production of multiples is an adaptive response to a variable environment, or simply an interesting developmental aberration remains to be demonstrated. However, novel developmental responses to present–day fluctuations in salinity suggest that ongoing environmental shifts may drive substantial changes in marine invertebrate developmental patterns.

9.1 ALLEN, JD*; ARMSTRONG, AF; College of William and Mary, University of California, Davis; jdallen@wm.edu
Developmental flexibility in a variable environment: lessons from sand dollars and sea urchins
Despite recent reports of intraspecific developmental plasticity in marine invertebrates, exceptions to the rule of species–specific developmental patterns remain rare. Here we describe unusual intra–clutch variation in the development of an echinoid echinoderm. To generate this variation we exposed sand dollar and sea urchin embryos to increased temperature and low salinity environments. For these types of nearshore animals, the intertidal and shallow subtidal environment is a place of high variability in salinity and temperature. We found that under moderate levels of salinity and temperature stress, the sand dollar, Echinarchinus parma, exhibits the unusual developmental pattern of producing multiples (twins, triplets and quadruplets). For echinoderms, this is only the second report of the production of multiples under conditions embryo experience in the real world; the first described briefly by Mortensen 75 years ago. Multiple production is much more frequent in E. parma than in the other nearshore echinoids examined: Strongylocentrotus droebachiensis and Lytechinus variegatus. We hypothesize that the differences we observed in the propensity to produce multiples are due to differences among echinoids in the strength of the hyaline layer that surrounds blastomeres during early development. We plan to test this hypothesis in other echinoids known to have frail hyaline layers, notably Eucladis tribuloides. Whether the production of multiples is an adaptive response to a variable environment, or simply an interesting developmental aberration remains to be demonstrated. However, novel developmental responses to present–day fluctuations in salinity suggest that ongoing environmental shifts may drive substantial changes in marine invertebrate developmental patterns.

January 3–7, 2013, San Francisco, CA
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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–gUILD 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.

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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 chameleons there is a tradeoff among movement performance. Convergence of performance in muscle–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 coolest environments 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 latitudinal gradation, with the mid–elevation taxa maintaining the highest degree of performance for both movements. 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.

ANDERSON, C.V.*; TOLLEY, K.A.; University of South Florida, Tampa, South African National Biodiversity Institute, Cape Town; cvanders@mail.usf.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 critical 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 cold 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 at the edge of the desert scrub and captured by pitfall trapping, about 87% of the total ants by number. Annually 10–12 lizards were radio and powder tracked, 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.

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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 radio and powder tracked, 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.

70.4 ANDERSON, D.A.*; SOUTHWOOD WILLIARD, A.; SCHARFF, F.S.; University of North Carolina Wilmington; dao2211@uncw.edu

The lizard and their activity periods and their daily feeding rates.

January 3–7, 2013, San Francisco, CA
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 how 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 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-acetyls lysine, 5–oxoproline, 5–methylcysteine) were lower in the fast 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 supported 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.
Delay of hatching in the sand dollar Echinarachnius 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 Echinarchnius 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-hatch 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 hatch 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-arm pluteus 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.

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 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 (Ms), 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 Ms 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.
6.2 ASTLEY, H. C.*; ROBERTS, T. J.; Brown University; henry_astley@brown.edu
Where 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 suggested 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.

43.1 AZIZI, E.*; ABBOTT, E.M.; Univ. of California, Irvine; eazizi@uci.edu
Anticipatory motor patterns limit muscle stretch during landing in toads
To safely land after a jump or hop, muscles must be actively stretched to dissipate mechanical energy. Muscles that dissipate energy can be damaged if stretched to long lengths. The likelihood of damage may be mitigated by the nervous system if anticipatory activation of muscles prior to impact alters the muscles operating length. Anticipatory motor recruitment is well established in landing studies and motor patterns have been shown to be modulated based on the perceived magnitude of the impact. In this study we examine whether motor recruitment in anticipation of landing can serve a protective function by limiting maximum muscle length during a landing event. We use the anconeus muscle of toads, a landing muscle whose recruitment is modulated in anticipation of landing. We combine in vivo muscle length measurements during landing with in vitro characterization of the force-length curve to determine the muscles operating length. We show that muscle shortening prior to impact increases with increasing hop distance. This initial increase in muscle shortening functions to accommodate the larger stretches required when landing after long hops. These predictive motor strategies may function to reduce stretch-induced muscle damage by constraining maximum muscle length despite variation in the magnitude of impact. Supported by NSF grant 1051691.

100.12 ATUKORALLAYA, S; WATERFIELD, V; FRANZ–ODENDAAL, TA*; Mount Saint Vincent Univ; tamara.franz–odendaal@msvu.ca
Development of the maxillary dentition in teleost fish
During the vertebrate craniofacial development the first pharyngeal arch forms two prominences which eventually give rise to the maxillary and mandibular bones. In most vertebrates, including humans, maxillary and mandibular bones together with the premaxillary bone have teeth. Usually, odontogenesis in the maxillary and mandibular jaws initiate simultaneously, however in the Mexican tetra (Astyanax mexicanus) this process appears to be uncoupled. This small fresh water teleost fish is a good animal model to study the evolutionary development of craniofacial structures. Tetra fish have teeth on the mandibular, maxillary and premaxillary bones. The initiation of oral teeth is first observed at 44 hpf in the mandible and in the premaxilla, and the first oral teeth start to erupt around the 5 dpf. Interestingly, the maxillary teeth erupt much later in life at around 100 dpf. In this study we sought to find the cause for the temporal difference in tooth development in these two bones. Whole mount bone staining and histology were conducted to identify the tooth development stages in M. tetra in selected age groups. The gene regulatory network behind this delay in maxillary tooth development was analysed using in situ hybridization. Our study will shed light on the developmental events leading to odontogenesis in the maxillary bone in this species and will broaden our understanding of tooth development events that occur in the first pharyngeal arch derived bones in vertebrates.
55.1 BADYAEV, A.V.; Univ. Arizona; abadyaev@email.arizona.edu
From emergence to evolution: Phenotypic integration of complex
offspring sex-bias
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.

40.4 BAIRD, A.J.*; MILLER, L.A.; Univ. of North Carolina, Chapel
Hill; ajbaird86@gmail.com
Tubular heart pumping in tunicates and other invertebrates.
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.

38.1 BALABAN, J.B.*; SUMMERS, AP; WILGA, CA; University of
Rhode Island, University of Washington; jbalaban@my.uri.edu
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
supported 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 Poisson’s 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.

8.1 BAHLMAN, JW*; SWARTZ, SM; BREUER, KS; Brown
University; joseph_bahlman@brown.edu
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 four 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.
126.4 BARAK, V*; BROWN, C; FASSBINDER−ORTH, C; Creighton University, University of Tulsa; virginia@creighton.edu 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 swallows 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 swallows. 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.

104.2 BARNES, B.M.*; WILLIAMS, C.T.; BUCK, C.L.; Univ. of Alaska Fairbanks, Univ. of Alaska Anchorage; bmmbarnes@alaska.edu Circadian rhythms in free−living arctic ground squirrels. In indigenous arctic reindeer and ptarmigan, circadian rhythms are not expressed during the constant light of a summer, 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.

48.5 BARIS, T.Z.*; OLEKSIAK, M.F.; CRAWFORD, D.L.; University of Miami/Rosenstiel School of Marine and Atmospheric Science; tbaris@rsmas.miami.edu 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 thermalcline across 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 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.

Hydrodynamic gait identification in squid using volumetric flow imaging

Squids employ two fundamentally distinct mechanisms of propulsion, pulsed jetting and fin oscillations. Simultaneously quantifying complex wake vortex flows from these two systems and identifying coordinated gaits with speed related propulsive performance benefits is a significant challenge, requiring new technologies and approaches. With the goal of identifying coordinated hydrodynamic gaits, flows around brief squid Lolliguncula brevis swimming against a current in a water tunnel were visualized and quantified using a volumetric (3D) approach, known as defocusing digital particle tracking velocimetry (DDPTV). The 3D flows generated by the jet and fins were complex, with multiple vortex wake patterns being detected for both the jet and fins, ranging from isolated to interconnected vortex structures. To help identify distinct wake patterns, quantitative tools, including proper orthogonal decomposition (POD) and topological techniques using critical point properties, were used to analyze the wake measurements, and propulsive performance metrics were calculated. While significant variability was observed, especially for fin flows, several distinct wake patterns were identified, suggesting that our approach has potential for (a) assigning quantitatively meaningful metrics to qualitatively observable differences in wake features and (b) identifying true hydrodynamic gaits in swimmers with multiple propulsive systems. Funded by NSF grant IOS-1115110.
S7–1.5 BATTELLE, Barbara–Anne; Univ, of FL, Whitney Laboratory for Marine Bioscience; battelle@whitney.ifl.edu

When the clock tells the eye: Lessons from an ancient arthropod

Eyes are major targets for regulation by circadian clocks, but effects of circadian clocks on vision are not fully understood in any system. Among invertebrates, effects of circadian rhythms on eyes are perhaps best understood in the American horseshoe crab Limulus polyphemus. This animal uses its compound lateral eyes (LEs) to find mates, and it spawns at night and during the day. Behavioral studies suggest Limulus see at night nearly as well as during the day, and electrophysiological studies show that its LEs are dramatically more sensitive to light at night than during the day. Half the nighttime increase in LE sensitivity can be attributed to signals from central circadian clocks. Circadian signals reach the eyes via axons from central, clock–driven, efferent neurons that project through the optic nerves. These efferent neurons are active at night and silent during the day. When active, they release the biogenic amine octopamine which elevates CAMP in post synaptic cells. The effects of clock input on LEs are diverse. Clock input at night drives changes in LE structure that increase photon catch and electrophysiological properties of photoreceptors such that their signal to noise ratio increases. Recent evidence shows that clock input also influences the dark–adaptive biochemistry of photoreceptors. Rhabdomeral concentrations of several proteins critical for the photoreceptive change significantly day to night. At night, the levels of opsin (Ops), the protein moiety of visual pigment, and the alpha subunit of the G protein activated by the visual pigment (Galpha), increase, and arrestin, the protein that quenches the photoreceptors, decreases. Clock input is required for normal nighttime increases in rhabdomeral concentrations of Ops and Galpha and these effects are mediated by octopamine and activation of the CAMP cascade.

128.4 BECK, M. L. *; HOPKINS, W. A.; HAWLEY, D. M.; Virginia Tech; beckmic@vt.edu

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 trace elements that pose health risks to human 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 nesting 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 swallows is not being adversely affected.

56.4 BEBUS, SE*; SMALL, TW; SCHOECH, SJ; University of Memphis; sebebu@memphis.edu

Developmental corticosterone exposure is correlated with exploratory behavior and learning flexibility in Florida scrub–jays (Aphelocoma coerulescens)

The level of corticosterone (CORT, the avian glucocorticoid), to which an individual is exposed during development can have long–term effects on personality and cognitive abilities. We quantified cognitive abilities and exploratory behavior of fourteen Florida scrub–jays (Aphelocoma coerulescens), 10–11 months of age, in a controlled, captive setting. We recorded exploratory behavior upon introduction to the test cage. Additionally, we tested each bird with a color association and a reversal learning task. These tasks required birds to locate food rewards buried in sand–filled wells of a particular color. Scrub–jays relied on color cues rather than location to find food rewards. Birds showed little variation in their ability to learn the color association. However, some birds more often visited empty wells after visiting reward wells, which may be indicative of increased exploratory behavior. Subsequently, we switched the reward color to evaluate reversal learning capability. Preliminary results show that the ability of birds to learn the color reversal was positively correlated with their baseline CORT levels as nestlings (i.e., taken at 11 days of age, n=10). Nestling baseline CORT levels also were positively correlated with both the latency to explore the floor of the cage and the time to first take food. Further measures of exploratory behavior are currently being analyzed. Plasma samples were also taken for baseline and stress responsiveness at capture and post−testing and these data will be presented as assays are currently underway.

145.3 BEDORE, CN*; MCCOMB, DM; FRANK, TF; HUETER, RE; KAJIURA, SM; Florida Atlantic University, Ocean Classrooms, Nova Southeastern University, Mote Marine Laboratory; cbedore@fau.edu

Effects of temperature and anesthesia on visual temporal resolution in elasmobranch fishes

As a result of human activity, some marine fish species are moving objects, or temporal resolution, has been correlated to habitat and lifestyle, and can be further modulated by temperature and light intensity fluctuations within the environment. Photopic (bright–light/day time) vision is typically faster than scotopic (dim–light/night time) because visual sensitivity is greater in dim light and integration time must be slowed to allow for capture of the maximum number of photons. Higher temperatures result in increased temporal resolution in both endothermic and non–endothermic fishes. Previous studies have used either anesthetized or paralyzed fishes to determine temporal resolution, measured as the maximum critical flicker fusion frequency (CFFmax). However, sedation with the anesthetic, tricaine methanesulfonate (MS–222), is thought to suppress sensory system responses, although empirical evidence is lacking. Therefore, we quantified scotopic and photopic CFFmax in the yellow stingray, Urobatis jamaicensis, at the extremes of its temperature range, 20°C and 30°C, and immobilized with anesthesia, MS–222, or a paralytic, Pavulon. Both low temperature and anesthesia (MS–222) reduced CFFmax. With an increase of 10°C, CFF max doubled from 12Hz to 25.3Hz (photopic) under Pavulon, whereas CFFmax increased by only 4Hz from 6.7Hz to 10.7Hz (photopic) under MS–222 anesthesia. In general, MS–222 anesthesia minimized the effects of both temperature and light–adaptation compared to Pavulon. Yellow stingray CFFmax was similar to the skate, another benthic batoid, but slower than shark species studied with the same technique. These results illustrate the effects of light adaptation, temperature, and anesthesia on visual function within the elasmobranch fishes.
69.6 BEERS, J.M.; Stanford University; jbeers@stanford.edu


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–blooded 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–blooded counterparts, which could place these animals in a precarious position with regard to future climatic warming.

36.2 BENNETT, MM*; 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, Megacheile rotundata

The alfalfa leafcutting bee Megacheile rotundata (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 diapausing 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 4°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.

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.
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.

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 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 outpaces 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.

How do bats turn?

An animal’s ability to effectively maneuver is crucial to its survival. The importance of maneuvering is especially evident among flying animals, which have evolved a particularly impressive collection of strategies. One of the simplest, yet most important, maneuvers amongst flyers is their ability to reorient their heading – or body yaw – in flight. Recently this mode of maneuvering has been investigated for several species of insects and birds showing a diverse array of evolved mechanisms to perform this simple maneuver. Here, we revisit this classical maneuver and investigate how bats perform low velocity turns. We use a model-based tracking framework to reconstruct detailed wing and body kinematics of maneuvering bats from high-speed video. Using this data, we simulate the aerodynamic forces on the wings of bats using both quasi-steady and direct numerical simulations. In turn, we use these aerodynamic models to construct integrated simulations of a bat to discern the mechanism that bats use to turn.
2.4 BERGSTROM, C.A.*; PACHECO, J.; FRITZ, T.; University of Alaska Southeast; cabergstrom@uas.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 between 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.

118.6 BEZAU T, 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 examples 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−base 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 level 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 archosauromorph 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 archosauromorph “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 progenesis explains many seemingly disparate transitions from a more ancestral archosauromorph 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 avialans 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 progenesis was strongly supported by corresponding decreases in body size and in time to sexual and somatic maturity. Furthermore, some modularity exists in the heterochronetic 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 hypoplastic 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 (relative of zebrafish, Poecilia reticulata) has been shown to exhibit growth in a manner similar to that of mammals, where hyperplasia and hypertrophy are 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 when 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 rhopalia 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.
Dont 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 as some control strategies for stability require large leg forces. 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 prioritise 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, and, 50% leg length obstacles with little variation in speed, and limit fall risks to only 8 in 10,000. Animals prioritise injury and fall avoidance over steady dynamics. The experimental data is consistent with a control policy involving feed-forward swing-leg control to minimise 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.

Comparison of walking mechanics in an arboreal and a terrestrial primate

Animals have several mechanisms available that may reduce their mechanical costs while walking. One important 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 video recorded 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.
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Materials 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–heding 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 6.3% 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.

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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 actinopterygian 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.

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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.

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Cross tolerance between modified atmospheres and low temperature in insects

Insects’ tolerance to use temperature treatments for post–harvest disinfection of crops depends on the insects basali ability to withstand or repair the stress associated with long–term low temperature exposure, or the ability to rapidly develop biochemical protection. Changes may be induced at the whole animal level (e.g. respiration rate, water balance), or at the molecular level (e.g. induction of cryoprotective metabolites and proteins). Post–harvest disinfection treatments can be augmented with modified atmospheres (e.g. high carbon dioxide and/or low oxygen) to improve their efficacy. Theoretically, the potential overlaps in the mechanisms which insects can use to counteract low temperature and modified atmosphere stressors may result in cross tolerance. Here, we examine different levels of responses after exposure to temperature and/or gas stress in larvae of the false coding moth, Thaumatoblemma leucotreta, an agricultural pest of southern Africa. Larvae were exposed to a range of temperature conditions (0°C, 25°C, 35°C), high carbon dioxide (6% CO₂) and low oxygen (2% O₂) treatments, both separately, as well as in various combinations, for different durations prior to a standard post–harvest disinfection exposure at −1°C. During these experiments, larvae were assayed for mortality, body water content, body lipid content, cell viability, membrane lipid composition, heat shock protein 70 and cryoprotectant expression levels. The results from these experiments will be discussed in the context of a range of mechanistic hypotheses proposed to explain insect low temperature tolerance and cross tolerance.
Debris coughs occurred in both asconoid and syconoid sponges: debris were ejected from excurrent oscules during a contractile wave. 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 botroides (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 or filtration) trapped and consumed in the canals of these highly spiculose sponges.

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.
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 animals 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^{-5} 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, Polycladida) 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.
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 sex determination. 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.

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 the ventral histoblast nests was counted. The species without appendages has similar cell counts 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.

Immune challenge 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 andterminal 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.
When and how do Tree Swallow chicks die during cold weather? Temperate-breeding alcrid 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 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 this species 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<0.05). 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 cue 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.

Demographic models can forecast climate change effects on scleractinian corals: the Pocillopora damicornis case study Climate change and ocean acidification (OA) are large-scale threats for coral reefs, yet despite a growing literature on the effects of temperature and pCO$_2$ on reef corals, few studies have attempted to forecast the effects at a population level. According to projections, seawater pH will decrease 0.3 to 0.4 by the end of the 21st Century, and temperature in tropical seas will be 3.2°C warmer. Using empirical analyses of the effects on respiration, survival, and calcification of early life stages of Pocillopora damicornis, we employed a demographic approach to forecast the consequences of climate change and OA on the population dynamics of this coral. Such approach can supply useful tools to forecast population dynamics under different environmental conditions. We constructed a size-based demographic model using life-history tables and transition probabilities for a population of P. damicornis in southern Taiwan and projected the population structure over 100 y under differing scenarios. The simulations incorporated a decline of larval survival due to increases in temperature and pCO$_2$; with the results suggesting that an increase of pCO$_2$ from 380 to 900 ppm could lead to a non-linear reduction in population density from 11.6 to 2.3 colonies m$^{-2}$ in 50 y. In the first 130 y population density remains 10.6 colonies m$^{-2}$, but thereafter declines quickly to 2.3 colonies m$^{-2}$ by 2162. A temperature increase from 26.4°C to 29.6°C could further reduce density to 2.1 colonies m$^{-2}$. The drastic decrease happens when larval survival reduce to 80%, suggesting early life stages can play an important role in the population dynamics of this species. Our model can be expanded to a metapopulation approach linking multiple populations using a connectivity matrix including empirical estimates of larval dispersal under future climate conditions.
68.2 BRAZEAL, KR*; HAHN, TP; UC Davis; kbrazeal@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. Differing 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 prohibited 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.

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 Accipitridae. 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.

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 species form Müllerian mimicry rings throughout the Neotropics. We have discovered that Heliconius eyes express recently duplicated genes (e.g. estradiol and testosterone associated with breeding) can delay the onset of molt. Differing 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 prohibited 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.

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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.
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.

Dietary carotenoids increase non-carotenoid coloration of female convict cichlids (Amantitlania nigrofasciata).

The carotenoid tradeoff hypothesis states that carotenoids must be traded-off among competing demands, but this is rarely tested in ornamented females. We used the reverse sexually dimorphic convict cichlid (Amantitlania nigrofasciata) to test whether the ornament could contain information about female fitness. Fish were supplemented with 3 levels of carotenoids, and then both spectral and chemical analyses on integument, and chemical analyses on ovaries, were performed. Dietary carotenoid supplementation increased the yellow coloration of the integument, but not actual carotenoid content of the skin. In fact, we found that the yellow patch is produced through a combination of carotenoid pigment and light-reflecting microstructures. Although only behavioral observations can determine the functional significance of the yellow ventral patch, our results indicate that ventral patches contain information about bearers carotenoid status. Future research on pigment-based signaling, particularly in fish, should consider the presence and role of structural coloration, in addition to the evolutionary pressures that reinforce honesty in intrasexual signaling.

Wnt signaling is known to be critical for proper embryonic development in most animals so is used to date. Still, a key evolutionary question involves the origin and evolution of this pathway in the last common ancestor of metazoan. Recently, the genome of Pleurobrachia bachei, a member of the early branching metazoan lineage Ctenophora, has been sequenced. Insights into the function of the Wnt pathway in P. bachei will provide information on early evolution of this key pathway. First, only three Wnt ligand genes (PbWnt6, PbWnt9, and PbWntX) were identified and cloned in P. bachei compared the ctenophore Mnemiopsis leidyi which has 4 Wnt ligand genes. Second, using in situ hybridization these genes showed differential expression in the combs, tentacles, mouth, ciliated grooves and polar fields of the adult P. bachei. However, surprisingly there were very low levels of expression in all the Wnt ligands in the P. bachei embryos. A genomic survey for other members of the canonical Wnt pathway revealed components of the destruction complex and antagonists were incomplete or missing from the genome as was also in Mnemiopsis. The extensive expression of Wnt ligands in the adult P. bachei indicates that Wnt could also be playing a role in neurotransmission in the adult.

Body temperatures along altitudinal and latitudinal gradients: interactions between phenotypes and multiple environmental stressors

The divergence between body and air temperatures is central to patterns of thermal stress associated with climate change. We use biophysical models to estimate body temperatures as a function of an organisms phenotype and environmental conditions (air and surface temperatures and radiation). Using alpine butterflies as a case study, we compare mean body temperatures and the incidence of thermal extremes along altitudinal gradients in both past and current climates. Organisms at higher elevation can experience more frequent thermal stress events despite generally cooler air temperatures due to high levels of solar radiation. Incidences of thermal stress events have increased more rapidly than increases in mean conditions due to recent climate change. Increases in air temperature have coincided with increased cloudiness with complex consequences for altitudinal patterns of thermal stress. We compare altitudinal trends, including seasonal overlap, between tropical and temperate mountains to ask whether mountain passes are higher in the tropics (Janzen’s hypothesis) when considering body rather than air temperatures. Our analysis highlights the potential fallacy of predicting thermal stress based solely on air temperatures and the importance of considering phenotype–environment interactions.
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.

Using reduced-order models to study dynamic legged locomotion: Parameter identification and model validation

Generating testable hypotheses for dynamic legged locomotion is challenging because motion imposes a continually-changing reference frame, and perturbations typically induce nonlinear effects. Fortunately, rhythmic biological motion is often highly stereotyped and low-dimensional, suggesting amenability to description by reduced-order dynamical models as proposed by the Templates and Anchors Hypothesis (TAH). Such models can predict experimental outcomes that cannot otherwise be quantified. For instance, during perturbations from the environment, purely mechanical self-stabilizing behavior can be defined, so that deviations resulting from neural feedback can be explored. However, given a candidate reduced-order model, there is seldom a direct method to measure free parameters and validate the model. Operationalizing TAH requires statistical tools to estimate parameters and select models using data collected within experimental paradigms. We propose a computationally tractable method for applying nonlinear regression to the piecewise-defined dynamical models that naturally describe terrestrial locomotion. We illustrate the technique using data from an experiment involving center of mass (COM) perturbations and mass distribution manipulations applied to running cockroaches. Preliminary results corroborated our initial finding that neural feedback could be delayed by ~1−2 strides after perturbation onset and demonstrated that a parsimonious spring−mass model for horizontal plane dynamics of sprawled running animals (Lateral Leg Spring) provides an accurate quantitative prediction of the animal’s COM dynamics during this interval. Our approach can be applied more generally to dynamical systems ranging from muscles to swarm coordination.

Transgenerational Effects of Parental Hypoxia on Vertebrate and Invertebrate Larvae

Non–genetic transgenerational modifications of offspring phenotype are increasingly evident in physiological studies. Indeed, this phenomenon 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 returned to normoxia for breeding and reproduction. A control population stayed in normoxia. The subsequently produced offspring (6−18 day old zebrafish larvae; 0−18 day old Daphnia larvae) were then exposed to severe hypoxia and their responses recorded. Additionally, physiological and metabolic traits of the larvae whose parents were exposed to hypoxia 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°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 higher metabolic rate. These effects dissipated with further development within a brood and with subsequent broods. Parental hypoxia exposure thus can be revealed as a factor in larval phenotype through non–genetic transgenerational mechanisms.

Nectarivory has evolved repeatedly, and avian lineages that have adopted a food−feeding strategy have a nectar−producing flower as the most probable 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 returned to normoxia for breeding and reproduction. A control population stayed in normoxia. The subsequently produced offspring (6−18 day old zebrafish larvae; 0−18 day old Daphnia larvae) were then exposed to severe hypoxia and their responses recorded. Additionally, physiological and metabolic traits of the larvae whose parents were exposed to hypoxia 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°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 higher metabolic rate. These effects dissipated with further development within a brood and with subsequent broods. Parental hypoxia exposure thus can be revealed as a factor in larval phenotype through non–genetic transgenerational mechanisms.

A hummingbird tongue in a shorebird head: Tuamoto sandpipers are nectar−feeders

Nectarivory has evolved repeatedly, and avian lineages that have adopted a food−feeding strategy have a nectar−producing flower as the most probable 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 returned to normoxia for breeding and reproduction. A control population stayed in normoxia. The subsequently produced offspring (6−18 day old zebrafish larvae; 0−18 day old Daphnia larvae) were then exposed to severe hypoxia and their responses recorded. Additionally, physiological and metabolic traits of the larvae whose parents were exposed to hypoxia 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°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 higher metabolic rate. These effects dissipated with further development within a brood and with subsequent broods. Parental hypoxia 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 understanding the processes of energy gain and expenditure of the modeled organism. However, many measurements are 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 on the shore over several tidal cycles. Limpets fed at a rate of 80–100 raps 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 organism 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 organism. An optimal set of basis modes allows us to rationalize biological kinematics describing the complex kinematics of an organism using only a few describing the complex kinematics of an organism using only a few

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 premature 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 compared to control guinea pig fetuses. Thus, we examined. Previous histological research demonstrated that NADH (oxidative enzyme) concentrations were greater in the scalenus muscles of betamethasone-treated compared to control 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 week, 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 (µmol/min·g wet muscle mass) and the average CS activity 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 BUXTMAN, C.L.*; WESTNEAT, M.W.; University of Chicago, Field Museum of Natural History; cmcorder@uchicago.edu

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

Muskies 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.

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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.
106.4 CAI, J.*; HEINEY, P.A.; SWEENEY, A.M.; University of Pennsylvania; caij@sas.upenn.edu
Building a Lens from a Single Protein: Small Angle X−ray Scattering on Squid Eyes
Throughout evolution, camera−type animal eyes developed spherical, graded refractive index lenses which eliminate spherical aberration. The graded refractive index is achieved by changing the density of proteins within the lens. To reduce unwanted scattering of light, the protein density fluctuations in the lens must be small. This effect becomes more significant in the periphery of the lens, where the protein density is lower than in the center. Squid lens material is dominated by only one protein isoform, making it a tractable system to understand how changes in protein biophysical properties contribute to bulk lens optical and material properties — in contrast, vertebrate lenses are an experimentally intractable mix of multiple, polydisperse isoforms. Our previous work has shown that the isoforms in the periphery of the lens have a more positive surface charge, implying that Coulomb interaction assemblies the protein in repulsive glass phase, with lower surface charges mediating assembly of progressively higher index lens regions. Here, we perform small angle x−ray scattering experiments on squid lenses. Each lens sample is separated into four concentric layers based on radius. Experiments show that the packing properties change gradually from the central core of the lens to the periphery. We also discuss how squid lens proteins interact with each other and how they are packed to form graded index glass. Future studies will apply the lessons learned from squid lens materials to manufacturing artificial self−assembling lenses with graded refractive index, which can be applied widely in industry.

48.4 CALHOON, E.A.*; JIMENEZ, A.G.; HARPER, J.M.; JURKOWITZ, M.S.; WILLIAMS, J.B.; Ohio State University, University of Michigan; calhoon.18@osu.edu
The relationship between life history in temperate and tropical bird species and lipids in fibroblast mitochondrial membranes
Temperate birds are thought to have a fast pace of life, having a shorter life−span with high reproductive output, whereas tropical birds are thought to have a slow pace of life. In support of this idea, tropical birds have lower metabolic rate, invest fewer resources in reproduction, and have higher adult survival rates compared with temperate birds. How these differences in life−history at the organismal level may be rooted in differences at the cellular level remains unknown. Here, we cultured fibroblasts of phylogenetically−paired tropical and temperate species, isolated mitochondria from each, and compared their mitochondrial membrane lipids. We found that temperate bird species tended to have more mitochondrial lipids than tropical species, especially cardiolipin, but that temperate species did not have significantly more mitochondrial protein and lipids in their cells. Since cardiolipin is highly localized to the inner mitochondrial membrane, this could indicate that temperate birds have more inner mitochondrial membrane, but not a higher amount of mitochondria. We also found that mitochondria from tropical species had higher amounts of plasmalogens, a lipid that could serve as an antioxidant. Overall, our findings are consistent with the idea that there are underlying cellular physiological traits which could account for the differences in whole animal physiology between animals with different life histories.

146.4 CALISI, R.M.*; KRAUSE, J.S.; PERFITO, N.; BENTLEY, G.E.; WINGFIELD, J.C.; Univ. of California, Davis, Univ. of California, Berkeley; beccacalis@gmail.com
Transitions in avian parental care: a role for hypothalamic gonadotropin inhibitory hormone (GnIH)
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, RPF, 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 RPF may serve as a potent RFRP receptor antagonist in mammals, its actions do not appear to function similarly in birds.

70.6 CALOSI, P*; TURNER, L.M; HAWKINS, M; NIGHTINGALE, G; BERTOLINI, C; TRUEBANO–GARCIA, M; FORD, A; SPICER, JI; Plymouth University, University of Portsmouth, piero.calosi@plymouth.ac.uk
The effect of exposure to multiple environmental challenges on multiple physiological responses: an inter−individual approach
Continuing increase in atmospheric CO2 anthropogenic emissions will lead to an increase in ocean−surface temperature of 3−5°C, and a decrease in pH of 0.3−0.4 units by 2100. Whilst marine intertidal organisms already experience periodical environmental fluctuations that exceed these values, and are believed to be adapted to these conditions, actual data on how they respond to chronic exposure is limited. Moreover, investigations to date have typically employed independent sample analysis (ITSA), which is a powerful tool for the detection of significant alterations of biological responses. However, ITSA does not take into account inter−individual variation and relationships between traits. Here, we investigated individuals’ metabolic rate (MR), gill Na+/K+−ATPase activity and upper thermal tolerance (UTT) in adults of the amphipod Gammarus marinus exposed for 15 days to combined elevated temperature and CO2. Briefly, ITSA detected significant up−regulation in gill Na+/K+−ATPase activity in individuals exposed to elevated temperature and CO2 and a significant decrease in upper thermal tolerance (UTT) in the high−CO2 treatment. ITSA revealed that UTT responses are largely but weakly MR−dependent, and that sUTT response to CO2 and temperature exposure depended also on individuals’ MR. We will discuss the advantages and disadvantages of integrating ITSA and ILSA when interpreting organisms’ biological responses within the context of global change.
Biominal ultrastructure, elemental constitution and genomic analysis of biominalization-related proteins in hemichordates

Here, we report the discovery and characterization of biominalization 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 hemichordate biominals are small CaCO3 aragonitic elements restricted to specialized epidermal structures, and in S. kowalevskii, are apparently secreted by sclerocytes. Investigation of urchin biominalizing 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 hemichordate genome. We will present corresponding results from the crinoid Florometra servatissima. These results increase the number of phyla known to biominalize and suggest that some of the gene-regulatory toolkit, if not mineralized tissue themselves, may have been present in the common ancestor to hemichordates and echinoderms.

Hyoid kinematics and hypaxial 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 with 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.

Sexual dimorphism of Hemidactylus frenatus along a latitudinalcline: testing Renchs rule in an ectotherm with intensemale–male competition in lower latitudes

Renchs 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 latitudinal cline 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 Renchs 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 Renchs 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 Renchs 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.
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.

A biologically-based GIS model for predicting outbreaks of mosquito-borne viral diseases

The Dynamic Continuous Area Space-Time (DYCAST) system is a biologically-based spatiotemporal model that uses public reports of dead birds to identify areas at high risk for West Nile virus (WNV) transmission to humans. We implemented this model prospectively during a dengue epidemic in California; daily risk maps were made using geographic information system (GIS) software during an unprecedented outbreak in California; daily risk maps were made available online and used by local agencies to target public education campaigns, surveillance, and mosquito control. DYCAST proved to be a timely and effective early warning system, with 80.8% sensitivity, 90.6% specificity, and identification of high-risk areas an average of 37.2 days prior to onset of illness. In subsequent years the model was implemented throughout the entire state of California. Additionally, we modified the models biological parameters based on the dengue infection cycle, and implemented an open-source version of the software retrospectively during a dengue epidemic in Ribeirão Preto, Brazil. Results indicate that the model provided early and accurate identification of high-risk areas, including the detection of cryptic interepidemic foci of transmission critical to efficacious control efforts. DYCAST predicted up to 90.3% (4,234/4,690) of cases, at a maximum mean of 66.3 days prior to onset of illness; sensitivity and specificity were 83.8% and 78.8%, respectively. Ultimately, this biological modeling approach has been shown to be an effective, inexpensive, and scalable solution for the surveillance and control of zoonotic diseases such as dengue and WNV, and has an effective, inexpensive, and scalable solution for the surveillance and control of zoonotic diseases such as dengue and WNV, and has ultimate effectiveness in 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 animal's 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.

Stress has long lasting effects on animal physiology, development, behavior, reproductive success and survival. The effects of stress are mediated by glucocorticoids, such as corticosterone (Cort), via membrane-bound or intracellular glucocorticoid receptors (GR). When an organism is exposed to repeated stressors early in life this can alter stress-responsive neurobiological systems persisting across all life history stages. Early developmental stress affects the size of the avian song control nuclei and song quality in many songbirds, including HVC (proper name) and RA (nucleus robustus arcopallii) are required for song learning and production, and the complexity of the male zebra finch (Taeniopygia guttata) courtship song is important in female mate choice. Early Cort treatment differentially reduced the HVC size, but not RA, in juvenile and adult male zebra finches. This suggests that the effect of developmental stress on the HVC size may be mediated through Cort via activation of GR within HVC. This may be a specific mechanism by which HVC size and song quality are altered in developmentally stressed birds. Taken together, this suggests a potential role for Cort in mediating adverse effects of developmental stress in adult male zebra finches and highlights the developmental plasticity of the zebra finch brain.
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 caught 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.

The advantages of gynodioecy vs. dioecy in plants

Plants exhibit the full spectrum of variation in both gender expression and sexual systems. Individuals can be male, female, simultaneous hermaphrodites, or sequential hermaphrodites. Populations can be comprised of any combination of these sexes, making plants an ideal system in which to study the relative advantages and disadvantages of each alternative strategy. Indeed, evolutionary transitions between sexual systems have received more attention in plants compared to other eukaryotes, both because of their extensive sexual variability and because several features of plant life histories—including immobility and modularity—make them remarkable subjects for evolutionary and ecological research. In this talk, I summarize over a century of research on the adaptive significance of gender variation in plants. I place particular emphasis on the repeated evolution of gynodioecy and dioecy, the stability and maintenance of these two sexual systems, and the important role of phenotypic plasticity in transitions between them. Dioecy (megandioecy) is the predominant sexual system in the animal kingdom, far exceeding any other, while gynodioecy is almost unheard of among animals. In plants, gynodioecy and dioecy are both relatively common and frequently derived, often co-occurring within plant genera. Perspectives on dioecy as a recently derived state can improve understanding of its adaptive significance. To do so in a broad context that allows for cross-kingdom comparisons, I address how predominant theories of the evolution of dioecy might be applied uniquely to plants vs. applied generally across eukaryotes.

Are swimbladders inverted lungs? Evidence from developmental genetics

The homology of lungs and swimbladders has been accepted to varying degrees by the great morphologists of the 19th and 20th centuries. We have recently shown that a shared developmental regulatory network underlies the early development of tetrapod lungs and the zebrafish swimbladder. This is the first genetic evidence supporting this proposed structural homology. One major unresolved incongruity regarding lung and swimbladder homology is that lungs bud ventrally from the gut while swimbladders bud dorsally, leaving some to the conclusion that lungs and swimbladders are not structurally homologous, but rather independent modifications of the posterior pharynx. However, comparative developmental biology has shown that a seeming structural inversion, such as the ventral to dorsal inversion of the nervous system in bilaterian invertebrates and chordates, can be due to an inversion of the ancestral patterning mechanism and not an independent structural origin. The developmental genetic mechanism specifying the ventral location of the tetrapod lung bud is well understood, and involves the mutual antagonism of the lung-specifying gene Nkx2.1 and its mutual antagonist Sox2. Our study examines the expression pattern of these two genes in the posterior pharynx and swimbladder bud in zebrafish. An inversion of the ancestral lung patterning mechanism would be strong evidence for the structural homology of these two structures and addresses a longstanding and controversial issue in comparative anatomy.
Effects of Limited Oceanic CO2 and Temperature on Sperm Motility and Swimming Speed in Northern and Southern Populations of the Sea Urchin Arbacia punctulata

In 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 urchins 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.

Low plant nitrogen content and high population density enhance migratory characters in a polyphenic locust

Locusts present an impressive and well-studied example of phenotypic plasticity in which population density regulates a variety of behavioral, morphological, and physiological traits that often culminate in migratory swarms. Oedaleus asiaticus, a north Asian locust, has outbreaks and migratory swarms comprised predominantly of brown morphs. Heavy livestock grazing promotes outbreaks by lowering plant nitrogen content and likely lowering the protein:carbohydrate ratio to the optimal range for this locust. However, it is unclear if a change in plant quality can modulate the effect of density on phase characteristics. We found that locusts reared at high population density and fed low-N plants (i.e. plants that are high quality for O. asiaticus) had the most enhanced migratory characteristics while locusts fed high-N plants (i.e. deleterious for this locust) consistently had decreased expression of migratory characters. These results do not support existing paradigms that poor-quality resources increase the expression of migratory phenotypes. We then compared feeding habits of the brown (outbreak) and green (non-outbreak) morphs. There was no difference in plant preference nor protein:carbohydrate intake target ratio; however, when confined to diets extreme in their protein:carbohydrate ratios, green locusts decreased consumption and brown locusts maintained a similar consumption rate on all diets. From these results we infer that the green morph strategy may be most beneficial for sedentary insects confined to limited food choices to avoid long-term deleterious effects of consuming an unbalanced diet, while the brown morph strategy of being more willing to consume suboptimal foods may be most beneficial for roaming insects.

A Comparative Look at Tail Movement During Narrow Branch Locomotion

A Comparative Look at Tail Movement During Narrow Branch Locomotion

Tails have been suggested to act as either counterweights or dynamic stabilizers to maintain balance during locomotion, functions that should be especially important on narrow substrates, e.g. branches. Most tests of these assertions have been based on mathematical modeling, purely morphological studies, or qualitative observation. Few empirical data exist with which to test tail function during narrow branch locomotion. We present cinematic data on tail movements in two primates, squirrel monkeys (Saimiri) and tamarins (Saguinus), during quadrupedal locomotion on a 3.2cm diameter pole. Ongoing studies are focused on describing locomotor tail movements in other arboreal animals as well (e.g., Petaurus). Morphological data suggest that Saguinus has reduced power-grasping abilities relative to Saimiri, perhaps necessitating compensatory means of maintaining balance on narrow substrates. To test this hypothesis, we used video analyses to document tail angular kinematics throughout strides. We predicted that tails used as effective balancing organs, whether as counterweights or dynamic stabilizers, should be held at elevated angles with respect to the substrate, thus maximizing rotational inertia and resistance to movement. Additionally, tails used as dynamic stabilizers should exhibit exaggerated movement over a stride. Controlling for variation in speed and body mass, we found that Saguinus holds the tail at more elevated angles (mean angular position: Saguinus 7.1°; Saimiri –15.5°; p<0.05) and moves the tail through wider ranges of motion (amplitude: Saguinus 26.1°; Saimiri 13.7°; p<0.05). Joint recruitment appears to be the primary variable across species. To test this hypothesis, we analyzed video analyses to document tail angular kinematics throughout strides.
111.4 CHAN, KYK*; GRUNBAUM, D; Univ. of Washington; kychan@uw.edu
Assessing effects of starvation–induced morphological variations on swimming of larval sand dollars with a novel biomechanical model and video motion analysis
Morphologies 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.

90.2 CHANG, J.*; EASTMAN, J.M.; ALFARO, M.E.; University of California, Los Angeles, University of Idaho; jonathan.chang@ucla.edu
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 phlawd. 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 enjoy 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.

11.2 CHANG, E.S.*; SHCHEGLOVITOVA, M.; CARTWRIGHT, P.; University of Kansas; eschang1@gmail.com
Comparative transcriptomes of cnidarian freshwater parasites
The myxozoan Myxobolus cerebralis and the enigmatic Polypodium hydroides 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 cnidarian, 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, Popkio 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.; MCDOUGAL, 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 bacteriophages

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 cephalopods. 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 Rhyhonomas 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 formed 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 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.

28.4 CHENY, JA∗; MIDDLETON, KM; KONOW, N; GIBLIN, EL; BREUER, KS; SWARTZ, SM; Brown University, Providence, RI, University of Missouri, Columbia; jonn.cheney@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 plagiopatagial 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 larva’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 indicate 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.
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 larva once or twice each lunar month when tidal conditions favor survival of these species. On shores with semidiurnal tides, the changing phase relationship between the lunar synod (29.53 days) and anomalistic (27.55 days) cycles modulates the amplitude and phase of 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), which we continuously monitored for 4.5 years and found that this simultaneous hermaphroditic pattern is related to the tidal height difference between the first and last quarter moons. Extreme synchrony, amplitude modulation and phase reversals in 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 eggs of 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.

Spermatozoa ultrastructural characters have shown to be informative in phylogenetic studies in many invertebrate groups. Comparative data exist on sperm ultrastructure across cestode orders, though information for the lecanicephalidean cestode order Lecanicephalidea is limited. The only previous data on lecanicephalidean sperm ultrastructure came from a specimen of Tetracanthcephalum (Justine, 2001). Mature spermatozoa of Tetracanthcephalum were described as possessing a single axoneme, crested body, and parallel cortical microtubules. Based on these data, Levron et al. (2010) postulated a spiral nucleus. Specimens of Tetraonococephalus as well as three additional lecanicephalidean genera were collected from rays in 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 axoneme, 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 rest body, Flapococephalus appears to have two crested bodies, and Tetracanthcephalum possesses 2 parallel cortical microtubules peripheral to the crested 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 spermatozoa ultrastructural characters can only fully be tested with a broader sampling of species within other cestode orders.
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.
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Vertebrate diversity and phylogeny across the fish−to−tetrapod transition

The popular idea of the fish−to−tetrapod transition covers a series of changes to the gnathostome body plan: mid−line fins are lost; digit−like replacement paired fins; a sacrum links vertebrae to hips; gills are reduced; a distinct neck separates the head from shoulders. Such changes (and many more) occur within taxa traditionally designated as fish, deep within the tetrapod stem lineage. Moreover, if traditional, anatomical character−based definitions of taxa are used, then the broad shape of tetrapod evolution resembles an ice−cream cone: the classic spindle diagram. A few proto−tetrapods exhibiting a classic mosaic of fish− and tetrapod−like features emerge within the Devonian Period some 380 million years ago, and these earliest forms constitute a phylogenetic fuse preceding a dramatic evolutionary radiation within the Mississippian (around 340 million years ago) from which sprang the roots of modern amniotes and lissamphibians. However, if the tetrapods are defined on the basis of all taxa more closely related to living forms than to lungfishes (or coelacanths), then the picture of diversity flanking the fish−to−tetrapod transition changes. Diverse and abundant Devonian tetrapods are cut down by the end Devonian (360 million years ago) Hangenberg extinction, the causes and consequences of which are only now being investigated. Modern vertebrate diversity, dominated by tetrapods, teleosts and elasmobranchs, is contingent upon this event. The fish−to−tetrapod transition occurred within a very different and earlier faunal setting, and begs questions about survivorship versus extinction, recovery and replacement, and the extent to which the phylogenetic pattern apparent among early tetrapods is repeated within the other major vertebrate clades.

18.1 COLLAR, D.C.∗; MEHTA, R.S.; HOLZMAN, R.; WAINWRIGHT, P.C.; Univ. of California, Santa Cruz, Tel Aviv Univ., Univ. of California, Davis; dcollar@ucsc.edu

The morphological and kinematic basis of suction feeding performance evolution

Organismal performance is a product of the size and shape of morphological structures and the way organisms use them (i.e., kinematics). Performance evolution, therefore, may result from change in morphology, kinematics, or both. Although performance has featured prominently in evolutionary studies, focus has generally been on performance as a link between morphology and ecology. Much less is known about the relative importance of the morphological and kinematic changes underlying performance evolution. In this study, we examine the basis of suction feeding performance evolution and fit evolutionary models to morphological, kinematic, and performance data for 17 centrarchid fish species and a robust, time−calibrated phylogenetic tree. We find that feeding performance has diverged toward separate adaptive optima in piscivores and insectivores, and this pattern is evident in morphology but not kinematics. Piscivorous centrarchids have enhanced success rates on evasive prey and evolved toward a morphological peak featuring large oral cavities, limited upper jaw protrusion, and shallow heads. Insectivores, on the other hand, have increased ability to feed on attached prey and have evolved small mouths, extensive upper jaw protrusion, and deep skulls. Despite their evolution toward separate optima for performance and morphology, piscivores and insectivores show no evidence of divergence in kinematics. These results suggest performance evolution has been a consequence of morphological but not kinematic changes. Even though both morphology and kinematics are important in determining performance, our results imply that different evolutionary processes have shaped these levels of design.
101.6 COLMENARES, DJ*; DYHR, JP; MORGANSEN, KA; DANIEL, TL; Univ. of Washington; djc20@uw.edu
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), 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 %/s. 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.

S11–1.6 COLLIN, R; STRI, Panama; collinR@si.edu
Genetic, Environmental and Social Control of Sex Change in Molluscs
Molluscs show a wide diversity of sexual strategies and mechanisms of sex determination. There are both gastropod and bivalve families that are each primarily dioecious, simultaneous hermaphrodites, or sequential hermaphrodites. The multiple evolutionary origins of sex change among molluscs would give power to comparative analyses of the factors associated with this strategy, but data on all but a few groups are too sparse to draw many solid conclusions. However, some generalizations can be drawn. Sex change is primarily protandrous in gastropods and either protandrous or alternating in bivalves. Many simultaneous hermaphrodites exhibit protandrous simultaneous hermaphroditism. Protandry may be considered an extreme case of this strategy but often occurs in groups that are primarily protandrous and is not so common among clades of simultaneous hermaphrodites. Sex change is associated with a sedentary life-style or limited mobility in gastropods, and possibly with brooding in both gastropods and bivalves? Sex change has been shown experimentally to be environmentally mediated. The timing of or size at sex change responds to interactions with conspecifics as well as environmental factors like food availability and stress. Finally, some evidence indicates that there is a genetic component to an individual’s propensity to change sex.

S1–2.2 COMBES, SA*; IWASAKI, JM; PANDIT, MM; SWITZER, CM; WEILAND, TJ; Harvard Univ, Univ Otago, NZ, Indiana Univ, Middlebury Coll; scombes@oeb.harvard.edu
The role of identity in predator–prey interactions: Are mechanics and strategy one–size–fits–all or tailored to each adversary?
The dynamics of predator–prey interactions vary enormously, depending on the substrate/medium in which they occur, and on the locomotory modes, motor and sensory capabilities, and behavioral strategies of predator and prey. Encounters are often described as either active chases, in which each participant is aware of and reacts to the other, or as ambush predation, in which predators pounce on unsuspecting prey. In reality, most interactions lie somewhere in the middle, and in many cases it is difficult to discern how (or even if) the participants respond to each others actions. To further complicate matters, most predators pursue a range of different prey, and most organisms are preyed upon by a variety of predators. Because mechanistic studies of predation are scarce, we do not yet know whether predators employ a general kinematic and behavioral strategy when pursuing most prey, or whether they tailor their pursuit to each prey type; nor do we know how widely related prey species differ in their survival strategies and in their motor and sensory capabilities. To address these questions, we examined aerial interactions between dragonflies and dipteran prey, filming encounters with high-speed video to reconstruct 3-d trajectories and quantify biomechanics and strategy. We studied five species of libellulid dragonflies pursuing four species of dipteran prey, including fruit flies, mosquitoes, houseflies and deerflies. By analyzing large numbers of encounters between different predator–prey pairs, we were able to identify common mechanical features of dragonfly predation, infer which prey species can sense and actively respond to approaching predators, and pinpoint key factors that help determine the outcome of predator–prey interactions.

116.1 COLLINS, A.G.*; DOHRMANN, M; National Systematics Lab, Smithsonian; collins@si.edu
Can greater relative complexity in skeletal structure explain why hexactinellid molecular–based phylogenies correspond better to traditional systematics, as compared to other sponge groups?
Continuous efforts over the past two decades let us improve the systematics of sponges through the simultaneous consideration of phylogenetic hypotheses and the distribution of morphological characters. For Demospongiae and Calcarea, molecular studies suggest that a fairly large number of higher–level taxa are not monophyletic. In contrast, for Hexactinellida (glass sponges) there is a relatively closer match between clades suggested by molecular analyses and traditionally defined taxa. One hypothesis to explain these contrasting situations is that hexactinellids exhibit a more complex set of characters used in traditional taxonomy, as compared to other sponges. Defining and measuring complexity is far from simple, but we attempt to quantify the relative complexity of those characters (body form, skeletal architecture, and spicule form) used in traditional taxonomy of sponges. We focus on structural complexity, as opposed to functional, emphasizing pattern over process, and attempt to measure the overall differentiation of these characters within clades. We quantify, albeit crudely, sponge skeletal complexity, defined as the length of the shortest complete description of an entity, by tabulating the number of terms used to describe it. Somewhat against expectations, we find that the lexicon used to describe demosponge skeletal structure is more than two times that of hexactinellids, suggesting the demosponges are both more diverse (structurally) and species rich than hexactinellids. If one normalizes by species richness, hexactinellid complexity greatly exceeds that of both demosponges and calcareans, which could explain why molecular phylogenies better reflect traditional glass sponge taxonomy.

SICB 2013 Annual Meeting Abstracts
January 3–7, 2013, San Francisco, CA
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Developmental and genetic basis of a morphological novelty in East African chichlids

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, submerged 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 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 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. We compared the results to our previously published screens of mussels in a simulated intertidal environment. Specifically, submerged 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.

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**128.5 COON, CAC*; BRACE, AJ; MARTIN, LB; Univ. of South Florida, Tampa; ccoon@mail.usf.edu**

**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 regional alterations in bone thickness and density, which may help bats to acquire active flight. 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 regional alterations in bone thickness and density, which may help bats to acquire active flight. This study investigates this fundamental issue of how environmental factors impact the evolution of skeletal morphology and function in bats.

**65.5 COOPER, L/N*; ROSS, A/E; FOLTZ, S/L; MOORE, I/T; DAVIS , J/E; Radford University, Virginia Tech; lnoelle.cooper@gmail.com**

**Stop on Red: Neophobia and corticosterone in house sparrows (Passer domesticus)**

When confronted with novel stimuli, animals must evaluate both the stimulus itself as well as their surrounding environment. Particular stimulus traits play an important role in determining both rapidity and depth of investigatory behavior. Color is a feature which may prove to be relevant to many passerine birds, given its natural association with food, sexual display and potential danger. In previous studies we have found that house sparrows (Passer domesticus) exhibit caution in approaching red colored items, in addition to a sex difference, with males displaying less hesitance than females. Here we will discuss this work as well as recent studies on the development of red avoidance and its relationship to fledging. We will also discuss the findings from recent studies of the effect of color exposure on circulating corticosterone levels, and the relationship between individual corticosterone response profile and an individual's exploratory behavior.

**28.2 COOPER, LISA N*; SEARS, KAREN; SIMMONS, NANCY; NEOMED, Ohio, University of Illinois, Urbana–Champaign, lnoelle.cooper@gmail.com**

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**103.4 COOPER, B.S.*; HAMMAD, L.A.; MONTOTH, K.L.; Indiana University; brassco@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, scott089@ucr.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 amylidate 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 cDNA were homologous to spidroins, but the high expression of glycine−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 Smelt, 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.

1.2 COSTA, D.P.*; SCHWARZ, L.K.; MARESH, J.; ROBINSON, P.W.; CROCKER, D.E.; Univ. of California, Santa Cruz, Sonoma State University; costac@uncc.edu

**A Bioenergetics Approach to Understanding the Population Consequences of Natural and Anthropogenic Disturbance**

A major hurdle with marine mammal conservation and management is to know if and when measurable short term responses result in biologically meaningful changes in populations. We have been measuring the behavioral and energetic response of pinnipeds to environmental variations such as ENSO events, which cause reductions in prey availability, to assess their ability to accommodate to changing conditions. The ability of animals to respond to natural perturbations can be used to estimate their response to anthropogenic disturbance. Pinnipeds offer a unique system to study this question; there are extensive data on their reproductive and foraging energetics that can be coupled with their reproductive success. Long term demographic data exist that can be used to infer population consequences. Finally, they exhibit a diverse range of life history patterns from income breeders to capital breeders. First we consider whether there is a difference in the ability of capital and income breeders to accommodate to environmental perturbation. Second using northern elephant seals we integrate these bioenergetic measures to examine the coupling between short term reductions in foraging success to reproductive success and whether and when this results in a population level effect.

42.4 COVI, J.A.*; BADER, B.D.; CHANG, E.S.; MYKLES, D.L.; Univ. of North Carolina at Wilmington, Colorado State Univ., Bodega Marine Laboratory; covi@uncw.edu

**Comparative assessment of Smad expression in two models of muscle atrophy for the blackback land crab, Gecarcinus lateralis**

In decapod crustaceans, reversible atrophy of claw muscle is imperative for successful withdrawal of the claw at ecdysis. The execution of this regulated atrophy is under the control of molting hormones termed ecdysteroids. By contrast, thoracic musculature atrophies in response to unweighting, but not elevated ecdysteroids. Published data for Gecarcinus lateralis support a role for a myostatin−like factor in mediating both atrophy induced by unweighting and atrophy regulated by ecdysteroids, albeit by what appear to be different regulatory strategies. Myostatin is a member of the TGF−ß superfamily well known for its role as a negative regulator of muscle mass in mammals. Transduction of the myostatin signal between its membrane−bound receptor and the nucleus is dependent on a family of transcription factors known as Smads. Phosphorylation of R−Smad by the myostatin receptor initiates Smad activation and translocation to the nucleus. Inhibitory Smads (I−Smad) limit the duration of the myostatin signal by antagonizing the action of R−Smads. Both I−Smad and R−Smad are expressed in decapod skeletal muscle. Expression of R−Smad mRNA in both unweighted and weighted thoracic muscle did not change appreciably during a molting cycle initiated by multiple limb autotomy. However, R−Smad expression increased significantly in claw muscle during premolt and decreased over 3.5 fold during postmolt. Expression of R−Smad during a molt cycle initiated by eyestalk ablation presented a different response; R−Smad copy number decreased during premolt in claw and thoracic muscle. This suggests that R−Smad expression in skeletal muscle is regulated, in part, by a factor produced in the eyestalks. Supported by NSF (IBN−0618205)
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.

**Shaping up: Aerodynamics and evolution of butterfly wing shape**

Wing shape is likely to be an important factor in aerodynamic force production and efficiency in insects. Despite a wealth of studies on wing shape in both birds and bats, however, relatively few studies have investigated the importance of wing shape for insects. For 270 species of butterflies (Rhopalocera), we extracted wing outlines from images of male specimens. For each of these wing outlines, we calculated wing centroid and aspect ratio values, as well as estimating body mass and wing loading from specimen images. Wing centroid and aspect ratio vary systematically with body size, with a smaller wing centroid and higher aspect ratio associated with larger body size in butterflies. Lower wing centroids are also strongly associated with higher wing loading. Comparative analysis shows these relationships are independent of the phylogenetic history of the species studied. Finally, steady-state computational fluid dynamics analysis of the same wing shapes across a range of Reynolds numbers confirms that wing shape has a strong influence on aerodynamic efficiency of wings. This study indicates that wing shape (a) has phenotypic consequences for insect flight performance and (b) shows strong variation across species, and is thus an excellent candidate for future comparative studies on insect flight performance.
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.

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 anlagen 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 anlagen 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.

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.

Chondrichthyes: investigating the roots of the chimaeroid cranial condition

Chondrichthyes includes elasmobranchs and holochelopans, 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 Deltoptichius, a Lower Carboniferous holocelaphan, while excavating the fossil fish site at Bearsden, Scotland (Serpukhovian: ~326–318 Ma). Deltoptichius 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 dermocranium. Additional comparisons with recent chimaeras and early chondrichthysans such as Chondrichelys, iniopterygians, and Pucapampella, allowed us to investigate character transformations that occurred during the evolutionary history of this group. Deltoptichius shares with modern holocelaphans 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 holocelaphan taxon.
The Cotyledon 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 Ophioplatus filograneus was examined. Arm tips, cleaned of soft tissue, were studied using scanning electron microscopy. Vertebral ossicles originate under the ocular in half. The two ambulacral ossicles grow towards each other; the stem branches and eventually interdigititate like a three–dimensional jigsaw puzzle. As vertebrae 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 interdigitation of ambulacral ossicles forms an immobile joint, a gomphoid synarthrosis, joining vertebral ossicles in echinoids. We examined the gomphoid synarthrosis in vertebral 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 O. filograneus vertebræ is not, however, strengthened in this way. Other ossicle systems in echinoderms reported to fuse include compound plates and auricles of Aristoteles lantern in echinoids, genital plates of irregular echinoids, the circumboreal ring of brisingid asteroids, and infraorbital 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.

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 clades of brachyuran crustaceans, 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 placodocid Placodus sp., were also analyzed and compared to the predicted optimal tooth shapes.

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

Lindsey Crockett 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 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-migration moult score 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.
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.

Can exaptation facilitate terrestrial invasion? Oral kinematics of two suction feeding gobies (family Gobiidae) 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.
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 eggshells 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. Both the number and volume of meiofaunal organisms consumed decreases with predator standard length, suggesting strong reduction of meiofauna in the diet around a predator size of 25 mm. The use of different prey response variables to characterize a diet shift, with insights into the potential roles of morphology and behavior driving this particular diet shift, will be discussed.
38.4 DALTOn, B. E. *; CRONIN, T. W.; CARLTON, K. L.; RANA. We then examine the cane toad in vitro passive and active DAVIES, S*; DEVICHE, P; Arizona State University; DANOS, N*; AZIZI, E; Univ. of California, Irvine; . We exposed captive birds to long days to stimulate the KEGG database. Further analysis of metabolic profiles, in from early blastemal, and early and late proecdysial limb buds using contains putative isoforms not detected through cDNA library databases are both BLAST and keyword searchable. The database gives generated pilot transcriptome profiles to examine steady state Among crustaceans, genomic and RNA−seq datasets are limited. We are tightly coordinated with the molt cycle, i.e. accompanied by distinct fluctuations in circulating ec dys steroid titers, providing a phase. These phases, 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 just 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; sunetra.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 proliferating 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 ec dys steroid titers, 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 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 ec dys steroid responsiveness, should provide information on gene pathways subject to ec dys steroid control.

100.1 DANOS, N*; AZIZI, E; Univ. of California, Irvine; ndanos@uci.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 hypothalamicpituitarygonadal (HPG) axis remains poorly understood. We examined the effect of food availability on the HPG axis of adult male Aberts 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, or two weeks of food restriction followed by two weeks of ad lib food. Two weeks of food restriction decreased body mass, furcular fat, and pectoral muscle. Food availability had no effect on the number, area, or optical density of gonadotropinreleasing hormone (GnRH−I) cell bodies, or the optical density of GnRH−I fibers in the median eminence (ME). Treatment also had no effect on the number or optical density of gonadotropin-inhibitory hormone (GnIH) cell bodies, 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; an androgen−sensitive secondary sexual characteristic) was a function of food availability, with food restriction decreasing CP width and reinstating ad lib food increasing CP width. Thus, food availability affected the HPG axis, but this influence was specific to some components of the axis. Specifically, food restriction may affect the HPG axis by increasing GnIH secretion and decreasing T secretion.
54.4 DAVIES, S/W*; TREML, E; KENKEL, C/D; MATZ, M/V; University of Texas at Austin, The University of Queensland; davis4s@kennesaw.edu

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 predict the growing 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 reef 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 genetic 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.

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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 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.

S2–1.3 DAY, Troy; Queen’s University; tday@ mast.queensu.ca

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.

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The deep homology of the tetrapod limb: Combining fossil and genetic datasets.

The evolution of tetrapod limbs from fish fins was a significant functional shift. But how significant was this shift in terms of morphology and gene regulation? The fossil record provides insight into the morphological changes. However, to understand the underlying mechanisms we must peer into the gene regulatory networks of living vertebrates. Until recently, data from gene expression and functional studies in tetrapods and teleosts supported the notion that the distal region of the tetrapod limb, the autopod (wrist, ankle, and digits), was an evolutionary novelty. In contrast, the fossil data suggests that the autopod was already present in fish fins prior to the origin of tetrapods, and was subsequently modified for new adaptive roles in terrestrial locomotion, feeding, and support. Data from phylogenetically more basal extant taxa has helped to reconcile these datasets. Hox genes encode transcription factors that provide positional identity along animal axes, including the axes of the fins/limbs. Our analysis of Hox expression in a basal actinopterygian, the North American paddlefish, Polyodon spathula reveals patterns of expression long considered to be developmental hallmarks of the autopod and shown in tetrapods to be controlled by a digit enhancer regulatory region. But we also observe differences: For example, in Polyodon, early and late phases of HoxD expression overlap proximodistally, whereas in tetrapods these phases are spatially segregated. These data demonstrate that aspects of Hox expression once considered unique to autopod space, in fact, ancestral to tetrapod limbs. However, our data also show that tetrapod limbs exhibit a unique regulatory context different in key ways from the fins of fish. Together, these results suggest that novelty in the tetrapod limb has arisen by changes in regulation of an ancient and conserved pattern of gene expression.
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.

Hox genes encode transcription factors that play essential roles in anterior–posterior patterning during the development of most metazoans. While most research has concentrated on their involvement in body plan specification during development, their role in regeneration following removal of body segments has only recently begun to be investigated. *Capitella teleta*, a polychaete annelid, displays spatial and temporal co–linearity of Hox genes in both larval and juvenile stages. *Capitella* is also able to regenerate posterior segments following amputation and continually generates segments from a posterior growth zone throughout its life. We are investigating the role Hox genes play in these processes. We examined expression of 11 of the 12 known *Capitella* Hox genes in 14 day juveniles and compared them with previously described expression patterns in 3 day juveniles. At both stages, Hox genes are expressed in the ventral nerve cord ganglia in discrete yet overlapping domains along the anterior–posterior axis. However, a subset of patterns differ between 3d and 14d juveniles. Following amputation of 14d juveniles, certain Hox genes show dynamic expression patterns while the expression of others is unchanged. Expression of Hox genes in regenerating tissue is preceded by onset of cell proliferation and expression of various putative stem cell markers, such as *vasa*, *nanos* and *piwi*. This indicates that following initial proliferation and cell specification of precursors, at least some Hox genes are likely involved in patterning the regenerating ventral nerve cord. These and further investigations will not only reveal the importance of the Hox code in *Capitella* regeneration, but will also shed light on the evolution of patterning during regeneration.

Ecologist and physiologist are familiar with Hutchinson's notion of ecological niche, the multidimensional space delineated by the range of resources in which a species survives and reproduces. Yet, few of us are used to include time among the critical orthogonal axes that define this multidimensional space. Recent studies have shown that the time allocation to specific physiological and behavioral functions is likely critical for survival. The pattern of activity of individuals in the wild can change dramatically and studies in our laboratory have shown that these temporal niche switches may be based in radically different physiological mechanisms. I will discuss the notion of temporal niche, the importance of temporal niche switching and present data on the underlying mechanisms determining the temporal niche of a species.
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**Performance of Thunniform Propulsion: A High Bio–fidelity Experimental Study**

Tunas, lannid 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 narrow necking of the caudal peduncle and high aspect ratio lunate tail that generates lift–based thrust. For these unique reasons, TP has received considerable attention from biologists and engineers. TP is assumed to have the highest propulsive performance (PP) of all swimming modes, meaning high propulsive efficiency at fast swimming speeds. However there is no direct empirical evidence to support this common idea, due to the difficulty of obtaining force measurements for these animals. Consequently, indirect approaches are used, such as theoretical and experimental studies. But these experiments oversimplify the animal (motion, shape or material property) and/or the flow condition. Our goal was to assess the PP of the Atlantic bluefin tuna, Thunnus thynnus, which is our case study for TP, by an experimental approach of the current highest bio–fidelity. A computed tomography scanner and a polyjet® 3D printer were used to make two tail models: one with materials of similar properties than the in vivo measurements and a rigid one. Each model was actuated in a water tunnel by a computer controlled, motorized system to follow motion paths typical for a tuna. Propulsive efficiencies and thrust coefficients were calculated from the forces and torque measurements for each motion regime. Vortex shedding was visualized by means of digital particle image velocimetry. In conclusion, the PP of other animals and propellers were compared with our results, and major parameters responsible for this enhanced performance were identified.

**107.6 DEMES, KW*; PRUITT, JN; HARLEY, CDG;**
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**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 tissues which compose them. In mechanically stressful habitats, intraspecific 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 lead 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–thinning, 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 has important evolutionary implications.

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**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 pulled 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 cheliosporioides*, a coraline 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 *Calliathron* 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 adhesion 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 MW. (2011) J. Exp. Biol. 214: 1571–1585.

**17.7 DEORA, T.*; SINGH, A.K.; SANE, S.P.; National Centre for Biological Sciences, TIFR, Bangalore; tanvtd@ncbs.res.in**

**A general mechanical model of the Dipteran thorax**

The evolutionary miniaturization of body size in diverse insects means that their wing beat frequencies have to substantially increase to meet the aerodynamic requirements of flight. In many cases, wing beat rates can 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.
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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 clade uniting amniotes and aganthans; 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 amniotes such as mice, in the jaw primordia of S. canicula.

**18.4 DES ROCHES, S.; TORRESDAL, J.; MORGAN, T.; BRINKMEYER, M.; HARMON, L.J.; ROSENBLUM, E.B.; University of Idaho, University of California, Berkeley; simone.desroches@gmail.com**

**BEYOND BLACK AND WHITE: COMPARATIVE ECOMORPHOLOGY IN THREE RAPIDLY EVOLVING LIZARD SPECIES AT WHITE SANDS**

Determining which traits enable organisms to colonize and persist in new environments is crucial to understanding adaptation and ecological speciation. Selection can simultaneously act on morphology and behaviour to influence performance. We investigated ecomorphological change during adaptation and incipient ecological speciation for three lizard species in New Mexico that have white and dark forms on White Sands and the surrounding Chihuahuan Desert, respectively. For each species, we compared morphology, startle response behaviour (to a simulated predator), and sprint speed performance (on white sand or dark soil substrate) between colour forms. In all species, the two colour forms exhibited differences in morphology (e.g., body size, limb length) and startle response (on matched and mismatched substrates). Sprint speed also differed between forms on alternate substrates. Although not related to morphological differences between forms, speed was influenced by startle response on alternate substrates in two species: individuals that sprinted immediately when stimulated achieved a faster maximum. Our results demonstrate a relationship between performance and behaviour in White Sands lizards and their dark soil counterparts suggesting that differences in behavioural response across populations may be important during ecological speciation. More generally, our results demonstrate the importance of examining the effect of both morphology and behaviour on performance.

**69.3 DETRICH, H.W.*; YAN, Y.L.; TITUS, T.; ALLARD, C.; ALBERTSON, R.C.; PÓSTLETHWAIT, J.H.; Northeastern Univ., Boston, Univ. of Oregon, Eugene, Univ. of Massachusetts, Amherst; icenun@neu.edu**

**Evolutionary developmental biology of notothenioid fishes: through the genomic looking glass**

Comparative genomics provides a global perspective of the evolutionary changes in developmental programs that control phenotypic diversity among related organisms, and many of these naturally adaptive phenotypes mimic deleterious human diseases. Some Antarctic fish provide an evolutionary mutant model for osteopenic diseases of elderly humans. Ancestral notothenioid fish were benthic and lacked a swim bladder, an organ of buoyancy. As the Southern Ocean cooled to ~1.9°C, notothenioids filled pelagic niches left vacant by local extinction of other species by evolving strategies to reduce body density, including decreases in bone mineral density in several clades. To identify genes causing the adaptive demineralization of bone in Antarctic fish, which may be orthologous to genes responsible for low bone mineral density in aging humans, we are comparing the molecular genetics of skeletal development in embryos of the robustly ossified, benthic Bullhead notothen, *Nototherina coriceps*, and of the osteopenic, bentheoplagic Blackfin icefish, *Choneocephalus aceratus*. First, we have generated reference transcriptomes for the two species by sequencing total cDNA from multiple bones and soft tissues by RNAseq. Second, we have cultured embryos of the two species and sampled them at intervals to obtain stage-specific total mRNA. Cross-comparison of the reference-normalized developmental cDNA samples will enable us to identify the molecular–genetic basis of the evolution of osteopenia by the icefish, and our results may provide clues to age–related osteopenia in humans. Support: NSF grant ANT–094517 (HWD); NIH grant R01AG031922 (JHP, HWD, RCA).
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... Here, we report findings from a 4-year project with the Pseudoceratina (sp.). A third species represents another askeletal genus of DIAMOND, SE*; Pelini, SL; Ellison, AM; Gotelli, DJ; DIAL, KP*; Martin, TE; Univ. of Montana, Missoula; cf. sp.) were consistently some of the strongest outliers, Anomoianthella Suberea is placed as a separate clade. This phylogenetic variance in ant responses to warming, we found that carpenter ants occupying conditions well below their thermal limits. We further... change owing to environmental temperatures being close to their... ability of physiological tolerance of extreme temperatures in... species, we cannot develop predictions for how each species might... to environmental novelty. However, because these changes are... 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.

S6–1.6 Diamond, SE*; Pelini, SL; Ellison, AM; Gotelli, NJ; Sanders, NJ; Dunn, RR; North Carolina State Univ., Bowling Green State Univ., Harvard Forest, Univ. of Vermont, Univ. of Tennessee; sarah_diamond@ncsu.edu

Using physiology to predict ectotherm responses to environmental change

Over changes in land–use and climate ensure that species are increasingly likely to encounter novel environments. This places a renewed urgency on understanding biological responses to environmental novelty. However, because these changes are occurring at a global scale with potential impacts on millions of species, we cannot develop predictions for how each species might respond. Rather, we need a predictive framework that reduces the dimensionality of this task by identifying key characteristics of those taxa and regions that are most at risk. We focus on the predictive ability of physiological tolerance of extreme temperatures in ectotherms. Here, we build upon our previous work showing that ants inhabiting lower latitudes tend to be at the greatest risk under climate change owing to environmental temperatures being close to their thermal limits. Among our two large–scale experimental warming arrays, positioned at the northern and southern boundaries of temperate hardwood forests in eastern North America, ant thermal tolerance was strongly predictive of ant responses at the low latitude site where temperatures routinely exceed ant thermal limits, but not the high latitude site where temperatures remain below ant thermal limits. While thermal tolerance explained a substantial portion of the variance in ant responses to warming, we found that carpenter ants (Camponotus sp.) were consistently some of the strongest outliers, occupying conditions well below their thermal limits. We further dissect the mechanisms underlying carpenter ant responses to warming, focusing on additional physiological traits including immune defenses and species interactions between ant hosts and their symbionts.

S8–2.1 Diaz, M.C*; Thacker, R.W.T; Redmond, N.; Collins, A.G; Museo Marino, NE, Venezuela, U. Alabama at Birmingham, USA, NMNH, Smithsonian Institution, USA; taxochica@gmail.com

Don't judge a book by its cover: Discovering two new Verongida genera (Class Demospongiae, Porifera)

Integrating morphological and molecular data is crucial when morphological characters are absent, or poorly represented, requiring genetic evidence to discern species identity and relationships. Among hundreds of specimens collected by the PorToL project were two morphospecies lacking any evidence of skeletal elements, one from Panama, the other from Moorea. Histological and molecular (18S) evidence were gathered to identify them. Histological sections of the Panama material corroborated the absence of any skeleton, and showed the existence of large, sac–shaped choanocyte chambers. The 18S analysis revealed that this species is allied with members of Ianthellidae (Verongida), which includes three genera with a total of 19 species, none present in the Caribbean. This species has a sister group relationship to a clade containing the skeleton–bearing Ianthellidae (Ianthis and Anomoianthella), while the third askeletal genus Hexadella is placed as a separate clade. This phylogenetic information supports the erection of a fourth genus for this family. Histological sections of the Moorea material revealed representatives of three genera among the samples initially considered to represent a single species. One showed the presence of amorphous, pith–dominated fibers (Pseudoceratina cf. purpurea) and another showed the existence of rare single fibers with pith and bark (Suberea sp.). A third species represents another askeletal genus of Verongida, placed within a clade of Aplysinellidae and Pseudoceratiniidae by 18S analyses. These findings demonstrate the importance of complementing the histology of askeletal sponges with genetic information that can clarify the real affinities and/or identities of the taxa.
Endocannabinoid regulation of glucocorticoids in 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 system 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 (TnA), 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 TnA 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.

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 mancullatus) 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).
The Genetics 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 New Jersey and represents a possible range expansion past their northern-most limit in Delaware. Subsequent reports of this species have been documented in Illinois and recently metamorphosed tree frogs have been collected throughout the species range are being analyzed in order to place the new NJ population in the context of species-wide studies. Based on mtDNA data, the new population was established via colonization by Delaware tree frogs, and genetic analyses were undertaken. The NJ population was established via colonization by Delaware tree frogs. MJM.

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 (carnivorous, veliger larva, barnacle nauplii and copepod larvae) affect the forces they experience while swimming in the water column, and while 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 reoriented 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.
**Escape responses in fishes**

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.

**Developing molecular techniques to assess resilience in large benthic foraminiferan communities**

Large benthic foraminifera (LBFs) compose a significant portion of calcareous sediments in coral reef ecosystems, buffering against die-back 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 Baculogypsina sphaerulata collected from intertidal algal flats of the coral island Xiao Liu Chiu, Taiwan. Data indicated reduced protein secretion and molt. Moreover, regardless of the light treatment city birds developed their testses earlier than forest conspecifics. In 2012, birds under light at night developed their testses up to one month earlier than control birds kept under dark nights. The same effect was detected in the timing of testosterone secretion and molt. Moreover, regardless of the light treatment city birds developed their testses earlier than forest conspecifics. In 2012, birds under light at night kept their reproductive system shut down for the entire spring and did not molt, whereas control birds showed the same timing of reproduction and molt of 2011, with city birds being earlier than forest birds. In conclusion, here we show that i) light at night can advance timing of reproduction and molt and ii) chronic and long-term exposition to light at night can suppress fitness-relevant life-history stages such as reproduction and molt. Our results emphasize the impact of human-induced lighting on the ecology of hundreds of millions of animals living in cities and call urgently for an understanding of the fitness consequences of light pollution.

**Escape responses in fishes**

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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–amniote tetrapods, teleosts, and cartilaginous fishes. From these comparisons it is possible to reconstruct the functional evolution of the melanocortin–2 receptor, a critical component in the HPA/HPI of teleosts and tetrapods.

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 patterns of physiological and 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.

Mechanical interactions between organisms and their environments are integral to locomotion, but mechanical responses of soils and sediments to forces applied by burrowing organisms are poorly understood. Recent work has shown that muddy sediments are elastic solids through which animals extend burrows by fracture. However, *Armandia brevis*, a mud–burrowing ophelid polychaete annelid, lacks an expansible anterior consistent with fracturing mud, and instead uses undulatory movements to burrow. Here we show that A. brevis neither fractures nor fluidizes sediments, but instead uses a third mechanism, plasticly rearranging sediment grains to create a burrow. In addition, the curvature of the undulating body fits meander geometry used to describe rivers, and changes in curvature over time driven by muscle contraction are similar for swimming and burrowing worms, indicating that the same gait is used in both media. Large calculated friction forces for undulatory burrowers suggest that sediment mechanics affect undulatory and peristaltic burrowers differently; undulatory burrowing may be more effective for small worms that live in sediments not compacted or cohesive enough to extend burrows by fracture.
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 fuelled 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 low glycerol upon transiting the gill. Upon passage through the liver circulation the RBCs should reload at high extracellular glycerol levels.

Mechanics of bat vocal folds

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⁻¹°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 = 35.11) and resistance significantly lower (p<0.0001, F = 54.21) 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 conduct 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.

Evaporative Heat Loss

Although the use of mineral licks by diverse Amazonian birds and mammals is well known, the ultimate motivation for such behavior remains unclear. Because aerosol deposition of salts declines with distance from oceanic sources, lick visitation in the western Amazon can best be explained by demand for salt given the low concentration of this micronutrient in the plant tissues consumed by these taxa. Empirically, we have shown that sodium limitation influences anti–foraging behavior, and impinges via effects on microbial and invertebrate decomposers on ecosystem rates of carbon cycling. The biogeographical context of sodium availability has been largely overlooked but has substantial pantropical implications for herbivore and decomposer performance in inland rainforests.

Phylogenetic analyses of gene expression have great potential for addressing a wide range of questions. They will, for example, provide new tools for understanding the relationships between genes and phenotypes by identifying genes that have evolutionary shifts in expression that are correlated with evolutionary changes in morphological and developmental characters of interest. There are a variety of challenges that must be addressed for such studies to realize their potential. There are the technical challenges of measuring gene expression that confront any investigator working with non–model organisms, including the isolation of high quality RNA and assessing biological variation in field–collected samples. The other major set of challenges is to develop comparative methods suitable for phylogenetic analysis of large multidimensional datasets. In most comparative studies, the number n of samples (independent contrasts) has been greater than the number p of variables (characters). The behavior of comparative methods for these classic n greater than p problems is now well understood under a wide variety of conditions. In gene expression studies, and studies based on other high–throughput tools, the number n of samples is dwarfed by the number p of variables. These new n less than p comparative analyses raise a variety of challenges. In particular, the covariance matrices are non–invertible. This precludes some standard analysis methods, and raises the risk that observed covariances are an artifact of the limited number of samples rather than actual relationships. A variety of developments in other fields where non–invertible covariance matrices are obtained are directly relevant to these challenges in comparative analyses.

Food intake in vertebrates is under the regulation of appetite stimulating (e.g. neuropeptide Y, ghrelin) and appetite inhibiting (e.g. corticotropin–releasing hormone) signals in the brain. The efficacy of these brain signals are influenced by environmental and social factors as well as the hormonal milieu within the animal. Previous work has established that stress and cortisol consistently decrease food intake in fish. However, the link between cortisol and appetite is not well understood in any species of fish. The response to acute stressors is likely adaptive, but when exposed to chronic stress, the adaptive value might be lost. A recent report from our laboratory has shown that a single injection of cortisol decreased food intake in tilapia, which appears to be mediated by a reduction in the ghrelin signaling pathway via NPY in the telencephalon region of the brain. The present study was designed to test the direct effects of cortisol on regions of the brain known to regulate appetite. The telencephalon and hypothalamus were individually dissected from tilapia and cultured separately in cortisol–containing media for 24 h. Following treatment, mRNA levels of genes involved in appetite regulation were quantified from each brain region. In the telencephalon, cortisol decreased NPY mRNA levels while increasing the ghrelin signaling pathway. In the hypothalamus, cortisol decreased CRH and NPY mRNA levels. This study is novel because it is the first to report the direct effects of cortisol in fish. Furthermore, these data suggest that the direct actions of cortisol on appetite might be mediated by a decrease in NPY and hypothalamic CRH as well as an increase in the ghrelin signaling pathway in the telencephalon. Supported by USDA to LGR.
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 catabolizing 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. otoccipital) 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 developed 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.
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, 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; $10^{-7}$–$10^{-4}$ 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 25.5°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.
113.1 EDWARDS, TM; Louisiana Tech University; tedwards@latech.edu

Estrogenic Plant Flavonoids

Our lab has shown that 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-taxa 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.

106.5 EERNISSE, D.J.; BROOKER, L.R.; Cal State Fullerton, Univ. Sunshine Coast, Qld.; deernisse@fullerton.edu

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 they 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 Toniciidae or Acanthopleuridae 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 again different with likely unrecognized species diversity. Improved phylogenetic and biogeographic resolution will allow us to relate variation in ocelli to the pattern of evolutionary diversification.

95.2 EDWARDS, JE*; LAILVAUX, SP; University of New Orleans, Louisiana; edjesiccaedwards@gmail.com

Sexual Interactions between female pairs and male pairs of Anolis carolinensis and Anolis sagrei Lizards

The introduced lizard Anolis sagrei is known to commonly replace Anolis carolinensis as the most abundant anole of urban areas and other open environments. Although studies of interspecific interactions typically focus on males, interactions between females also might play an important role in shaping habitat use within multi−species communities. To measure interspecific aggressive behaviour in each sex, we caught 90 A. carolinensis and A. sagrei males and females of various sizes and randomly matched female−female and male−male pairs in staged interspecific interactions in lab. We examined whether species identity, bite force, dewlap size and body size affected the outcome of interspecific interactions, and tested the prediction that bite force and size would be the most important determinants of interaction outcomes in both sexes. Preliminary analyses suggest that interactions between female conspecifics may potentially play a larger role than interactions between males.

123.3 EGGE, AR*; NOH, S; ELLER, OC; HAHN, DA; MORGAN, TJ; Kansas State University, University of Florida; aegge@ksu.edu

Physiological and Genomic Variation in Rapid Cold Hardening and Developmental Acclimation in Drosophila melanogaster

Adaptation and plastic responses to daily and seasonal fluctuations can lie in both long− and short−term adaptive responses controlled by functional regions of the genome. The rapid cold hardening response (RCH) and the developmental acclimation response (DACC) are two types of acclimation that have been widely explored. RCH manifests itself as an increase in survivorship or fitness of an organism following a pre−treatment of minutes to hours at a cooler temperature before exposure to a cold shock temperature, while DACC pre−treatment spans egg−to−adult development. Full physiological and genetic analyses of the variation in RCH and DACC have yet to be explored. Drosophila melanogaster is a cosmopolitan species often used as a model organism for tracking genetic responses to environmental stresses and adaptation. Our research focuses on the comparison of short (RCH) and long term (DACC) cold acclimation in the Drosophila Genetic Reference Panel (DGRP) to determine the genetic and physiological sources of variation among lines of natural Drosophila melanogaster. Each line was reared at both 18° C and 25° C, and tested for survivorship at a one−hour cold shock and a two−hour RCH pretreatment followed by a one−hour cold shock to determine the RCH and DACC responses. There was significant genetic variation among the lines for both short− and long−term acclimation responses. The phenotypic responses did not share any significant SNPs across the DGRP genomes, although RCH at 25° and DACC were phenotypically correlated among the DGRP lines. Functional mutation analysis has confirmed the functional role of several associated candidate genes in short or long−term cold acclimation responses.

January 3−7, 2013, San Francisco, CA
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 \( a \) and \( a \) adrenergic tonus, but with greater potency for cholinergic and serotonergic vasoconstriction, in Antarctic nototheniids 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 nitrodiators 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 nototheniids, showed both similarities and differences making simple inferences about phenotype vs. genotype difficult. In light of a reduced importance for the classical adrenergic and nitroergic 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 nototheniids and non–nototheniids, 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 artery 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 airway 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 experience 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.

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. marsupialis, 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. quadrumanus and T. haplonema) seasonally local to North Carolina. Differences in facilitation properties were found between muscle sheets as well as different size classes of the same species. These results may offer clues to the functioning of different muscle sheets in executing complex swimming behaviors.

Hyperlid amphipods in the Eastern Tropical Pacific migrate across a temperature gradient of 10 degrees or more and spend daytime at oxygen levels less than 5µM. 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 ± 0.47 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.
Elzinga, M. J.*; Dickinson, M. H.; California Institute of Technology; University of Washington, University of Washington; elzingam@caltech.edu

The ability to regulate forward speed is an essential capability for flying animals. Here, we use a dynamically scaled robot to gain insight into how flapping insects adjust stroke features to regulate and stabilize level forward flight. The results suggest that few changes to hovering kinematics are actually required to meet lift and thrust requirements, and the primary driver of equilibrium velocity is the aerodynamic pitch moment. This finding is consistent with prior hypotheses and observations regarding the relationship between body pitch and flight speed in fruit flies. We considered three different deformations of hovering wing kinematics, which were inspired by previous experimental studies and that result in the generation of a pitch moment: a shift in the mean stroke position, upstroke to downstroke differences in stroke deviation. The results suggest that a shift in the mean stroke position is a likely candidate for trimming the pitch moment at all speeds, whereas shifts in the wing rotation angle are required only at high speeds. The results also show that the dynamics may be stabilized with the addition of a pitch damper, but the magnitude of required damping increases with flight speed. We posit that differences in stroke deviation between the upstroke and downstroke play a critical role in this stabilization. Fast mechanosensory feedback of the pitch rate enables active damping which becomes inherently gain scheduled with flight speed when pitch torque is generated by differences in stress. This provides an elegant solution for flight stabilization across a wide range of flight speeds.

52.5 Elsberry, L.A.*; Burnaford, J.L.; California State University, Fullerton; lelsberry@fullerton.edu

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 Endocladias 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 alga 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 (winter=10°C, 20°C, 30°C; summer=20°C, 30°C, 40°C). We quantified netling 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 47 post−hatch. We found that the rate and duration of begging of all netlings in the CORT treated nests was greater than that of netlings in food supplemented and control nests. In addition, the adults with CORT treated netlings in their nest visited a greater number of times per hour and fed netlings more frequently than did controls. Individual netling behavior and data on netling baseline and stress−induced CORT levels (collected on Day 11) will also be discussed.

132.5 Elderbrock, EK*; Small, TW; Schoech, SJ; Elsberry, L.A.*; Burnaford, J.L.; University of Memphis; kldrbrck@memphis.edu

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 netling's nutritional needs. When a netling 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 individuals corticosterone (CORT) levels, a hormone known to influence begging and parental behavior. We studied the role of food availability by indirectly supplementing all netling 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 netling per assigned CORT treated nest a CORT−injected wax worm twice−daily for 4 days (Days 8−11 post−hatch) and a second netling in the same nest a vehicle−injected wax worm. We quantified netling 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 47 post−hatch. We found that the rate and duration of begging of all netlings in the CORT treated nests was greater than that of netlings in food supplemented and control nests. In addition, the adults with CORT treated netlings in their nest visited a greater number of times per hour and fed netlings more frequently than did controls. Individual netling behavior and data on netling baseline and stress−induced CORT levels (collected on Day 11) will also be discussed.

83.3 Eliasön, C.M.*; Maia, R.; Shawkey, M.D.; University of Akron; cmel16@uakron.edu

Color evolution and interspecific variation in the wings of ducks

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.
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.

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.

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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.
Sexual patterns in fishes are incredibly diverse compared to other vertebrates, as hermaphroditism is taxonomically widespread and takes on many forms including simultaneous, protogynous, and protandrous hermaphroditism, bi-directional sex change and androdioecy. The proximate mechanisms that influence the timing, incidence, and forms of hermaphroditism in fishes are supported by numerous theoretical and empirical studies on their mating systems and sexual patterns, but few have examined aspects of sex allocation theory within a phylogenetic context. However, comparative phylogenetic reconstructions of the evolutionary history of several families of teleost fishes have begun to emerge and are providing clues regarding the mechanisms that have shaped the evolution of sex allocation in animals. For example, evolutionary transformations from protogynous to gonochorism in groupers (Epinephelidae) are associated with equivalent transformations in mating group structure from paired to group spawning, and sperm competition is considerably higher in gonochoristic species than in protogynous species. These results provide explicit phylogenetic support for predictions of the size advantage model (SAM), demonstrating that selection for protogynous sex change decreases as mating group size and sperm competition intensity increase. Comparative analyses of sex change in wrasses (Labridae) provide further support of the SAM and suggest that male size advantage drives the evolution of protogynous sex change. Finally, phylogenetic reconstructions of sexual patterns in seabasses (Serranidae) indicate that sexual patterns in fishes can evolve in several directions within single lineages and do not require functional intermediates.
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 (SFB), 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 habitat, competition with and predation from non-native species, as well as contaminants and poor water quality have been attributed to this decline. This presentation will draw from our recent studies on ESA–listed fish species: delta smelt (Hypomesus transpacificus), green sturgeon (Acipenser medirostris), and chinook salmon (Oncorhynchus tshawytscha). The delta smelt is an endemic SFB species with an annual life cycle and distinct life stages each with unique tolerances to salinity, turbidity, temperature and these factors in combination. Both green sturgeon and Chinook salmon are anadromous species that migrate through the SFBD and spawn in the associated watersheds. Adults and young–of–the–year encounter small– and large–scale agricultural and/or municipal water diversions during migration and entrainment risk is an understudied but significant source of mortality. We will highlight how physiological and behavioral studies that consider multiple and potentially interacting stressors are not only mechanistically revealing, but are necessary to define the habitat requirements of endangered species to aid resource managers in making informed decisions in support of fish conservation.

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 (Sida nebovaxii, Sialia sialis, Sialia mexicana). After sequencing, we enriched an average of 4,160 (95 CI = 93) 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).
Post-synaptic Density (PSD) and Axon Guidance Genes in the Transcriptomes of 8 Sponges

Sponges are morphologically simple metazoa that lack nerves or any form of synapse, yet the genome of the sponge Amphimedon possesses nearly all the genes required for synaptic communication. It is possible that Amphimedon is unusual among sponges in either lacking clearly identifiable synapses or in possessing PSD genes that are used for other functions. Here we report on findings from the transcriptomes of 8 sponges which represent all 4 sponge classes: Hexactinellida (Aphrocallistes vastus), Calcarea (Sycon cactus), Homoscleromorpha (Corticium candelabrum), and Demospongiae (Spongilla lacustris, Petrosia ficiformis, Pseudospongos suberitoides, Ircinia fasciculata). We used HMmer and BLAST search tools to find gene homologs in each of the transcriptomes and confirmed gene identity by phylogenetic analysis. As in Amphimedon, all 8 sponge transcriptomes possess many of the PSD genes. Among the sponges, Aphrocallistes shows the greatest number of PSD gene absences. Furthermore, while Amphimedon lacks ionotropic glutamate receptors (iGluRs), Corticium, Sycon and Ircinia have genes which Blast to iGluRs and contain motifs present in these channels. We also searched the transcriptomes for classical axon guidance molecules. Molecules identified in some sponge transcriptomes include netrin, deleted in colorectal cancer (DCC), unc5, neogenin, slit, robo, semaphorin, neuropilin and the cell adhesion molecule, DSCAM. The widespread presence of synaptic and neurodevelopmental molecules in sponges strongly implies these molecules functioned in other pathways or systems before being coopted into the neural tissues and systems of other metazoa, or that sponges lost neuronal tissues.
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 hypoxia. 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-series. 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 suggest the pulmonary bypass shunt, by admixture of deoxygenated and oxygenated blood, reduces blood oxygen tension and limits oxidative damage to systemic tissues. Palaearctoatmospheric 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 bird must have necessitated upregulation of antioxidant expression. Funded by NSF grants IOB 0445680 and IOS 922756 to JWH.
3.6 FISH, F E*; NEAL, D; FONTANELLA, J E; DINESSO, N; GABLER, M K; West Chester Univ., Pennsylvania, LaVision, Michigan; fish@wcupa.edu

Flow patterns associated with swimming motions of hentic and pelagic batoids as visualized with DPIV

Batoid 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 propulsive 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 rays 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 correlated with swimming speed for each swimming mode, buoyancy control and with proximity to the bottom.

126.2 FITZES , JS*; PARKER COLLIER, SM; OSWALD−RICHTER, KA; RAMSEY, JR; GAMMILL, WM; ROLLS−SMITH, LA; Vanderbilt University, James Madison University, Jeffreys.fitzes@vanderbilt.edu

Batrachochytrium dendrobatidis, an emergent pathogen linked to amphibian declines, produces factors that inhibit adaptive immunity in amphibians and mammals.

Batrachochytrium 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, Homolaphylaxis 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

144.3 FISH, JL*; DEPEW, MJ; MARCUCIO, RS; Univ. of California, San Francisco; jennifer.fish@ucsf.edu

Developmental influences on variation and asymmetry of the jaw

 Evo−devo as a discipline seeks to understand how variation is generated in a way that can influence evolution. Variation is a salient feature of both normal and abnormal development, but the mechanisms responsible for its generation are largely unknown. We investigate developmental mechanisms generating variation in the lower jaw, or mandible, utilizing two strains of mutant mice that exhibit variable reduction in jaw size and asymmetry, Fgf8 and Satb2. Fgf8 is a secreted signaling factor that is expressed in multiple domains of the epithelia surrounding the developing jaw. Satb2 is a transcription factor that is expressed in the mesenchyme of the developing jaw. Reduction in gene dosage of either Fgf8 or Satb2 causes micrognathia. Although both mutants exhibit asymmetry in the severity of the defects, Fgf8 mutants exhibit directional asymmetry, with the left side of the jaw more severely affected. In contrast, asymmetry in Satb2 heterozygotes is random. Further, significant reduction in jaw length is observed in mice heterozygous for Satb2 (~50% Satb2), whereas mice heterozygous for Fgf8Delta (~50% Fgf8) alleles are phenotypically normal. Micrognathia occurs in Fgf8 mutants only when Fgf8 is less than 40% (~50% Fgf8Neo/Neo mutants). Notably, Satb2−/− (heterozygous) mice have a greater variation in mandibular length relative to both WT and mutant genotypes. These data indicate a non−linear relationship between genotype and phenotype, which likely derives from random perturbations in other intrinsic factors. We discuss how differences in the regulation of Fgf8 and Satb2 may contribute to differences in their susceptibility to random developmental perturbations, and thus differences in variation in RNA and protein levels and, ultimately, jaw size.

29.2 FITZPATRICK, B. M.; Univ. of Tennessee; benfitz@utk.edu

Symbiont transmission and maintenance of interspecific disequilibrium in structured populations

Microbial symbioses might be as ubiquitous and influential as genes in the evolution and development of some plant and animal phenotypes, and in some cases (e.g., mitochondria) the line is blurred between symbiont and host. Here I explore the proposition that host−symbiont relationships lie on a continuum from the intimacy of genes and organelles to the indifference of casually co−occurring species. A key question is whether symbiont transmission is similar enough to Mendelian gene transmission to generate and maintain associations between genomes that can evolve in the same way as conventional genotypes. I show that intergenic associations can be described by the same basic models used for conventional linkage disequilibrium with one critical difference: recombination between genes ranges from 0.0 to 0.5, whereas recombination between host and symbiont ranges from 0.0 to 1.0. Thus, covariance between host and symbiont genomes depends on population history, geographic structure, selection, and vertical transmission rate, just as disequilibrium between genes within a genome. Host−symbiont coevolution can be affected by intergenic epistasis and nonrandom mating just as coevolution between genes within a conventional genome. I illustrate the theoretical continuum between multilocus genetics and host−symbiont dynamics with a simple hybrid zone model where interspecific disequilibrium is maintained by population structure, and a reformulation of a gene−culture coevolution model with humans as hosts and cattle as symbionts.
3.1 FLAMMANG, B.E.*; LAUDER, G.V.; Harvard University; bflammang@post.harvard.edu
Backwards swimming by bluegill sunfish requires multifin coordination
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 alternated 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.

11.7 FODOR, A*; KOHN, A.B.; SWALLA, B.J.; MOROZ, L.L.; Univ of Florida, Univ of Washington; zebinnin@gmail.com
Quest for Muscle Specific Genes in Pleurobrachia bachei: Had mesoderm independently evolved in Ctenophores?
The nature and development of a mesoderm in basal metazoans has been questioned for over a hundred years, with arguments based on Porifera as the most basally branching lineage and Cnidarians possessing a diploblastic body plan with myoepithelial cell. However recent phylogenetic analysis suggests that Ctenophora may be the earliest lineage of animals, yet processing true neurons and muscles and remarkably complex behaviors. To address the molecular bases of the origins of muscular organization, we searched for the presence of mesoderm and muscle specific genes in the genome of Pleurobrachia bachei. Although some well–known bilaterian myogenic transcription factors were absent in the ctenophore genome, we found and cloned several muscle markers such as tropomyosin and calponin as well as ²–catenin and ² T–Box transcription factors. Interestingly, in situ hybridization of these genes showed expression not only in the muscular regions of P. bachei, but in the epidermal tissues as well, indicating there is an unknown function for these genes in non–muscular cells. At the same time some well–defined muscles were either not labeled or the expression of relative muscular markers was relatively low. The expression patterns for selected genes were also quite variable in P. bachei embryos. Our data suggest that ctenophores might represent a unique example of parallel evolution of mesoderm and muscular organization where many features in this lineage had evolved independently from cnidarians and bilaterian animals.

57.5 FOLTZ, S. L.*; DAVIS, J. E.; ROSS, A. E.; ROCK, R. P.; MOORE, I. T.; Virginia Tech, Radford University; sarahf8@vt.edu
Food supplementation of urban and rural sparrows: effects on corticosterone, weight, and territorial aggression
Urban areas are novel habitats that present animals with new challenges and opportunities. Our previous studies on song sparrows (Melospiza melodia) in southwestern Virginia found various physiological and behavioral differences between urban and rural populations. Specifically, urban populations often have higher baseline and post–stressor corticosterone levels, lower weight, and heightened territorial aggression relative to rural populations. Because both weight and corticosterone are related to energy balance, we hypothesized that variation in food availability between habitats may drive these observed differences. To test this hypothesis, we provided supplemental food to half of the observed territories in both urban and rural habitats. Territorial aggression was assessed by a simulated territorial intrusion in which we played previously recorded male song and observed the focal birds behaviors. Birds were then caught, bled, and weighed. Surprisingly, we found no effect of habitat type or food supplementation on weight or corticosterone levels. However, rural control birds were significantly less aggressive that rural fed birds and all urban birds, indicating an effect of feeding and relationship with urbanization. Our results indicate that birds were not food–limited in this study season. However, because control birds weight and corticosterone levels did not differ between habitats, we cannot conclude whether transient food limitation may have driven habitat–related differences observed in past years. The increased aggression of rural fed birds suggests that additional food may impact perceived territory quality or interactions with neighbors in habitat–specific ways.

SICB 2013 Annual Meeting Abstracts
January 3–7, 2013, San Francisco, CA
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.

Insulin as a differential regulator of lipid mobilization in fasting northern elephant seals

Animals that experience fasting concomitant with metabolically demanding activities are presented with conflicting demands of energy savings and energy expenditure. We aimed to understand how fasting, molting northern elephant seals and fasting, lactating northern elephant seals differentially regulate the mobilization of lipid reserves and 2) how milk lipid content is understood. Fasting, molting northern elephant seals and fasting, lactating northern elephant seals differ significantly (p<0.05) with mass, adiposity, NEFA and TAG. Decreasing insulin appears to be the differential regulator of lipolysis in lactating females increasing cortisol was measured. Milk lipid increased from 31% lipid to 51% lipid over ~17 days of fasting and lactation. In lactating females increasing cortisol and decreasing insulin were significantly (p<0.05) related to NEFA levels, but in molting seals, only increasing cortisol was significantly (p<0.05) related to circulating NEFA. Milk lipid content varied significantly (p<0.05) with mass, adiposity, NEFA and TAG. Growth hormone was not related to metabolites or milk lipid. Decreasing insulin appears to be the differential regulator of lipolysis in lactating seals versus molting seals, facilitating the additional liberation of stored lipids required for milk synthesis. Milk lipid is strongly impacted by the supply of substrate to the mammary gland, indicating that the regulation of lipid mobilization from adipose reserves may be responsible for changes in milk lipid content.
Are roads a barrier to gene flow in a sand burrowing lizard, the Florida Sand Skink, Plestiodon reynoldsi?

The scrub of peninsular Florida is a highly imperiled ecosystem and home to numerous federally listed species. Effective conservation of these species will benefit from understanding how anthropogenic habitat modification alters the genetic characteristics of populations. Roads are a common anthropogenic habitat modification, and understanding their effect on local populations is important for management. Our goal is to determine if Florida State Road 40 (SR40), which bisects the Florida scrub habitat of the Ocala National Forest in northern peninsular Florida, is a barrier to gene flow in the threatened Florida Sand Skink, Plestiodon reynoldsi. The fossorial Sand Skink requires fine, well−drained sand for locomotion; thus, roads may have a direct impact on individual movement. Construction of SR40 began between 80 and 100 years ago, for which approximately 20–25 generations of the Florida Sand Skink have occurred prior to sample collection. We collected individuals (n = 44) from sites north and south of SR40 and screened them for allelic variation at 8 microsatellite DNA loci and mitochondrial DNA variation at the cytochrome−b gene. Because we know the approximate time SR40 altered the habitat of the Florid Sand Skink, we may be able to calibrate the time required for genetic characteristics of the local populations to change. We will also compare our findings to those from recent studies of the Florida Sand Skink in the southern extent of its range.

Sexual conflict during mating in red−sided garter snakes as evidenced by genital manipulation

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.

Natural occurring ranges in water quality affect early development in the sea urchin Tripneustes gratilla: implications for distribution of invasive algae

Kaneohe Bay, Hawaii has undergone rapid increases in invasive algal species. Along with this increase in algae has been the loss of a major algal grazer within the bay, the sea urchin Tripneustes gratilla. Numerous environmental factors could be driving the loss of T. gratilla across the bay that may act on different life history stages; however, little is known about these driving factors. Here we explore how naturally occurring differences in water across the bay influence T. gratilla fertilization. Results indicate using waters from some regions of the bay result in fertilization success that is 60% of that obtained using clean filtered seawater and water obtained in the open ocean. The data have shown that offshore onshore gradients exist in fertilization success. Fertilization in this species is sensitive to many environmental pollutants that are associated with terrestrial runoff, thus water quality may play a major role in the reproductive potential in these important grazers, which may cascade through the system resulting in increased algal cover and decreased coral reef health.
42.3 FUQUA, R.D.*; MONROY, J.A.; NISHIKAWA, K.C.: Northern Arizona University; rene.fuqua@nau.edu
Residual force enhancement: evidence for Ca²⁺-activation of titin

When active muscles are stretched, tension increases and then settles to a steady state that is greater than the isotonic force at the stretched length. The mechanism underlying this behavior, termed residual force enhancement (RFE), remains unknown. Previous studies have suggested that titin-based stiffness increases in the presence of Ca²⁺ and contributes to RFE. We hypothesized that the N2A region of titin binds Ca²⁺ to increase titin stiffness. To elucidate the role of the N2A region during active stretch, we tested soleus muscles from three genotypes of mdm mice, in which the mutant gene has a deletion in the N2A region. Muscles were actively stretched in two of three solutions, Krebs buffer then BDM, which prevents the formation of strongly-bound crossbridges, or Krebs buffer then dantrolene, which inhibits Ca²⁺ release. By comparing RFE of muscles in these solutions we isolated the effects of Ca²⁺ activation. BDM was used to determine if crossbridge interaction plays a role in RFE. Dantrolene was used to determine the roles of other elements in muscle that are also Ca²⁺-dependent. In all three genotypes there was no difference in RFE following stretch in BDM, suggesting that the observed increase in force is not due to crossbridge interaction. However, both wildtype and heterozygous muscles showed a decrease in RFE following stretch in dantrolene, suggesting that RFE is Ca²⁺-dependent whereas, mdm mutant muscles were not affected. Data from wildtype and heterozygous mice suggest that RFE is due to a non-crossbridge, Ca²⁺-dependent mechanism. Data from mdm mutants suggest that this mechanism involves the N2A region of titin. Supported by NSF IOS–1025806.

108.3 GAGNON, YL*; JOHNSEN, S; Duke University; yl.kay@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 extended scenes. The most suitable lenses at these depths maintain high image contrast at the viewer's cutoff 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.

126.1 GAMMILL, WM; ROLLINS-SMITH, LA*; Vanderbilt University School of Medicine; louise.rollins-smith@vanderbilt.edu
Antimicrobial peptide defenses of southern leopard frogs (Rana sphenocephala) against the pathogenic chytrid fungus, Batrachochytrium dendrobatidis

Southern leopard frogs (Rana sphenocephala) coexist in habitats in which the pathogenic chytrid fungus, Batrachochytrium dendrobatidis (Bd) is prevalent. Because this species is not in serious decline, it is likely that it possesses adequate skin defenses against this pathogen. One important innate defense is the production and release of antimicrobial peptides (AMPs) into the mucus of the skin. Four antimicrobial peptides have previously been described for this species, but their activity against Bd in growth inhibition assays has not previously been tested. We confirmed the presence of these four AMPs in R. sphenocephala adults collected in Tennessee by MALDI-TOF and tandem mass spectrometry. We showed that the natural mixture of hydrophobic peptides found in the skin mucus effectively inhibits Bd growth, and the individual pure synthetic peptides inhibited at micromolar concentrations. Injection of norepinephrine results in long-term depletion of skin peptides, and ongoing studies will determine whether peptide depletion results in greater susceptibility to Bd infection. These studies are designed to demonstrate whether AMP defenses are essential for protection of this species from Bd infections. Support: NSF grants 0843207 and 1121758 to LR-S.

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.
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 involvement 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, bottlenose 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, 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. 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.

The proteomic response of the porcelain crab, Petrolisthes cinctipes, following acclimation to fluctuating temperature, pH, and aerial exposure treatments

Petrolisthes cinctipes, following acclimation to fluctuating temperature, pH, and aerial exposure treatments

An individuals fitness depends critically on their ability to obtain and retain resources, which may be linked to their willingness to leave shelter (boldness), explore novel habitats, or engage in aggressive encounters. These behavioral attributes often are consistent within but divergent among individuals; that is, individuals often exhibit consistent individual differences in behavior, or behavioral types. The aim of this study was to evaluate consistency of behavioral types (boldness, exploration, and aggression) within and between−genotypes and populations. Given environmental variation among populations, we predicted that differential selection pressures would result in significant variation in behavioral types across populations while reducing within−population variation.

Variation Within and Among Populations in the Behavioral Types of Mangrove Rivulus (Kryptolebias marmoratus)

An individuals fitness depends critically on their ability to obtain and retain resources, which may be linked to their willingness to leave shelter (boldness), explore novel habitats, or engage in aggressive encounters. These behavioral attributes often are consistent within but divergent among individuals; that is, individuals often exhibit consistent individual differences in behavior, or behavioral types. The aim of this study was to evaluate consistency of behavioral types (boldness, exploration, and aggression) within and between−genotypes and populations. Given environmental variation among populations, we predicted that differential selection pressures would result in significant variation in behavioral types across populations while reducing within−population variation.

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Hunting requires strategies to track prey and strike in the absence of vision. Neural components involved in cytoskeletal restructuring. Proteins associated with the molt cycle, respiration, and other regulatory functions also played a role in characterizing the heat shock response, reflecting the major changes in homeostasis in response to environmental stress.
127.4 GARZA DE YTA, A.; Aquaculture Global LLC; agarza@crm-agg.com
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 $60 MNX and sometimes $50 MNX 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.

2.5 GEORGE, A.B.*; DE BURON , I.; MCELROY, E.; College of Charleston; abgeorge@cofc.edu
The effects of the parasites, Cardicola laruei and Hennegraya cynoscioni, on the swimming performance of spotted seatrout, Cynoscion nebulosus
Parasites are often associated with detrimental impacts on host physiology, but very few studies have examined the impact of parasites on the swimming performance of fish. In this study, we aimed to determine the impacts of two parasite species, Cardicola laruei and Hennegraya cynoscioni, on the swimming performance of spotted seatrout, Cynoscion nebulosus. For 18 fish, we quantified burst swimming speed (U\textsubscript{burs}) and critical swimming speed (U\textsubscript{c}) as indicators of anaerobic and aerobic swimming abilities, respectively. The effect of H. cynoscioni on swimming performance could not be determined because none of our experimental fish were infected with this parasite. 72% (13/18) of the fish were infected with C. laruei. Linear regression showed a significant (P = 0.02) positive relationship between C. laruei infection density and U\textsubscript{c}, but no significant relationship (P = 0.17) between density and U\textsubscript{burs}. The unexpected positive correlation between C. laruei granuloma density and U\textsubscript{c} may be explained by changes in heart muscle cell function as a byproduct of infection.

60.2 GEHMAN, AM; University of Georgia; alyssamina@gmail.com
Predation and parasitism: It’s not all bad news
There are multiple theoretical studies predicting the outcome of the addition of predators in host–parasite systems. In a direct developing and castrating system, high levels of predation on infected individuals will likely lead to a reduction in parasite infections, but empirical data is currently lacking. The Rhizocephalan barnacle parasite Loxothylacus panopaei provides an ideal system for investigating parasite response to predation. L. panopaei is invasive from the Chesapeake Bay to Florida and infects the mud crab Eurypanopeus depressus. It has been hypothesized that E. depressus maintains a small size because it is able to escape predation by hiding in the interstitial space between oyster shells. E. depressus with adult L. panopaei infections carry a large externa, the external reproductive organ of the parasite, which increases the crabs size and could decrease mobility. I investigated whether infected mud crabs were more susceptible to predation by the native blue crab Callinectes sapidus than their healthy counterparts. In all treatments infected crabs were consumed at higher rates then healthy crabs, with some predators exclusively consuming infected crabs. On average, infected crabs were consumed three times as often as healthy crabs. With predators selectively feeding on infected hosts the parasite populations could be driven to extinction. In this system, a native predator may be helping to protect the native crab species from its invasive enemies.

98.3 GERMAN, DP; Univ. of California, Irvine; dgerman@uci.edu
Digestive enzyme activities elucidate the digestive strategies of prickleback fishes (family Stichaeidae) with different diets
The patterns of digestive enzyme activities along the digestive tract of an animal can reveal the strategy that an animal takes to acquire resources from their food. In this study I examined how the activity levels of carbohydrases, proteases, and lipase change along the guts of five closely related prickleback fish species with different diets: Cebidichthys violaceus (herbivore), Xiphisterus maculos (herbivore), Astropus purpureus (omnivore), Physicichthys chirus (omnivore), and Anoplarchus purpurescens (carnivore). Digestive enzyme activities were measured in the pyloric caeca (which include pancreatic tissue in pricklebacks), and in the proximal, mid, and distal intestines of the fishes. All five species showed decreasing amylase activity moving distally along the intestine, whereas disaccharidase activities tended to peak in the mid intestines of the herbivores and omnivores, and decrease moving distally along the intestine of the carnivorous A. purpurescens. Collectively, these observations, in concert with moderate concentrations of short chain fatty acids in the fishes guts, are consistent with the plug–flow reactor model of digestion, and suggest a reliance on endogenous digestive processes as opposed to microbial endosymbionts. Enzyme activity patterns (including proteolytic and lipolytic activities, which are in progress) will be discussed in the context of the fishes feeding ecology and evolutionary history.
Plastic selection, and the potential for adaptation in newly established populations

GHALAMBOR, C.K. *; HANDELSMAN, C.A.; RUHELL, E.W.; Colorado State Univ.; cameron.gibbs@colostate.edu

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 cogradient, where the plastic response is in the same direction favored by selection, or countergradient, where the response deviates from the direction of selection. Cogradient 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-adaptive, 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.

January 3–7, 2013, San Francisco, CA
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 20,979 ± 86.1km² non-nursing. CA size ranged from 0.467km² nursing and 0.4ε 9.7km² non-nursing. Overlap between nursing and non-nursing ranges also varied greatly among individuals (HR: 13.995.0%, CA: 99.0%). Nursing females continued to utilize 52.0±5.5% of their non-nursing HR but only 19.1±5.45% of their non-nursing CA. In our cross-sectional analysis, a large portion (77.7±1.54%) 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 morphologies 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 complete pathways of cranial nerves can for the first time be fully visualized in post-embryonic vertebrates (Alligator mississippiensis and Dromaius novaehollandiae) using iodine-enhanced (i-ε) µCT methodologies. To date, methods using Lugols iodine (1 : 1KI) have been employed to study invertebrates, vertebrate embryos, and parts of adult rodents, rabbits, and a yearling alligator 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 i-ε 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 foot remains unclear. Insight into the fundamental processes that control adhesion 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 (0.5–6 mm). 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 3 mm. 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.

Evolution in the Deep Atlantic

The deep-sea is a vast and complex ecosystem with a rich and highly endemic fauna. Many contemporary research has focused on the ecological mechanisms that allow the persistence of 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 congeneric 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.

Workflow for Comparative Analysis of Transcriptomes: The quest for novel signaling pathways

The rapid growth of genomic datasets is an enormous technical and conceptual challenge in data processing. To address this challenge, we developed an integrated zero-click analysis pipeline with an automated zero-click analysis pipeline with an integrated signaling peptide prediction system. This pipeline is capable of processing and visualizing RNA seq data in less than a day. This greatly improves the pipeline’s computational throughput, keeping pace with the rapid advances of sequencing technology in recent years. The developed workflow has been validated with 60+ RNA-seq datasets obtained from 10 species of ctenophores (one of the most basal lineages of Metazoa) and 50+ species of molluscs, acoels, arthropods, and basal deuterostomes. All 60+ sequencing projects were designed to select organisms whose unique neural organization, development, cellular structures and behaviors aid in understanding the origins and evolution of nervous systems. As a result, we first identified the most evolutionarily conserved and fastest evolving subsets of genes underlying the origins of neuronal innovations. We hypothesize that secretory peptides can be the earliest intercellular signaling molecules. Consequently, the workflow is designed to simultaneously predict secretory signaling peptides across species. As an illustrated example, we investigated the effectiveness of our peptide prediction system in the quest for enigmatic signaling molecules in ctenophores. Importantly, we also validated our predictions by in situ hybridization to determine localization of the primary secretory cells. Our initial results suggest a diverse set of novel signaling peptides in ctenophores most of them have no homologies across other phyla.
**S5–2.3 GODWIN, J*; SLANE, MA; GEMMELL, NJ; North Carolina State University, University of Otago; John.Godwin@ncsu.edu**

**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 estrogenic 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.

**S11–2.1 GODWIN, J*; LUCKENBACH, JA; HOLLER, BL; DANIELS, HV; BORSKI, RJ; North Carolina State University, National Oceanic and Atmospheric Administration; John.Godwin@ncsu.edu**

**Environmental influences on sex determination in flatfishes**

Flatfishes of several genera display unusual sex determination patterns where both genetic and environmental influences play important roles. Two well–studied species of Paralichthys flounders (southern flounder, P. lethostigma, and Japanese flounder, P. olivaceus) exhibit approximately 1:1 sex ratios when reared at intermediate temperatures, but male–skewed sex ratios when reared at either high or low temperatures. These rearing temperature effects extend to somatic development with male–biased temperatures also producing poorer growth. These growth differences may be adaptive, as female Paralichthys flounder grow larger than males. The mechanisms underlying temperature effects on growth involve conserved pathways in vertebrate sex determination. Sex determination can be manipulated with sex steroid hormones and female development is associated with elevated expression of gonadal aromatase and the transcription factor FoxL2 mRNA while male determination is associated with expression of Mullerian inhibiting substance mRNA. Other environmental influences can also influence sex determination. Rearing of southern flounder juveniles in light blue tanks increases the proportion of males relative to that observed with darker backgrounds and is associated with higher whole–body cortisol concentrations. Consistent with a role in mediating environmental influences on sex determination, exogenous cortisol masculinizes sex ratios in both Japanese and southern flounder. This linkage between the endocrine stress axis and conserved sex determination pathways may provide a mechanism for adaptive sex ratio modification in a spatially and temporally variable environment.

**88.4 GOETZKE, H.H.*; FEDERLE, W.; University of Cambridge; hhg24@cam.ac.uk**

**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 adhesive 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 (Pseudoscyphrus 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.

**121.3 GONZALES, C.M.*; GOSLINER, T.M.; Duke University, California Academy of Sciences; cggonzales@calacademy.org**

**Resolving the genus Philine: Description and phylogenetic placement of six previously undocumented species (Gastropoda: Opisthobranchia)**

Species of the genus Philine, one of the most species–rich genera of opisthobranchs, are predatory sea slugs who use their ability to secrete poisonous toxins to avoid being eaten by other organisms. Furthermore, they have few natural enemies, allowing them to be found anywhere from intertidal mudflats to deep sea bottoms in oceans all around the globe. Recently, the California of Sciences embarked on the 2011 Hearst Expedition to the Philippines. During the expedition, many Philine specimens were collected that were catalogued as unidentified species. This project analyzed the genus Philine, using molecular and morphological approaches to determine the number of new species found on the expedition. Each specimen was illustrated and carefully dissected. Then, key anatomical features were documented further through the use of a compound microscopy imaging system and Scanning Electron Microscopy, to obtain resolution images. In addition, DNA sequencing was conducted on the CO1, H3, and 16S genes of our specimens. These data were then edited and evaluated to yield a current phylogenetic tree of the known species of Philine that includes these recent discoveries. After finding some undigested food in the gizzard of a Philine individual and genetically sequencing the CO1 gene of this matter, we were able to compare it with certain bivalves of the family Mytilidae and determine if this family could be part of the Philine diet. From these studies, we have determined that the collection examined from the Philippines contains six undescribed species. Each has a unique set of morphological characters that distinguish them from their closest relatives and are representatives of at least three different lineages, based on molecular data.
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.

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 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 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.

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 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 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 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 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.
121.6 GRAJALES, A*; RODRIGUEZ, E; American Museum of Natural History; agrajales@amnh.org
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.

49.2 GREENE, MJ; University of Colorado Denver; michael.greene@ucdenver.edu
The organization of “wars” by pavement ants
The pavement ant (Tetramorium caespitum) is a trap 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.

75.6 GREENLEE, K. J.*; SOCHA, J. J.; EUBANKS, H. B.; LEE, W.–K.; KIRKTON, S. D.; North Dakota State University, Virginia Tech, Jackson State University, Argonne National Laboratory, Union College; kendru.greenlee@ndsu.edu
Developmental changes in tracheal system structure and function in the caterpillar, Manduca sexta
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 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.
101.1 GREETER, JSM*; HEDRICK, TL; Univ. of North Carolina at Chapel Hill; jgreeter@live.unc.edu

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 whole−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.

703 GROOM, DJE*; TOLEDO, MCB; WELCH, KC; University of Toronto, Universidade de Taubate; derrick.groom@mail.utoronto.ca

The effect of elevation on hummingbird flight energetics: metabolic cost of flight in a changing environment
Global climate change is projected to impact species diversity and range. In particular, many species will move to higher elevations in an effort to track their environmental niche. However, for all organisms, moving upwards poses its own set of challenges. This is strikingly problematic for flying animals, as flight becomes difficult at elevation due to changes in air density and oxygen availability. Previous studies have demonstrated that highland hummingbirds are generally larger and have larger wings relative to body size compared to lowlanders, which allows them to fly at lower air densities and temperatures. We seek to elucidate the metabolic cost of flight for hummingbirds at different elevations, and how aerobic capacity changes with elevation and size. We hypothesize that elevation, and consequently low oxygen availability, exerts a metabolic constraint on hovering flight by limiting maximal aerobic output. As a result, species found at higher elevations will have a comparable hovering metabolic rate to similarly sized lowlanders. However, the metabolic rate of highlanders will rise more rapidly under increasing power output challenges than lowland species. This would indicate that hummingbirds have a metabolic limitation to the elevation they can inhabit. Hummingbirds were captured at three sites (9m, 1000m, and 1800m asl) in the Atlantic Forest in the state of Sao Paulo, Brazil by mist netting. Metabolic rate was assessed during normal hovering flight and during sustained weight lifting. Weight lifting is used to increase the power requirements of flight, independent of oxygen availability. Information regarding metabolic capacity will allow us to understand the implications of elevation on energetic performance.

135.5 GRIECO, TM; University of California, Berkeley; griece@berkeley.edu

Silurana (Xenopus) tropicalis as a model system for the evolution of odontogenesis
The highly conserved developmental mechanisms of odontogenesis illuminate the ways in which vertebrates have created highly adaptive and morphologically variable phenotypes from similar genetic underpinnings. The frog model Silurana (Xenopus) tropicalis, with its expanding genetic and genomic potential along with the large amount of comparative data derived from Xenopus laevis, provides a system to test hypotheses of tooth developmental mechanism function and evolution. I discuss how S. tropicalis lends itself to comparison across vertebrates when used with our extensive knowledge of mouse and fish tooth development, and how comparison between frogs allows us to understand what happens to the conserved mechanisms of odontogenesis when faced with a life history containing a prolonged, specialized larval stage. I use data from histological sections and gene expression during first generation tooth initiation to describe odontogenesis in tadpoles. First−generation teeth appear laterally before they appear medially, but alternation as reported by other researchers has been difficult to visualize in this study population. I consider evidence from these time series as it bears on hypotheses of dental patterning and initiation across vertebrates and within animals with late−developing dentitions.

754 GROOTHUIS, T.G.G.*; GOERLICH, V.C.; DIJKSTRA, C.; University of Groningen, NL, University of Bielefeld D; a.g.g.grootuis@rug.nl

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 to what extent 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.
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 to 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.

Reconstructing the Bite of the Giant Miocene Piranha, Megapiranha paranensis

The evolution of gnathostome jaws, along with bite forces that can capture and masticate active prey is a key functional innovation underlying the diversification of early Devonian vertebrates. As a result of their fundamental importance to promoting the success of vertebrates, the jaws and bite forces of extinct species have been repeatedly investigated through computer modeling, bite simulations, and anatomical comparisons to living relatives. Here we present the first ever in–vivo bite forces recorded from wild piranhas (Serrasalmidae) and model their bite using 2–D lever and linkage mechanics. Integrating this empirical data with allometry, bite simulations, and 3–D finite element analyses (FEA), we are able to reconstruct the biting abilities and infer the feeding ecology of the extinct giant Miocene piranha, Megapiranha paranensis. An anterior bite force of 320 N from the black piranha, Serrasalmus rhombeus, is the strongest bite force recorded for any bony fish to date. Results indicate the extinct M. paranensis bite force ranged from 1240–4749 N and reveal its novel dentition was capable of withstanding high bite stresses and crushing vertebrate bone. Comparisons of body size–scaled bite forces to other apex predators reveal that both S. rhombeus and M. paranensis have among the most powerful bites estimated in carnivorous fishes. Our results provide the first functional insights into the extraordinary biting abilities of piranha jaws as well as provide strong biomechanical evidence that M. paranensis was a formidable osteophagous predator of the Miocene.
A cladistic assessment of familial relationships on the basis of morphological characters obtained low support for the monophyly of Mycalina, with Isodictyidae 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 Podospongidae 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 Podospongidae (Diacarnum, 28S & COI), as well as the confirmation of Abyssocladiidae assignment to Cladorhizidae (28S & COI). The PoToL project 18S tree confirms the non–Mycaline affinity of both former families, and suggests that Esperiopidae (Amphilectus) may be a sister of Isodictyidae (Isodictya), both being sister of Podospongidae (Diacarnum, Negombata, Neopodospongia). This project also suggests that Desmacella lampra may actually belong in Mycale, that Mycalidae (Mycale) and Guitarridae (Guitarra) may be sister groups, and that Latrunculina (Latrunculia, Tsitsiskamma) 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 Esperiopidae, Guitarridae and Latrunculidae, and additional subgenera of Mycale. It is also important to add Cladorhizidae into more comprehensive trees.
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 grew 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. 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; hanloc2107@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 alter 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; bkamel@ucmerced.edu

Tissue specific gene expression in the fresh water snail Biomphalaria glabrata: implications for bio-mineralization and shell formation
The lack of good manipulatable models to study bio-mineralization 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 bio-mineralization. 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 bio-mineralization-related genes.
139.5 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.

35.4 HARVEY, TA*; PRUM, RO; Yale University; todd.harvey@yale.edu

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 delineation 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 cryptis, 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 mechanisms of stunning 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 plumes. 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.

147.2 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.
139.4 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 *Halocaridina 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.

1.9 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.

94.5 HAWKINS, M.B.*; JANDZIK, D.; CRUZ, A.; STOCK, D.W.; Harvard University, Cambridge, MA, University of Colorado, Boulder; michaeltrewhitt@fas.harvard.edu
The evolution of fin barbels by the co-option of fin developmental mechanisms
Barbels are sensory projections from the head that are found in 27 of the 62 orders of fishes, ranging from hagfishes to goatfishes. The phylogenetic distribution of barbels and substantial differences in their structure among groups suggest that they have arisen independently numerous times. The repeated evolution of complex structures may be facilitated by the co–option of existing developmental mechanisms. We tested this hypothesis for barbel origins by examination of gene expression and function during barbel development in the Channel Catfish, *Ictalurus punctatus*, and the Hn–regulated expression of posterior group *HoxD* genes controlling morphological asymmetry along the anterior–posterior axis. We also compared the development of maxillary barbels to that of the other barbel pairs present in the Channel Catfish, the chin and nasal barbels, which arose in catfish (siluriform) evolution after the appearance of maxillary barbels. We found evidence for similar outgrowth and anterior–posterior patterning mechanisms was observed in all barbel pairs, the different pairs are divergent in the expression of Fgf, Dlx, and *Hox* family members. We propose that barbels first arose in catfishes by the co–option of paired fin developmental genetic mechanisms, with the resulting barbel program similarly deployed during the origin of the chin and nasal barbels. In addition to providing insight into the origins of barbels in catfishes, our findings identify candidate mechanisms for the independent origins of these structures in other vertebrate groups.

144.6 HEAD, J.J.*; POLLY, P.D.; University of Nebraska–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 bodies of many groups of reptiles 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 separately 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 different 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 morpho–know 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.
Symbiotic 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, escl1 and escl2, cycle in host tissues. Whereas both cycled in the head with a similar pattern to that found in other animals, escl2 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 escl1 transcription patterns in the light organ were dependent upon the presence of symbionts. Mutants of V. fischeri defective in luminescence (lux-) failed to induce escl1 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 mollusk, 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.

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. In compensatory adjustments in mechanics 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.

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 varies dramatically, e.g., birds with high leg investment spend less energy in locomotion. However, the mechanisms of how limbs influence 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 leg performance 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 prey 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 male northern quolls: is 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–recapture 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. Spiracles 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 + 0.0243, R²=0.0015). 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 pCO₂ and pO₂. This work was supported by the NSF grant IOS–0920683 (TJB).

77.4 HEISS, E*; VAN WASSENMERGH, 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 morphological diversity 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.

The survival cost of reproductive investment: higher fattening rates lead to increased risk of mortality to a novel disease

In mixed (income-capital) breeding birds that reproduce in a seasonal environment, a combination of arrival date and arrival condition on the breeding grounds, as well as the rate of gain in condition following arrival, influence the timing of reproduction. Individuals that gain in condition the quickest lay earlier, invest in larger clutches and generally incur higher fitness. However, it has recently been shown that in the presence of a highly virulent disease higher reproductive investment is associated with higher mortality risk, although the exact mechanism(s) for this link is unclear. We studied the pre-breeding energetic physiology of an Arctic-nesting colony of Common Eiders (Somateria mollissima) at East Bay Island, Nunavut during an ongoing avian cholera (Pasteurella multocida) outbreak first beginning in 2006. We collected blood samples from arrival female eiders, tracked them through reproduction, and recorded mortality in high and low cholera outbreak years. We used energetic metabolites (plasma triglycerides – TRIG) as a measure of the rate of condition gain and examined its relationship to breeding propensity, lay date and the downstream effects these traits had on survival. Higher TRIG individuals were more likely to breed and had earlier laying dates. However, individuals with higher TRIG had an increased risk of mortality regardless of breeding propensity or whether they timed reproduction to the peak of cholera outbreaks. We demonstrate that increases in physiological investment in reproduction can trade-off with survival in the presence of a highly virulent disease.

Dewlap displays and predation risk in green anole lizards

In some animals, signals are consistently correlated with another trait and are thus considered reliable. Theory predicts that signal reliability is maintained via costs imposed upon the signaler. One such cost may be increased risk of predation. Male green anole lizards (Anolis carolinensis) use the dewlap as a reliable signal of maximum bite force capacity. However, the costs that maintain signal reliability in dewlaps are unknown. We tested whether dewlap displays increase predation risk by disabling dewlap displays in a sample of adult male green anoles. We compared the recapture rates of these males against animals given a sham treatment and found that recapture rates did not differ between the groups. We also used clay models to test how dewlaps and their color profile affected predation attempts. We found that models with naturally colored dewlaps (pink with UV reflectance) were struck by predators more often than models with green dewlaps and models with no dewlaps. We explore hypotheses that could explain the apparent contradictory evidence between sedentary models and free living animals.
101.3 HENNINGSSON, P. *; BOMPHREY, R. J.; Univ. of Oxford, UK; per.henningsson@zoo.ox.ac.uk

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 (ε), 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 εi 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.

146.2 HENSON, J.R. *; FREEMAN, D.A.; Univ. of Memphis; jrhenson@memphis.edu

Different neural target tissues mediate melatonin–dependent regulation of the RFamides, kisspeptin and gonadotrophin–inhibitory hormone, in Siberian hamsters
Siberian hamsters exhibit seasonal rhythms in physiology and behavior that aid in their ability to cope with annual changes in the environment. These include intra-annual changes in reproductive function, body mass, energy balance, and pelage coloration that are driven by changes in day length. For example, short day lengths inhibit, whereas long day lengths stimulate the reproductive axis. Day length is encoded by the duration of nocturnal pineal melatonin (Mel) secretion, which acts at several neural Mel target tissues to alter reproduction via changes in the release of hypothalamic gonadotrophin–releasing hormone (GnRH). Interestingly, GnRH neurons do not express Mel receptors, suggesting that regulation of GnRH by Mel is mediated by factors upstream of GnRH neurons. We assessed the effect of Mel on two up-stream GnRH regulators, kisspeptin (Kiss1) a positive regulator, and gonadotrophin–inhibitory hormone (GnIH, also termed FPRF–3) a negative regulator. We extended the Mel duration locally within specific target tissues in male hamsters housed under long day length by employing Mel-containing cannulas implanted into either the suprachiasmatic nucleus (SCN) or the nucleus reuniens (NRe). Extending the Mel duration at either target tissue elicited the expected testicular regression, and evoked site–specific effects to the RFamides. Mel administered to the SCN resulted in a reduction in Kiss1 immunoreactivity (−IR) in the anteroventral periventricular nucleus and Mel localized to the NRe resulted in a reduction of GnIH–IR in the dorsomedial hypothalamus. The results indicate that these two RF–amides are regulated independently by Mel acting at distinct target tissues.

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 the regulation of gene expression, is well developed or highly innervated as that of goldfish, a complex 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. The cypriniform palatal organ has long been thought to play a role in feeding. 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.

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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.
**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 diameters (1, 4, 40 mm) 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.

**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.
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.

Sponge 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.

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/phenoset/

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 larva to a settlement test using elevated KCl in seawater. We found that exposure to strong turbulence causes previously refractory, pre–competent larvae to respond to KCl 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.
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Virtual labs and activities: Tools for students and an opportunity to broaden your Broader Impacts
Our team facilitates educational outreach at the high school and college level by producing high quality, topical, freely–accessible digital tools designed to complement classroom and laboratory experiences in biology and environmental science. The enormously popular Sea Urchin Embryology site (launched in 1997) exploits the numerous possibilities of using sea urchins and their embryos in the classroom. Its modern counterpart, Virtual Urchin, offers interactive activities and tutorials ranging from microscopy skills to an ocean acidification (OA) experiment, where students explore a current research issue by entering our 'virtual lab bench,’ setting up an OA experiment (using real data from our colleagues Thorndyke & Dupont) and measuring the effects on urchin larval growth. We designed our lab bench in a modular fashion, and are modifying it for a lab involving embryo manipulations and microinjection. We have also designed activities on salmon migration, and, most recently, an international high school project allowing students to calculate, explore and discuss their carbon footprints. The modular design of our tools allows us effective dissemination of a wide range of research topics while addressing their broader impacts, now a strict requirement of many funding agencies, notably NSF. We propose a partnership with SICB members, where our media design and curriculum staff works with researchers to develop and disseminate high quality educational outreach activities based upon their research. We discuss possibilities for funding such activities, including inclusion in individual research grant proposals.

HOFMEISTER, J.K.K.; University of California, Berkeley; jenkkhof@berkeley.edu
Physiological response and local adaptation of marine invertebrates to natural variation in the ocean acidification seascape
Understanding how marine ecosystems will respond to future anthropogenic change, e.g., ocean warming and ocean acidification – is a critical priority for the research community. Central to this goal is knowing whether marine organisms possess the physiological plasticity or adaptation capacity to adjust in a rapidly changing environment and thus avoid extinction. In this presentation I will overview results from our research program that examines physiological plasticity and local adaptation in populations of marine invertebrates along the U.S. Pacific coast. Here, variation in upwelling regimes from Washington to southern California generate spatial and temporal gradients in concentration of CO2 that shoal to surface waters during upwelling events, bringing cold, low pH waters to benthic populations near shore. These episodic events of natural acidification likely act as a selection regime where some populations may have more resilience to future ocean acidification due to local adaptation. In order to identify the mechanistic underpinnings of calcifying marine invertebrates to acclimatize or adapt to increasing CO2, we co–located oceanographic sensors for pCO2 and pH with biological measurements to examine physiological plasticity (e.g., metabolic rates, change in body size and transcriptomic responses). Additionally, genetic surveys have been done to identify genetic variation. The results of the project suggest that there is heterogeneity in seawater conditions across this large biogeographic space the California Current Large Marine Ecosystem (CCLME) and that the performance of two invertebrates, sea urchins and mussels, varies with this variation in a manner that suggests local adaptation and differential responses amongst species.

HOEKSTRA, L.A*; SIDDIQ, M.; MONTOTH, KL; Indiana University; lhoekstra@indiana.edu
Phenological mechanisms and climatic seasonality of clonal octopuses revealed by the accelerating effect of temperature
Organisms respond to environmental change in 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.

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S9−1.7
VirtualUrchin that shoal to Drosophila
Virtual labs and activities: Tools for students and an opportunity to broaden your Broader Impacts
We discuss possibilities for funding such activities, including inclusion in individual research grant proposals.
The effect of muscle fibre recruitment on force–velocity properties and the implications for Hill−type models

Hill−type muscle models, which are broadly used in human applications, provide a simple way to predict muscle force based on fibre 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 anaesthetized 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 N cm−2 vs. 4.49 N cm−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 principles 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 (SIFF), can be used to study the adaptive significance of prey morphologies, behaviors and sensory abilities. SIFF 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.**

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**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 representation of an 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.
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 presets 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.
Females, in a population where many small females are aggressive with males.

Thermodynamic and pressure), which affect the equilibrium of a dynamic, open (non-linear) system. In our experiments rapidly thermodynamic and pressure relationships creating conditions inimical to life. Thermodynamic gradients and their coupled transport processes may experience energy inputs that exceed rates of dissipation. Dynamic, open (non-linear) systems rely on vascular networks for heat and energy input and rapid changes occur across many gradients (chemical, mechanical, hydrological, etc.).

In this study, larvae were reared in a 2 (28 & 31°C) x 2 (40 & 20 kPa) factorial design. 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); and 3) acute high temperature (PO2 of 21 kPa at 31°C). In contrast, larvae reared in chronic 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) & 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; University of Queensland; r.wilson@uq.edu.au
Can we improve 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.

89.4 Hutchinson, Jr; Royal Veterinary College, Structure and Motion Laboratory; jrhutch@rvc.ac.uk
Assessing the evidence for the evolution of asymmetrical gait in Crocodylomorpha

Some Crocodylia use asymmetrical gaits, including bounding and galloping, at near-maximal speeds. This ability is commonly assumed to have evolved in stem Crocodylomorpha, related to changes in limb/axial morphology. Body size is typically assumed to limit the capacity to use asymmetrical gait, but it is unknown how size might mechanistically constrain such athleticism. I report on collaborative efforts to reconstruct these constraints and how they shaped locomotor evolution in the crocodile lineage.

Experimental data (50–100 Hz video; also limited forceplate data) were collected from 189 near-steady strides of 32 individuals from 15 species of Crocodylia across a broad speed range (0.15–4.4 m s−1). Locomotor parameters were quantified for each stride and compared statistically. These experimental data reveal the absence of asymmetrical gaits in Alligatoroidea, whereas Crocodyloidea >2.5m total length do not use asymmetrical gaits. Otherwise, many aspects of crocodylian locomotion vary more within species than among them.

Additionally, for 6 taxa, we conducted scaling analyses of anatomical data for the 78 limb muscles of 18 individuals (0.13–278 kg) (e.g. physiological areas calculated from muscle mass, pennation and fascicle length) to examine whether limb muscles showed structured changes for supporting faster gaits at larger sizes. Alligatoroidea and Crocodyloidea lack any strong evidence for allometry of limb muscle architecture. Similarly, while axial bracing systems could constrain/enable such gaits, their biomechanics remains only qualitatively explored. Better evidence for limb/axial function–form linkages in extant Crocodyloidea, as well as qualitative morphology of fossils, could resolve this mystery and reconstruct when, how and why asymmetrical gaits evolved in Crocodylomorpha.

138.1 Husak, J. F.; Keith, A. R.; Witty, B. N.; University of St. Thomas; jerry.husak@stthomas.edu
Making Olympic lizards: The effects of sprint and endurance training in lizards

Exercise training is well known to affect a suite of physiological and performance traits in mammals, but training effects are less clear in other vertebrate groups. We examined performance and physiological differences among green anole lizards that were trained for sprinting or endurance, or not trained at all. Trained lizards underwent an increasingly rigorous training regime over 8 weeks, whereas untrained lizards were handled as a control. Sprint–trained lizards were run an increasing number of times per day, three days a week, on an inclined racetrack. Endurance–trained lizards were run for 30 min per day, three days a week, on a treadmill that was progressively increased in incline. All three groups improved in endurance capacity by at least 10% on average, and all groups decreased in sprint speed on average, but there were post–treatment differences in performance capacity. Lizards trained for endurance had significantly higher post–training endurance capacity compared to the other treatment groups, but groups did not show post–training differences in sprint speed. Acclimation to the laboratory environment and training explain some of our results, but we explored potential mechanistic explanations for these results as well, including differences in hematocrit, heart size, muscle masses, proportion of muscle fiber types, and response of different muscle fiber types to specialized training. Our results offer some caveats for researchers, but they reveal insights into how muscles and performance are impacted by training.
64.1 IAMS, SM*; BEATUS, T; GUCKENHEIMER, J; COHEN, I; Bowdoin College & Cornell University, Cornell University; smiff@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.

27.2 IRSCHEK, 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 organismal features of the gecko foot. We then provide a prospectus for the future of gecko adhesion through a more integrative perspective.

61.5 IRIARTE–DIAZ, J.*; ROSS, C.F.; University of Chicago; jossdiri@gmail.com

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.

125.4 ISERI, V.J.; KLASING, K. C.*; Univ. California, Davis; kcklasing@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 live 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.

January 3–7, 2013, San Francisco, CA
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.

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.

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 locomotor 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.
53.2 JANZEN, F*; WARNER, D; BRONIKOWSKI, A; MILLER, D; Iowa State Univ., Univ. Alabama, Birmingham, Penn State Univ.; fjanzen@iastate.edu
Miles to go before I sleep: reduced fitness at older ages in a long–lived reptile
Theory predicts that senescence will evolve when selection operates less strongly on traits that are expressed at an old age relative to those expressed at a young age. Although identifying reproductive deterioration and reduced survival at old ages provides an indication of senescence, how age–related changes in reproductive output and survival translate to actual fitness is largely unknown. We quantify the strength and direction of age–specific natural selection and its temporal consistency concerning reproductive output and survival of >1000 mature female painted turtles (Chrysemys picta) across 20 field seasons to further our understanding of how selection affects deterioration of reproductive function and/or survival (or lack thereof) in long–lived organisms. Clutch size and choice of vegetation cover over nests did not differ with maternal age, but older females laid larger eggs and nested more frequently, earlier in the season, and farther from water than younger females. Despite this moderate increase in reproductive function at old ages, fitness declined with advancing age, particularly for individuals with relative high egg output. Moreover, demographic analyses revealed fairly low mortality across reproductive ages, 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.

109.1 JAWOR, J.M*; HOOKER, J.D.; University of Southern Mississippi; jodie.jawor@usm.edu
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 irregularly 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 females response was more complex and tended to co–vary with temperature. We suggest that in male cardinals, once they have an active HPG axis, no further modification of activity may be beneficial, while females may benefit by having a physiological response system that can more closely track environmental change.

12.3 JASZLICS, A.*; PARDO, J.D.; University of Texas at Arlington, University of Nebraska at Lincoln, University of Calgary; jaszlics@huskers.unl.edu
Patterns of development and diversity in the crocodilian skull
Variation in ontogenetic trajectories plays a critical role in shaping morphological diversity of the vertebrate skull. Crown group crocodilians are a potentially informative research group for this phenomenon because they demonstrate extensive morphological diversity in the skull despite conservative ecologies. Previous studies of crocodilian skull morphology suggest that variation correlates to biomechanical constraint during feeding. In order to test whether the diversity of crocodilian skull morphologies reflects variation in developmental trajectories, we constructed ontogenetic trajectories in all four major extant crocodilian lineages (Alligatoreidae, Crocodylidae, Tomistoma and Gavialis), using geometric morphometric analysis of growth series within and between lineages. We found that the entire skull is tightly integrated throughout ontogeny for all taxa. Differences in adult skull shapes between crocodilian genera primarily reflect variations in juvenile morphology, as well as variation in the overall length of the ontogenetic trajectory. Although skull development in Gavialis is tightly integrated, the observed pattern of growth differs significantly from that seen in all other crocodilian genera. Because this divergent trajectory is associated with landmarks in the rostrum and suspensorium, we hypothesize that the unique feeding mechanism of true gharials constrains morphology throughout ontogeny, which shapes both the aberrant ontogenetic trajectory and adult morphology of this species. These results suggest that divergent morphologies can evolve despite ontogenetic constraint.

89.5 JAYARAM, K*; SPRINGTHORPE, D; HALDANE, D; MCKINLEY, S; DIROCCO, A; FULL, R.J; University of California Berkeley; kaushikj@berkeley.edu
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 and12mm heights. Surprisingly, animals ran within the vertically restricted space with 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.

Physiology in deep time: Using extant vertebrates to model behavioral and functional aspects of the Devonian land transition

Extant air-breathing fishes can be used to infer the physiological and behavioral changes that occurred during the fish–tetrapod land invasion (early Middle to Late Devonian) that otherwise could not be studied due to the lack of living stem tetrapods. Here we describe two such projects from the laboratory of the late Jeffrey B. Graham. Mudskippers (Teleostei: Gobiidae), which possess many respiratory and locomotive specializations for amphibious life, were used to study how changing atmospheric O2 concentrations in the late Paleozoic may have influenced the emergence and subsequent radiation of the first tetrapods. Japanese mudskippers (Periophthalmus modestus) exercised on a treadmill under 7, 21, and 35% atmospheric O2 to study the 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.

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Physiology in deep time: Using extant vertebrates to model behavioral and functional aspects of the Devonian land transition

Extant air-breathing fishes can be used to infer the physiological and behavioral changes that occurred during the fish–tetrapod land invasion (early Middle to Late Devonian) that otherwise could not be studied due to the lack of living stem tetrapods. Here we describe two such projects from the laboratory of the late Jeffrey B. Graham. Mudskippers (Teleostei: Gobiidae), which possess many respiratory and locomotive specializations for amphibious life, were used to study how changing atmospheric O2 concentrations in the late Paleozoic may have influenced the emergence and subsequent radiation of the first tetrapods. Japanese mudskippers (Periophthalmus modestus) exercised on a treadmill under 7, 21, and 35% atmospheric O2 to study the 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.

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.
Why do giant squid have giant eyes?

Giant and colossal deep-sea squid (Architeuthis and Mesonychoteuthis) have the largest eyes in the animal kingdom, but are also significantly smaller than the largest eyes of other species. The question of why giant squid have such large eyes is of particular interest because of the limited information available on their visual behavior.

The large eyes of giant squid are well-adapted for detecting very large predators, such as sperm whales, which have very large eyes of their own. However, giant squid are also capable of detecting smaller predators, such as other squid, which have much smaller eyes. This suggests that giant squid may have evolved their large eyes for a variety of purposes.

The large eyes of giant squid also make them more vulnerable to predation, as their large eyes are visible to predators from a great distance. However, giant squid are also capable of detecting predators from a great distance, which suggests that their large eyes may also serve to detect predators before they are detected by other squid.

In conclusion, the large eyes of giant squid are well-adapted for detecting both large and small predators, and they are also vulnerable to predation. Further research is needed to understand the adaptive significance of the large eyes of giant squid and how they have evolved.

References

4.1 JONES, Corbin; University of North Carolina; cdjoness@email.unc.edu
High throughput genomic sequencing is revolutionizing biological research and is rapidly expanding the number of organisms with genomic and transcriptomic (RNAseq) data. These new sequencing technologies produce large numbers of short (<100 bp) reads, which are best suited for assembling unique regions of a genome or transcriptome. These short reads also have inherent technical weaknesses. Short reads perform poorly when assembling repetitive regions of the genome and are problematic when measuring gene expression across members of gene families. These problems are compounded when short reads are used to assemble a genome, annotate genes within that genome, and measure the expression of the genes within that genome. Using a combination of synthetic and experimental data, we illustrate some common pitfalls of measuring the transcriptome using a draft genome. Not surprisingly, gene families are particularly problematic. Our data also suggest that isoform prediction—one of the strengths of RNAseq over microarrays—can be erroneous when applied to draft genomes. Based on these data, we define a set of good practices that can improve the quality of inference from RNAseq experiments applied to draft genomes. However, polishing and closing of draft genomes will ultimately be the critical step to preparing them for highly accurate RNAseq analysis.

74.4 JUSUFI, A.*; BYRNES, G.T.; FULL, R.J.; Univ. of California, Berkeley; ardian@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%) glided safely on the vertical target. By contrast, tailless geckos experienced catastrophic swings 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 forefoot slipgage stimulates tail depression. Strategies incorporating tail assisted responses can improve the vertical landing performance and stability of both animals and robot planes.

35.3 JUDGE, J. L.*; HASZPRUNAR, G.; UC Berkeley, Ludwig–Maximilians University Munich; jennajudge@berkeley.edu
A 3D investigation of the morphology of lepetellid limpets (Lepetella sierrai); hypotheses on feeding ecology and symbiosis
The Lepetelloidea, a clade of small limpet–shaped gastropods, represents a case study in continental margin and deep-sea diversification. Lineages in this clade have been found associated with various substrates, including hydrothermal vents, seeps, wood, whale bone, polychaete tubes, elasmbranch egg cases, seagrass rhizomes, algal holdfasts, crab carapaces, and sponges. It is unclear how each lineage utilizes its substrate; as a food source, a grazing surface, or a substrate that positions them in a reducing environment suitable for chemoautotrophic symbionts. Symbiosis is an obvious trait that would provide a lineage with a clear advantage in a nutrient-poor environment like the deep-sea, indicated by the prevalence of chemosymbiotic animals at hydrothermal vents. One lepetelloidean family, Lepetellidae, lives specifically on or inside empty polychaete tubes of the genus Hyalinoecia. The detailed morphology of a Mediterranean species, Lepetella sierrai, has been reconstructed from serial sections using the 3D modeling software AMIRA, and compared to other members of the genus. A unique alimentary tract, with huge oesophageal pouches, no true stomach, and an extensive multi-lobed midgut is shown. Additionally, a bacteriocyte system surrounding the entire mantle rim has been revealed via light microscopy and TEM. This is the first recognized evidence for microbial symbiosis in lepetelloidean limpets. A feeding ecology combining nutrition from the sugar phosphate polymer worm tube and chemoautotrophy is likely. Further investigation of this and other lepetelloidean feeding ecologies will contribute to revealing the drivers of evolutionary success in this limpet clade that lives on a high diversity of substrates utilized by few other lineages.

4.5 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 sponges form 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 ammonia 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 to ambient water. Our findings suggest that the water properties of the reefs may depend heavily on sponge reefs being present just as the reefs rely on SOG water properties.
Advective 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 (2200 ppm) CO₂ concentrations in replicated experimental trials. Animals raised under elevated pCO₂ demonstrated developmental changes. The distribution of the proportion of paralarva 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.

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 hypothesize 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 vacuolar 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.

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.

On the evolution of ant thermal performance: clues from a Neotropical forest

Thermal performance curves quantify the ability of an individual to interact with its environment across a range of temperatures. Thermal performance curves reflect critical thermal minima and maxima, thermal range, and the activity energy (or Q10) of behavior. They have implications for both ecosystem services and the future of biodiversity in a warming world. We report thermal performance of worker tempo for 92 species of ant from the Neotropical forest of Barro Colorado Island Panama. Consistent with the Thermal Adaptation Hypothesis canopy ant populations averaged Thermal ranges that were 7°C higher than populations from the understory (n=69), brought about by higher Critical Thermal Maxima. Consistent with the Size−Inertia hypothesis, CTmax and CTmin increased and decreased respectively ca. 2.5 °C for every 10−fold increase in body mass; a pattern repeated within dimorphic species. Moreover, a second mechanism adapting canopy ants to the warmer canopy was suggested by the 3.5 °C greater mass−corrected CTmax for canopy populations. Average ambient temperatures are predicted to increase by 5 °C in this Panama forest by 2080, suggesting a pre−adaptation for canopy ants to a warming world. However the temperatures of surfaces, and not open air, are those experienced by tiny cursorial organisms. The number of sunny hours may be a more important, and far less understood, driver of thermal ecology for invertebrates that live on terrestrial surfaces. Finally, the Q10 of activity ultimately arises from the concerted action of enzymes, most of which require metal atoms. We test the Q10−Bioaccumulation hypothesis that posits that species with lower concentrations of these metals have commensurately higher Q10s.

Biodiversity in a warming world: understanding the economic cost of growth

Water economy indices have implications for both ecosystem services and the future of biodiversity in a warming world. We report thermal performance of worker tempo for 92 species of ant from the Neotropical forest of Barro Colorado Island Panama. Consistent with the Thermal Adaptation Hypothesis canopy ant populations averaged Thermal ranges that were 7°C higher than populations from the understory (n=69), brought about by higher Critical Thermal Maxima. Consistent with the Size−Inertia hypothesis, CTmax and CTmin increased and decreased respectively ca. 2.5 °C for every 10−fold increase in body mass; a pattern repeated within dimorphic species. Moreover, a second mechanism adapting canopy ants to the warmer canopy was suggested by the 3.5 °C greater mass−corrected CTmax for canopy populations. Average ambient temperatures are predicted to increase by 5 °C in this Panama forest by 2080, suggesting a pre−adaptation for canopy ants to a warming world. However the temperatures of surfaces, and not open air, are those experienced by tiny cursorial organisms. The number of sunny hours may be a more important, and far less understood, driver of thermal ecology for invertebrates that live on terrestrial surfaces. Finally, the Q10 of activity ultimately arises from the concerted action of enzymes, most of which require metal atoms. We test the Q10−Bioaccumulation hypothesis that posits that species with lower concentrations of these metals have commensurately higher Q10s.
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.

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, 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.

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 fin GRFs are inclined more medially. 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.

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.
**63.6 KELLEY, K.M.**; REYES, J.A.; California State University, Long Beach, Pacific Coast Environmental Conservancy; kmkelley@csulb.edu

**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 with the same individuals, it is possible to evaluate contaminant exposures, effects, and endocrine system status using correlutive 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]

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**40.2 KENALEY, C. P.**; LAUDER, G. V.; Harvard University; cpkenaley@gmail.com

**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 will 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. Constrained by the properties and positions of joints found in the bass skull and powered by DC linear motors representing the levator operculi, adductor mandibulae, hyopophyseal, 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). 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.

**8.5 KENKEL, C.D.**; ALMANZA, AT; MATZ, MV; Univ. of Texas at Austin; carly.kenkel@gmail.com

**Physiological and genetic underpinnings of local coral adaptation in the Florida Keys**

Coral reefs throughout the world, and especially in the Caribbean, are experiencing declines attributable to direct anthropogenic impacts on reef ecosystems exacerbated by the effects of global climate change. However, the relationships between environmental parameters and coral reef health are far from clear. In the Florida Keys, offshore reefs experience seemingly benign environmental conditions yet exhibit consistently lower coral cover and lower coral growth rates than mid—channel and inshore patch reefs that are subject to higher nutrient loads and thermal extremes. We preformed reciprocal transplants of the mustard hill coral, *Porites astreoides*, between two inshore and two offshore reefs to identify patterns of local adaptation and the physiological and/or genetic mechanisms that enable this species to inhabit both reef environments. Each of the four locations was represented by 15 genotypes (individual colonies), which were fragmented and outplanted at local and foreign sites. Samples of each individual were collected after six months and one year. Microsatellite analysis of the coral host revealed subtle but significant genetic subdivision between inshore and offshore populations, potentially facilitating local adaptation. Following the first six months of transplantation, offshore—origin corals exhibited higher growth rates and higher protein content than inshore corals at all sites. In addition, all coral genotypes tended to grow less at offshore sites compared to inshore, suggesting the presence of some unidentified stressor(s) that might explain lower coral cover at offshore reefs. Ongoing analysis of additional metabolic parameters in both the host and symbiont together with host global gene expression profiling with RNAseq will provide further insight into physiological and molecular mechanisms underlying these patterns.

January 3–7, 2013, San Francisco, CA
DYNAMICS OF FAT AND LEAN MASS IN REFUELLING 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 refuelling 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 to 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 refuelling 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.

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 individuals will be highlighted and video clips will serve to illustrate birds, habitats, and history.

SICB 2013 Annual Meeting Abstracts

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 chondrocytes 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 anterius 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.
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. Phylogenetic analyses of extant phocids suggest that pierce and suction feeding are the most primitive feeding mechanisms and are independent of other specializations. grillpack@wisc.edu

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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 nestling 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.


102.3 KILBOURNE, B.M.; University of Chicago; brandon.kilbourne@uni–jena.de

Scale effects and rotational inertia in the limbs of quadrupedal mammals

Recent biomechanical studies have revealed that the metabolic cost of swimming the limbs is a significant portion of the total metabolic cost of terrestrial locomotion. Such studies suggest that limb rotational inertia, which reflects gross limb morphology, is relevant to understanding the mechanical cost of terrestrial locomotion. Yet scant data on limb inertial properties currently exist. Limb inertial properties—moment of inertia (MOI), mass, and radius of gyration—were measured from the fore- and hindlimbs of 44 species of quadrupedal mammals (representing eight major clades) to understand how limb rotational inertia varies with body and limb size. Muscles were left in situ on limb bones in order to measure limb inertial properties for the entire appendicular musculoskeletal system. Relative to body mass, limb length is positively allometric, with larger mammals having longer limbs relative to their body mass than smaller mammals. Fore- and hindlimb MOI is negatively allometric with limb length, with an allometric exponent of ~4.45 being significantly less than the predicted slope (5.0). Though the difference in actual and predicted exponents seems small, the negative allometry of hindlimb MOI results in a considerable decrease in MOI in larger limbed mammals relative to the predictions of geometric similarity. Thus, relative to limb length, larger mammals have limbs that consume less energy to swing than smaller mammals. Fore- and hindlimb mass scale with negative allometry relative to limb length. Radius of gyration a measure of limb shape scales with negative allometry (hindlimbs) or isometry (forelimbs) relative to limb length. Thus, hindlimb mass shifts proximally relative to hindlimb length with increasing limb size in mammals. Positive allometry of limb length and the negative allometry of limb inertial properties have a high potential to reduce the locomotor costs of large mammals relative to their size.

102.4 KIENLE, SS; San Diego State University; sarah.stachura@gmail.com

Hungry Pinnipeds: The Comparative Feeding 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.

126.3 KIM, TW*; TAYLOR, J; LOVERA, C; BARRY, JP; Monterey Bay Aquarium Research Institute; ktrown@mbari.org

Ocean acidification impairs olfaction and elevates respiration in deep sea hermit crabs, with high variation between individuals

Future ocean pH is projected to drop considerably at all depths as surface water continues to absorb rising levels of atmospheric CO2; this acidification is expected to be lowered by 0.2−0.4 units by the end of this century. Still the ability of organisms to adapt to lower pH has been far less explored in deep water species than shallow water species. To test the effect of environmental acidification on deep-sea animals, we compared behavioral and physiological features of the deep-sea (~900 m) hermit crab Pagurus tanneri between pH 7.6 (ambient control) and pH 7.1 (low-pH experimental) lab conditions. No significant difference was detected between treatments for some parameters, such as oxygen consumption and the boldness of crabs, measured as time spent in shell after attack by a potential predator (octopus). At lower pH, however, hermit crabs decreased their rates of antennular flicking (the equivalent of sniffing) and also tended to have a slower speed of prey detection, indicating that lower pH can impair olfactory function. Respiration rates transiently increased in response to higher CO2 level at 4 weeks after treatments but returned at 9 weeks. Furthermore, hermit crabs at lower pH showed higher individual variation in antennular flicking rates, prey detection speeds, and respiration rates. This pattern suggests that, although ocean acidification impairs some abilities linked to survival, the ability of P. tanneri to cope with lower pH appears to vary considerably among individuals, potentially promoting population survival by natural selection.
48.6 KINGSTON, A.*; HANLON, RT; CRONIN, TW; University of Maryland, Baltimore County, Marine Biological Laboratory, Woods Hole, MA; analom1@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 parfactory 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. Immunohistochemistry 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.

55.6 KINSEY, S.T.; University of North Carolina Wilmington; kinsey@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 minimal 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 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.
**SICB 2013 Annual Meeting Abstracts**

**S6–1.4 KITAYSKY, AS; University of Alaska Fairbanks; askitaysky@alaska.edu**

**Mechanistic links between climate variability, stress, and population processes in seabirds**

Climate change is likely to affect food web dynamics in marine ecosystems and thus availability of food to breeding seabirds. Consequences of food shortages for population dynamics of long-lived seabirds are not well understood. I will present the results of our long–term studies of the effects of climate variability on plankton– and fish–eating seabirds breeding in the continental shelf regions of sub–Arctic. I will also discuss our recent advances in studying the consequences of nutritional stress for the quality, sexual maturation, and senescence of individuals, which contribute to the greater goal of understanding how populations of upper–trophic–level predators breeding in the North Pacific may respond to climate warming.
S9–1.2 KLOK, CJ*; HARRISON, JF; Arizona State University; cjklok@asu.edu

Interactions between temperature and oxygen and the evolution of body size in invertebrates

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. É6) 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.

I20.2 KNUTSON, VL*; GOSLINER, T; San Francisco State University, California, California Academy of Sciences, San Francisco; vknutson@gmail.com

New species, same damn color: Benefits of using molecular data to identify diversity in a poorly studied group of sea slugs

Gymnodoris is a genus of sea slugs that contains approximately 35 described species distributed throughout the Indo–West Pacific. The group displays a variety of feeding habits including cannibalism and parasitism, which offers an opportunity to study the evolution of feeding specialization. However, the relationships between species have not been assessed, and much of the diversity remains undescribed. Many of the species descriptions are poor and lack sufficient details, making it difficult to match existing names to specimens. Preliminary sampling indicates that Gymnodoris is a diverse, previously taxonomically neglected group, with tens of undescribed species. Two major difficulties with this group are the similarity of color patterns between different species, and a lack of distinctive external morphological characters. These issues make molecular markers particularly useful for identifying and delineating species. Using molecular markers, we were able to detect the presence of 7 different species of Gymnodoris living at one collection site, when in the field we could only detect 4 morphospecies. In addition, based on the molecular mitochondrial markers 16S, cytochrome oxidase subunit I (COI) and the nuclear marker histone 3 (H3), we present evidence for cryptic diversity within some well known, widely distributed taxa. Ultimately, a phylogeny of Gymnodoris will bring more attention to this previously neglected genus of nudibranchs and serve to help us understand the evolution of the specialization of feeding in this group.

S3–2.2 KNUESEL, Jeremie*; KARAKASILIOXIS, Konstantinos; CRESPI, Alessandro; RYCKZO, Dimitri; CABELGUEN, Jean-Marie; ISPEEERT, Auke Jan; École Polytechnique Fédérale de Lausanne, Switzerland, Groupe de Recherche sur le Système Nerveux Central, Département de physiologie, Université de Montréal, Montréal, Canada, INSERM U862 – Neurocentre Magendie, Bordeaux, France; jeremie.knuesel@epfl.ch

Gait transitions between swimming and walking in salamander: lessons from numerical modeling and robotics

The ability to efficiently move in complex environments is a fundamental property both for animals and for robots, and the problem of locomotion control is an area in which neuroscience and robotics can fruitfully interact. Animal locomotion control is in a large part based on central pattern generators (CPGs), which are neural networks capable of producing complex rhythmic patterns while being activated and modulated by relatively simple control signals. These networks are located in the spinal cord for vertebrate animals. In this talk, we will present how we model CPGs of lower vertebrates (lamprey and salamander) using systems of coupled oscillators, and how we test the CPG models on board of amphibious robots, in particular a salamander–like robot capable of swimming and walking. We will show how a CPG model designed for a stereotypical behavior (e.g. swimming lamprey) can be extended to support a diversity of locomotor behaviors observed in the salamander (e.g. swimming, forward and backward stepping and underwater stepping). Additionally, a new salamander–like robot able to replicate the three dimensional movements of the salamanders skeleton will be demonstrated. This robot will enable tests of more complex models owing to its multi–segmented limbs and its 25 degrees of freedom in total (compared to 12 used in our previous robots).

25.5 KOCH, RE*; HILL, GE; Auburn University; rebeckabethkoch@gmail.com

Searching for evidence of a runaway process in art and literature

Although sexual selection is universally accepted as an explanation for ornamental traits in animals, the specific mechanisms that produce extreme elaboration of display traits remain unresolved. The runaway sexual selection model proposes that arbitrary female preference can escalate to drive a male display to a novel and sometimes extreme form in a short period of time. The actual speed of such trait change has never been stated specifically, but it is always presented as much faster than that of traits evolving through natural selection. Many changes in morphological traits have been documented in wild animals on a time scale of decades; we can therefore expect a runaway process to produce novel ornamental traits at least that rapidly. Though the runaway model has been validated by mathematical simulation, no empirical study to date has shown clear evidence of the process in action. Because runaway sexual selection is quick–acting by nature, we should expect to find indications of rapid change in ornamental traits documented in literature or reflected in art as the same species of animal is illustrated across centuries. We searched for evidence of such changes by examining lifelike bird art from the past 100–5000 years and comparing the visual traits of these birds to those of their modern counterparts. We also searched the literature and interviewed experienced ornithologists for examples of such change. To date we have found no cases of rapid change in sexually selected traits in any species of bird.
81.1 KOEHL, M.A.R.; Univ. of California, Berkeley; cnidaria@berkeley.edu

Diet effects on adhesion of settling marine larvae in turbulent pulses of water flow

Many benthic marine animals produce microscopic larvae that are dispersed by ocean currents. These larvae can only recruit into new habitats on which they have landed if they can resist being washed away by ambient water flow. The adhesive strengths of microscopic organisms such as larvae are typically measured by exposing them to steady flows of different velocities to determine the boundary shear stress at which they are dislodged from a surface. However, our field and flume measurements of water velocities at the scale of larvae on surfaces in different microhabitats within rugose benthic communities (coral reefs, fouling communities) revealed that larvae are exposed to brief pulses of rapid flow as turbulent eddies and waves sweep across the substratum. I used a picospritzer to subject settling larvae of byrozoans, tube worms, and sea slugs to realistic pulses of moving water to measure their adhesive strength under more natural flow conditions, and to determine how such fluctuating flow affected their behavior. I found that the response of a larva to a pulse of flow depended on larval behavior at the time the pulse hit, and on the larva’s recent history of exposure to flow pulses. Crawling larvae were more likely to be blown away than stationary larvae, and larval adhesive strength usually increased with duration of attachment to a surface. Larval “glues” that act like viscous fluids when larvae were sheared off surfaces in steady flow behaved like elastic bounce cords when larvae were exposed to brief pulses of rapid flow. Therefore, to determine how ambient water motion affects the ability of settling larvae to recruit into benthic communities, we must measure larval responses to flow that varies on the rapid temporal scales encountered by the larvae in natural habitats.

113.4 KOHL, K.D.*; WEISS, R.B.; DALE, C.; DEARING, M.D.; Univ of Utah, Univ of Utah; kohlf78@gmail.com

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 efficiently tested with 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.

11.3 KOENIG, KM*; MEYER, E; GROSS, JM; Univ. of Texas, Austin, Oregon State University; kmkoenig@utexas.edu

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 Cephalopoda, 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.

71.6 KOHN, A.B.*; MOROZ, L.L.; University of Florida, Whitney lab, abkohn@msn.com

Single-cell 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 and single-cell RNA-seq (scRNA-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 for deciphering the logic of gene regulation and the full scale integrative activity of genomes across phyla.
120.1 KOHN, AJ; Univ. of Washington; kohn@uw.edu
Morphology, molecules, molluscs, and modern monographs: A
revisionary systematics case study
Taxonomy, classification and phylogenetic interpretation of shell
marine molluscs have traditionally relied primarily on shell
characters, the most durable and often the only ones available for
study. However, recent advances in molecular genetics have
dramatically altered this tradition. In the hyperdiverse neogastropod
genus Conus of 800-700 extant species, DNA sequences provided the
first species-level phylogenetic hypotheses in 1999. Inconsistencies
between molecular data and shell morphology–based taxonomy soon
became apparent both in Conus and elsewhere in the superfamily
Conoidea. Concurrently, increasing attention to other morphological
characters, particularly of the hypodermic needle–like radular teeth,
indicates greater congruence with molecular data than the latter have
with shell characters. Here I report on a systematic revision of the
extent species of western Atlantic Conus north of Brazil, applying
shell, radular, and molecular characters as far as possible to the 263
nominal species described from 1758 to 2011. For the 53 species
whose validity the results support, the study estimates infraspecific
variation and differentiates each species as clearly as possible from
its most similar congener. It describes shell and radular tooth
characters quantitatively and analyzes key mitochondrial genes both
as taxonomic characters and to evaluate phylogenetic relatedness
among species. I summarize the current species–level phylogeny of
western Atlantic Conus, but molecular genetic information is
presently limited to small sample sizes and fewer than half the
species. Molecular data have revealed the existence of cryptic species
with indistinguishable shell morphologies in other regions, and
future work will most likely increase the number of known valid western
Atlantic species.

8.3 KOMOROSKE, LM*; HASENBEIN, M; LINDBERG, J;
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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.;
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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 33 000 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.
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.

31.4 KRASNOV, B.R.*; KHOKHLOVA, I.S.; Ben–Gurion University of the Negev; krasnov@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.

12.6 KRAATZ, B.P.*; BUMACOD, N; WEDEL, M; AZEVEDO, B; Western University of Health Sciences; bkraatz@westernu.edu
Evolution, Ecology, and Modularity 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 mimotonids (ca 55Ma), exhibit a facial region that is remarkably similar to that of living lagomorphs, but a relatively primitive basicranium. It was 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.

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 these 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 these animals 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 opsins, we determined the evolutionary relationship and examined spatial expression patterns of the two A. irradians 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.
12.4 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 approximate 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 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; akrochmal2@washcoll.edu
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 abilities. 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 pedicle are the primary mediators of positioning of the ipsilateral antenna. Ablation of these mechanosensory receptors 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, SDT; GARCIA, L.; FARRELL, TM; MACDOUGALL−SHACKLETON, S.; University of Western Ontario, University of Western Ontario; bkrieng@uwo.ca
Decline in conditions during the juvenile period impair behavioral flexibility, while consistently poor developmental conditions impair spatial memory of zebra finches

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. Analysis showed 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 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.
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 microclimates). 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.
**134.5 LAHMAN, SE*; MOORE, PA; Bowling Green State Univ.; slahman@bgsu.edu**

Spatial 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 chemoreception, 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 spatio-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 chemoreception. Based on these results, organisms should be able adjust their search strategy to differences in information received.

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**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 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.

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**115.4 LAILVAUX, SP*; WILSON, R; KASUMOVIC, MM; tobias.landberg@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.

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**6.5 LANDBERG, T*; WARKENTIN, K; WILINK, B; MOUNT, K; CLOUSE, E; WHITEMAN, H; Murray State University, Boston University, University of New South Wales; 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 Pennsylvania and Kentucky we raised larval Red-Eyed treefrogs (RE; Agalychnis callidryas; n=344) and Cope's Grey treefrogs (CG; Hyla chrysoscelis; 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 (tibialfibula), 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.
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 (Scelesorus 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.

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 time of day in which spawning occurs are relatively harder with increasing body size, yet suction index showed no effect of body size.
Quantifying center of mass motion in swimming fishes

Movement of the center of mass (COM) during locomotion is a key parameter that is crucial for understanding the dynamics of movement in animals. Many studies of terrestrial locomotion have focused on motion of the COM during walking and running, but to our knowledge there is little information on how the COM moves during fish swimming, and no data on whether different patterns of body bending produce differences in COM motion. In this study we present an analysis of COM oscillations in steadily swimming fishes. Using the particle image velocimetry (PIV) method commonly used for flow visualization to instead track patterns on the body, we estimated COM movement of three fish species and swimming types: carangiform and labriform (sunfish, Lepomis macrochirus), anguilliform (eel, Anguilla rostrata), and gymnotiform (knifefish, Notopeterus chitala). We estimated COM movement in three dimensions (x: surge; y: sway; z: heave) and at three swimming speeds (0.5, 1.0, and 1.5 L/sec). Surge and sway COM oscillation magnitudes (peak to peak) were in the range of 0.4 to 1.5 mm (for fish of about 20 cm total length). Sway COM increased as swimming speed increased for bluegill and knifefish, but not for eels. Surge COM did not change with swimming speed and was largest for bluegill and smaller for both eels and knifefish. The COM was found to oscillate with twice the tail beat frequency. A log–log plot of COM oscillation cubed versus body mass for different animals shows positive allometry with a slope of 1.4, and fish COM oscillations fall significantly below this line indicating that fish have lower COM oscillations than terrestrial animals. Locomotion using body bending may reduce COM oscillation magnitudes compared to limb-based terrestrial locomotion using inverted pendulum or mass-spring mechanisms.
Differential energy allocation for protein synthesis in larval stages of Crassostrea gigas

All animal phyla originated in the sea but only a few of them have colonized freshwater. The transition to limnic ecosystems required multiple adaptations to cope with highly variable temperatures, salinities, oxygen concentrations, and other parameters that make freshwater environments hostile to animal life. Consequently, freshwater animals typically represent only a few lineages within each phylum that made the transition from marine waters. Freshwater sponges are globally distributed and common members of limnic biotas. They are currently classified in the suborder Spongillina within the class Demospongiae. However, their phylogenetic relationship to marine species and the time of their transition to freshwater environments remain controversial. The earliest freshwater sponge spicules are found from two disjoint time periods: from Permo-Carboniferous deposits of Europe and from Jurassic deposits of Europe and North America. It is unclear, however, whether the observed gap in the fossil record is a paleontological artifact or a reflection of two independent transitions to fresh water. Similarly, although freshwater sponges have been traditionally grouped with marine haptosclerids, several recent molecular phylogenetic studies reject this relationship. Here I use complete mitochondrial genome sequences from key representatives of demosponges to explore the phylogenetic position of freshwater sponges and to compare molecular and paleontological estimates for the time of their origin.

Differential energy allocation for protein synthesis in larval stages of Crassostrea gigas

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 potentials 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 different temperatures and for different genotypes using crosses of Crassostrea gigas.

The capacity to respond to environmental stress is likely related to metabolic efficiency. Defining the genetic bases of metabolic allocation has implications for understanding the role of genotype-dependent responses to changing environmental conditions.
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 angle 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 pectoralis 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 rosiicollis) 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.

Flight Artists: An outreach project that enables the general public to film natural flight using the worlds most advanced high–speed camera

In 2010–2011 we developed a world–unique outreach project Flight Artists with a large team of scientist, students, and support staff at Wageningen University. The goal was to enable the general public to use the worlds most advanced high–speed camera, the Phantom v710, to experience the magic of natural flight in their backyard in super slow motion. After we announced the project on national TV and radio we got 800 online–applications. This idea won the Dutch Academic year prize 2010 for the best outreach idea that translates high–impact research to the general public. The award and additional university funding and sponsoring, totaling 260k+, enabled us to purchase the Phantom v710 that can film up to 7500 fps in full color, to modify it into an unique field high–speed camera, buy an additional 30 (Casio EX–F1) consumer high–speed cameras, and build–up the infrastructure to deploy our outreach project nation–wide. We developed specific course materials and weekend courses to educate 460 Dutch members of the general public how to film flying wildlife in their backyard using our high–speed cameras. After they completed the course they used our cameras to pursue their own 2–day film projects focused on their specific interest in natural flight – ranging from flying birds and bats to insects. The outreach project was highly successful resulting in overwhelming positive responses from participants, several national TV programs and world–wide media attention. The project resulted in a large open–access high–speed video library: www.flightartists.com to inspire and facilitate research and teaching in animal flight world–wide. The project is currently continued at Wageningen University and Stanford University.
Streptocephalus are branchiopod crustaceans that are Setifer setosus swim within the and other non-malacostracan crustaceans Triops, Streptocephalus are Tenrecidae), a

Irradiance measurements were red-shifted with increasing depth, Statocysts have not been reported in branchiopod crustaceans, angular light distribution near the surface of an ephemeral pool. Testing orientation in an acrylic chamber that simulates natural gradient, and over time. Phototactic responses were observed within development. This study aimed to characterize the light environment, desiccation-resistant eggs that also require light to resume

Visual ecology of two ephemeral pool crustaceans: phototaxis and Streptocephalus (Branchiopoda: Notostraca) and Streptocephalus (Branchiopoda: Anostraca) Triops and Streptocephalus are branchiopod crustaceans that are often found within the same ephemeral subwater pools. They 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 ocelli (naupilar 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.

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 environmental conditions, allowing us to studying the dynamics of foraging flights with complex maneuvering. Many of characteristics of the prey capture flight, such as the interception angle and position of the prey, are based on a short timescale prediction of the prey's flight statistics ~100ms before takeoff. Once the interception flight has begun, a simple closed-loop guidance law, in which lateral acceleration is proportional to the angular velocity of the target and the dragonfly's speed, is used as an estimator of future target location. Preliminary head kinematics data show prey stabilization begins with a saccadic head movement immediately prior to takeoff, and this foveation of the prey is maintained actively during flight through continual head rotation. During flight, prey position varies 5–10x less in head-centered coordinates than body centered coordinates. I will discuss the dynamics of each of these components of the interception flight, and their relation to the underlying neural control system.

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 subwater pools. They 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 ocelli (naupilar 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 leveque@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.
45.4 LEVY, O*; BUCKLEY, L. B.; KEITT, T. H.; ANGilletTA, M. J.; Arizona State University, Tempe, University of North Carolina at Chapel Hill, Chapel Hill, The University of Texas at Austin, Austin; levyofi@gmail.com

Modeling the costs of thermoregulation in lizards: the interplay between competition, climate and vegetation cover in Scoloporus undulatus
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.

94.3 LEWIS, Z*; KERNEY, R; DORANTES, J; HANKEN, J; Harvard Univ., Cambridge, MA, Gettysburg College, Gettysburg, PA; zlewis@oeb.harvard.edu

Genetic and morphological vestiges of lost lungs in plethodontid salamanders
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 and functionally significant genes, including surfactant protein C. Surprisingly, adult plethodontids display novel pharyngeal expression of 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.

100.2 LEVY, M/G; NIRODY, J/A*; NEU, J/C; HENDRICKS, J/R; SLATKIN, M; OSTER, G/R; =EQUAL CONTRIBUTION, ; Univ. of California, Berkeley, Duke University, San Jose State University; jnirody@berkeley.edu

A neural–field model for the evolution of Conus shell patterns
Conus shell patterns are thought to be generated via a neurosecretory process. Gong et al. (2012) have shown that the parameters used to model this process can be used to infer phylogenetic histories. We construct a new formalism for this model and use it to examine intraspecific variation in Conus spurius, a species with a good 5 million year fossil record. We use UV imaging to reconstruct these fossil patterns and examine how morphospace may have changed over time. We propose that evolutionary trajectories within this parameter space correspond to an evolutionary history of the mantle neurosecretory network itself.

136.1 LEWIS AMES, C*; YANAGIHARA, AA; KEIL, D; LAWLEY, JW; VAN BLEK, J; GILLAN, B; BENTLAGE, B; BELY, A; COLLINS, AG; University of Maryland, College Park/Smithsonian NMNH, Pacific Biosciences Research Center, HI, University of Maryland, College Park, Universidade Federal de Santa Catarina, Brazil, Bonaire, The Netherlands, Boynton Beach Community High School, FL, University of Maryland, College Park, NMFS, NSL, Smithsonian NMNH, chanes1@umd.edu

Establishing the neotype of the enigmatic oceanic box jellyfish Alatina alata (Reynaud 1830) (Cnidaria: Cubozoa).
The winged box jellyfish Alatina alata has had a troubled taxonomic past. It was first discovered in the Atlantic Ocean and described as Carybdea alata Reynaud 1930, but no holotype was established, rendering the original description and accompanying line drawing as the only definitive reference for the species for more than 182 years. More than a century went by until C. alata was reported again in the Atlantic Ocean, despite various accounts in tropical Indo–Pacific waters. Notorious for causing the debilitating Irukandji–like syndrome, Alatina populations are relevant to the tourism industry, as they form monthly massive reproductive swarms 8–10 days after the full moon in some locations. Paradoxically, Alatina medusae have also been collected in the open ocean at great depths, an atypical habitat for cubomedusae, which usually occupy shallow coastal waters. Recently, nine nominal species formerly synonymized under the name C. alata were restored as different species within the new genus Alatina, leaving the epithet Alatina alata as the new combination for the only Atlantic species in the genus. Our recent discovery of a thriving Caribbean Alatina population in Bonaire (The Netherlands) allowed us to examine live medusae from the Atlantic, and to monitor monthly spawning events. Herein, we redescribe A. alata and establish a neotype for the species. Furthermore, we present results of molecular analyses of three geographical populations that support the hypothesis of a single widespread, variable species called A. alata (Reynaud 1830) by nomenclatural precedence.
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 sub-surface 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 tetrodynamics 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).

Animals induce aerial reorientation by swinging appendages or bending torsos. Inertial torques also play a role during terrestrial locomotion but ground reactions impede angular momentum. 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 typically began with curling and pivoting about the hind legs, 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 typically began with curling and pivoting about the hind legs, 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 typically began with curling and pivoting about the hind legs, 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 typically began with curling and pivoting about the hind legs, 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 typically began with curling and pivoting about the hind legs, 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 typically began with curling and pivoting about the hind legs, 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 typically began with curling and pivoting about the hind legs, 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 typically began with curling and pivoting about the hind legs, 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 typically began with curling and pivoting about the hind legs, 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 typically began with curling and pivoting about the hind legs, executed a rapid turn and then ran away from the stimulus.
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**

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 the 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 physiological 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 arterial properties. These arterial properties provide evidence that transmural pressures do vary has yet to be established.

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 the 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 arterial properties. 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 act as muscle force vectors. 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 Episoricus fumidus, Chodsigoa sodalis, Anourosorex yamashinai, and Blarina brevicauda (subfamily Soricinae). The T2 sesamoid bone supports the necks out: A novel sesamoid bone in crocidurine shrews.

24.6 LIGHTON, JRB*; FOERSTER, TD; KAICYALA, KJ; WISSE, B; Sable Systems International, University of Washington, University of Washington, lichton@sablesys.com

**Problem and solution: Multiplexing distorts metabolic data**

When measuring the metabolic rates of multiple animals, it is common practice to sample excurrent 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 future 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.

50.1 LINS, L. S. F.*; HO, S. Y. W.; WILSON, G. D. F.; LO, N.; University of Sydney/Australian Museum, University of Sydney, Australian Museum; luana.lins@sydney.edu.au

Evidence for Permio−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 gastropods, 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 munopsid radiation within the isopods suggests that the ancestors of this group evolved in the deep sea and did not move to shallow−water refugia during anoxic events.

93.2 LINQUIST, A.G.; BURNETT, J.B.; HATLE, J.D.; 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.

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 stacked which is on the CI domain. This site is hidden when CI domains are stacked.
8.6 LOCKWOOD, B.L.*; BYRD, N.; MONTOOTH, K.L.; Indiana University; blockwo@indiana.edu

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.

55.3 LONDRAVILLE, RL*; LIU, Q; DALMAN, MR; BAGATTO, B; Univ. of Akron; londreville@uakron.edu

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, lipid deposition, lipid metabolism, and many other systems, including bone growth and immune function. Because leptin has not been cloned in polar fishes, we used a genome-enabled model fish (zebrafish, D. 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 the leptin receptor (also with morpholino oligonucleotides). Leptin effects on metabolic rate are similar between mammals and zebrafish, and its effects on sensory structure development may be a clue to hearing loss common in diabetic humans. Reduced leptin signaling was also associated with reduced otolith size. 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.

I16.2 LOPEZ, JV*; CUVELIER, M; GILBERT, JA; LARSEN, P; WILLOUGHBY, D; WU, Y; BLACKWELDER, P; MCCARTHY, PJ; SMITH, E; VEGA THURBER, R; Ocean Center −Nova Southeastern University, Florida International University, University of Chicago, Argonne National Laboratory, Ocean Ridge Biosciences, Harbor Branch Oceanographic Institute at Florida Atlantic University, Florida International University/Oregon State University; joslo@nova.edu

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 dosed with 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 Corexit exposure. 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 organissmal 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 correctly 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 hormesis 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.

Feather corticosterone predicts offspring performance in a context-dependent manner
The use of feather Corticosterone (CORT) as a measure of integrated HPA activity is rapidly increasing in integrative studies of environmental stressors in numerous avian species. However, we currently know very little about how biologically-relevant stressors relate to feather CORT levels and even less about whether these levels can predict meaningful metrics of fitness. We examined whether a biologically-relevant manipulation of post-natal developmental stress translated into measurable and meaningful changes in feather CORT for a sexually-size-dimorphic passerine, the European starling (*Sturnus vulgaris*). Lower growth rates during the linear phase of growth and higher catch-up growth rates during the asymptotic phase predicted higher feather CORT in the larger, faster-growing males, but there was no such relationship in females. However, higher feather CORT predicted lower predator escape performance in both sexes, independent of treatment. Taken together, these results suggest that feather CORT can indeed capture variation in relevant environmental stressors, but that the context within which this stress is integrated must be well understood to appreciate what feather CORT levels mean for individual performance.

Embryonic heart rate is maintained in embryonic turtles in a nest
Amniotic eggs provide model organisms to explore the embryonic development of endogenous physiological circadian rhythms without the influence of maternal biorhythms. Recent studies have demonstrated that embryonic turtles within the nest respond to the developmental status of siblings by increasing both heart and metabolic rates, independent of temperature. A first step to understanding the physiological mechanisms underpinning this form of communication within a nest of ecotethermous organisms is to develop profiles of embryonic heart rates at different temperatures throughout incubation. We developed daily embryonic heart rate profiles of embryonic freshwater turtles in different group sizes, under constant temperature and lighting conditions to determine if circadian rhythms exist and at what stage of embryogenesis they become established. Murray River turtle eggs were incubated in darkness at constant temperatures (26°C and 30°C) in groups of six or individually and heart rates were monitored at 6hr intervals over 24–48 hrs every seven days throughout incubation. Circadian heart rate rhythms were detected at week four of incubation and were maintained until hatching in on species. Heart rates throughout the day varied by up to 20% at constant temperatures over a 24 hr period and were not related to time of day. Circadian rhythms of heart rate were not as developed sympatric species that do not hatch synchronously. This study established that endogenous circadian rhythms of heart rate are established early during embryogenesis and suggests biotic cues from siblings within a nest (eg. changes in heart rate) may be as important as external environmental cues (eg. temperature) for establishing developmental rates and coordinating hatching and emergence from the nest.
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.

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 0–18 cm/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.

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 thecal cells 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 (dh) around the time of ovarian differentiation. Ultrastructural results showed that differentiation and development of SPCs from undifferentiated to maturation 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 P450arom AB, but not against P450scx or 3β-HSD ABs, appeared first in the granulosa cells enclosing the vitellogenic oocytes at 100 dh. At this time, estrogen production in serum levels rapidly increased. At 7080 dh, IPC clusters invaded the interstitium among oocytes at the perinucleolar stage from the area near the blood vessels. IPCs increased in number in the interstitium among the previtellogenic oocytes, and some clusters 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 P450arom AB, but not against P450scx or 3β-HSD ABs, appeared first in the granulosa cells enclosing the vitellogenic oocytes at 100 dh. At this time, estrogen production in serum levels rapidly increased. At 7080 dh, IPC clusters invaded the interstitium among oocytes at the perinucleolar stage from the area near the blood vessels. IPCs increased in number in the interstitium among the previtellogenic oocytes, and some clusters began to enclose the outer thecal layer of the previtellogenic oocytes at 90 dh. Thus, folliculogenesis could be essential for active production of estrogen in the ovary.

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**100.5 Mackey, T.L.*; Jayne, B.C.; University of Cincinnati, Ohio; mackey.93@gmail.com**

**Meal size effects 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 environments, animals 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@stfx.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 echinoid 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 echinoids, 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. In most respects the larval nervous system of E. tribuloides more closely resembles that of non-echinoid larvae. We also used LiCl and 1-azakenpaullone (GSK-3β inhibitors) and ZnS04 (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.; Kingsolver, 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 (30−40°C) 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; madlige@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.
**121.4 MAH, C.*, FOLTZ, D.; Dept. of Invertebrate Zoology, NMNH, Washington DC, Dept. of Biological Science, Louisiana State University, mahch@si.edu**

**Biogeographic Insights from Molecular Phylogenetics of Pacific Northwest Sea Stars**

Recently molecular phylogenetic analyses of the Asteroidea have produced comprehensive and well-resolved trees for the Porcellanaster 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 taxa on the west coast of North America. Analysis of the Asteriidae shows it is composed of multiple clades corresponding to specific geographic/climatic regions. The boreal clade suggests endemism for asteroid species 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 goniaterid *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.

**43.6 MAHALINGAM, S; WELCH, KC*; University of Toronto, University of Toronto Scarborough; kwelch@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 hlex gas mixtures compared to when birds were hovering while lifting small weights and whether any differences were solely a function of muscle activation pattern. To do this, we simultaneously recorded wingbeat kinematics and electromyograms (EMGs) from the pectorals and supracoracoides (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 supracoracoides compared to the pectoralis, likely reflecting differences in muscle morphology.

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**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**

Previous attempts to quantify 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, suggesting the hypothesis that evolutionary radiation has deterministically 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.

**74.6 MAIA, A.*; COUTO, A.; ADRIAENS, D.; Ghent University, Belgium; anabelandia@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. spinosus*. *Hippocampus abdominalis* abundantly possesses 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 1cm 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 1.5cm) 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.
17.11 MALEC, A.M.; WILLIS, M.A.*; Case Western Reserve University; maw27@case.edu

Overlap between the fore and hind wings in the moth Manduca sexta is different associated with sex and weight in free flight. Moths and butterflies have four–wings, but most flight studies focus on their forewings and treat them as functionally two–winged fliers. In fact, previous studies showed that a variety of moths and butterflies can fly with their hind wings removed, but are less maneuverable. How the fore and hindwings work together to affect this increased maneuverability is unknown. It is known that the fore and hindwings in male and female moths are linked in anatomically different ways. By studying this natural anatomical difference in fore–hindwing interaction we might reveal how the wings interact in flight. In the moth Manduca sexta, females are larger and heavier, on average, than males so comparing the two sexes may provide important clues about how the wings, and the whole moth, operate together to generate the maneuvers we observe. To test the effects of weight, sex, and wind speed on fore–hindwing overlap, we marked male and female moths on the thorax, fore, and hindwings. By measuring the change in angle between the fore and hindwings as moths flew through either 75 cm/s or 150 cm/s winds, we were able to quantify the changes in wing overlap and thus wing area. Regression analyses revealed a significant relationship between wing area and body weight and analyses of covariance showed that this relationship was different in males and females. Further analyses and experiments are ongoing to determine if the observed changes in overlap are actively controlled by the moths or a passive property of the mechanics of the flight system. We thank Jennifer Avondet for her assistance in managing the insect colony and help with all aspects of this project. A.M.M. 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.

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Molgulid Ascidians have a Radical Heterochronic Shift in the Metamorphic Gene Network

Transcriptome and genome data offer an exciting new approach to examine the origin and evolution of the chordate body plan. Chordate body plan evolution can be studied with two tunicate species with radically different larval body plans the tailed ascidian Molgula oculata and the tailless M. oculata. Tailed M. oculata embryo have 40 notochord cells that are converged and extended, tail muscle cells flanking the notochord, and the otolith, a gravity sensory organ located in the head. The tailless M. oculata does not form a tail in their larval stage, and have only 20 notochord cells that do not converge and extend during larval development. We show by transcriptome analyses that the ascidian metamorphosis program begins earlier in molgulid ascidians. This radical heterochronic shift has been documented in another tailless ascidian, Molgula tectiformis, and is now reported for both the tailed, Molgula oculata and tailless Molgula oculata. Further functional data is necessary to determine if this pronounced heterochrony is the necessary preadaptation for tailless tadpole to evolve in molgulid ascidians. However, we forecast that these studies will facilitate the elucidation of the metamorphic signal in ascidian tadpole larvae, which is still currently unknown.

85.3 MANAHAN, D.T.; HEDGECOCK, D.; Univ. Southern California; manahan@usc.edu

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 larval 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 genetic 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.
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 of the Neotropical host-parasite system of the striped cuckoo (Tapera naevia excellens) and the rufous and white wren (Thryophilus rufalbus) during three reproductive stages: incubation, nestling, and fledging. We found that foster parents of cuckoo chicks had significantly higher levels of stress-induced, but not baseline, corticosterone during the post-fledging stage. Higher maximal levels of stress-induced corticosterone were associated with an increase in 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 (Thryophilus rufalbus) during three reproductive stages: incubation, nestling, and fledging. To determine if brood parasitism alters the trade-off between current and future reproduction, we measured parental care behavior and glucocorticoid levels in nestlings of the Neotropical host-parasite system of the striped cuckoo (Tapera naevia excellens) and the rufous and white wren (Thryophilus rufalbus) during three reproductive stages: incubation, nestling, and fledging. We found that foster parents of cuckoo chicks had significantly higher levels of stress-induced, but not baseline, corticosterone during the post-fledging stage. Higher maximal levels of stress-induced corticosterone were associated with an increase in parental care behavior and glucocorticoid levels in nestlings of the Neotropical host-parasite system of the striped cuckoo (Tapera naevia excellens) and the rufous and white wren (Thryophilus rufalbus) during three reproductive stages: incubation, nestling, and fledging.
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, whereas the sandbar shark did not show any correlation. Physiology of the dusky shark seems greatly affected by capture, relative to sandbar sharks, resulting in higher rates of at-vessel and post-release mortality.

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 contain 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 desiccation, exposure to novel predators and pathogens, and the risk of hatching into a hostile habitat. In most species of teleosts that nest terrestrially or semi-terrestrially, adults are fully aquatic, the risk of hatching into a hostile habitat. In most species of teleosts include desiccation, exposure to novel predators and 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.

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.
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 sympathy 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.

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 automatic 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 asexually, 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 asexual reproduction for 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 aomixis 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.

The role of parthenogenesis in shaping life histories of natural populations

The rapid and remarkable plasticity of individuals is one of the major challenges to current evolutionary theory. Asexual reproduction with fixed genomes can only support a limited plasticity. How do parthenogenetic animals cope with a dynamically changing environment? Here, we examine parthenogenetic animals' plasticity by looking at the rapid and remarkable plasticity of the cichlid fish Astatotilapia burtoni. We found that the cichlid fish Astatotilapia burtoni is a parthenogenetic fish, which has colonized numerous land-locked blue holes. These parthenogenetic animals can colonize both isolated and connected lakes and are able to adapt to new environmental conditions. For example, they can adapt to new food sources, such as fish, which are not available in their natural habitat. They are also able to adapt to new predators, such as humans, and can even adapt to new climates. This rapid and remarkable plasticity is a result of their parthenogenetic life history, which allows them to adapt to new environments quickly. Therefore, parthenogenetic animals are a useful model for studying the role of plasticity in evolutionary processes.
Sidewinding 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.

**References**

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**Abstract**

**Patterning 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 suggest 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.

**References**

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**Abstract**

**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 complementary 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 carbohydrate 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 two apparently disparate functional modules might be linked through the regulation of proteins converting pyruvate to oxaloacetate, which was a strong signal observed in both experiments. There is, therefore, a possibility that corals might possess a central regulatory mechanism for physiological adaptation or acclimatization, similarly to what has been observed through ecological genomics studies in three-spine stickleback fish (*Gasterosteus aculeatus*) and the Glanville fritillary butterfly (*Melitaea cinxia*).
76.5 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-fin 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 FBots 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.

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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 from 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.
Egg size and exogenous food level interaction to affect larval growth in tropical Echinometra spp. sea urchins

Planktotrophic 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 planktotrophic 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 environmental change. 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 metabolic rate was measured. The fasting mice exhibited predicted reductions in body mass, activity, BMR, and RER. Although RERs rapidly decreased by 6h−8h, they remained constant thereafter, precluding meaningful interpretations of changes in fuel oxidation. Breath testing revealed a clear, transient peak in 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.*; TOBALSKIE, B.W.; EMLEN, D.J.; University of Montana; mccullough.e@gmail.com

**Long and strong? Mechanistic 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 beetle 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.

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**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.; Univ. of Texas at Arlington; mcginty@uta.edu
The effect of temperature on the growth rates and oxygen consumption of 6 cnidian algal symbionts
Algal symbionts in the genus Symbiodinium that form mutualistic relationships with many cnidarians are critical to coral reef maintenance, growth and persistence, but little is known about their physiology, especially in how it relates to genetic diversity that exists within the genus. In particular, gaps surround our understanding of variation among different symbionts, and how that physiology changes during exposure to stressors associated with climate change, such as elevated temperatures. To investigate this, 6 different Symbiodinium cultures (types A1, A2, B1, B2, E1 and F2) were exposed to a range of temperatures and the resulting oxygen consumption rates and growth rates were compared. Cultures were acutely exposed to temperatures ranging from 25°C to 37°C (42°C for F2) and dark oxygen consumption rates were measured, allowing determination of maximum oxygen consumption rates and Q10 rates. Differences existed among algal types for the maximum rate, temperature where maximum rates were reached, which ranged from 31°C (B1) to 41°C (F2), and Q10 rates, with the lowest at 2.804 (E1) and the highest at 5.880 (B2). Growth rates at 26°, 30°, and 34°C were also measured and differences among Symbiodinium types were again observed. Preliminary analysis suggests that in some Symbiodinium types, oxygen consumption continued beyond temperatures where positive growth rates were maintained, indicating that algal cells are still alive at these temperatures but unlikely able to support their own growth. These findings, and the potential implications on the algal–cnidian symbioses, will be applied to elucidate the physiological responses of Symbiodinium to stressors associated with climate change and address their role in coral decline.

59.2 MCGLOTHLIN, J. W.*; FELDMAN, C. R.; BRODIE, JR., 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.

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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 the 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 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% but 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, TJ*; SCHONDUBE, JE; NICOLSON, SW; PINSHOW, B; FLEMING, PA; MARTINEZ 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 uricotelic 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).

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**Importantce 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 cheilonians 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 26% smaller than their sham 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.

126.3 MENZEL, L.P.*; BIGGER, C.H.; Florida International University; lorenzo.menzel@fiu.edu

**Antibacterial peptides from the caribbean octocoral Swiftia exserta.**

Endogenous small antimicrobial proteins (and peptides) are important components of the innate immune response of animals. Microbicidal peptides are widespread and have been found in all living organisms studied. Understanding of the evolution of innate immunity is not well developed, particularly those immune responses in cnidaria, our lab endeavors to study such immune responses in the octocoral *Swiftia exserta* (an azooxanthellate, ahermatypic anthozoan). Understanding aspects of coral immune responses may lead to ameliorating the precipitous decline of these important marine animals. The survival of sessile marine animals depends heavily on an efficient mechanism to protect themselves against infection/colonization by the multitude of microbes in the surrounding water column. In order to study the proteinaceous effectors of *Swiftias* antimicrobial defense we extracted branches in acidified water. Nuclei and large debris were removed, the clarified extract size fractionated with a 10 Kda cutoff membrane, and the filtrate then partially purified via continuous electrophoresis. Timed fractions were collected, concentrated by centrifugal evaporation, and tested for antibacterial activity with a two–stage radial diffusion assay. Several fractions exhibited potent antibacterial activity against gram–negative (*E. coli, P. aeruginosa*), and gram–positive (*S. aureus, L monocytogenes*) bacteria. These preliminary results from an anthozoan supplement the 2006 report on Aurelin (from the scyphozoan *Aurelia aurita*) to establish a repertoire of antibacterial peptides in cnidaria. Characterization of the antibacterial proteins (amino acid sequence and structure) found in *Swiftia* (and other cnidaria, animals that diverged before the protostome–deuterostome split) will further our understanding of the evolution of this crucial aspect of innate immunity.

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**Energy expenditure is independent of dive function in a deep diving vertebrate, the northern elephant seal**

Although energetics are fundamental to animal ecology, traditional methods of assessing metabolic rate are not both direct and instantaneous. Recently, continuous blood oxygen (O2) measurements were used to document energy expenditure in diving elephant seals (*Mirounga angustirostris*), demonstrating that an exceptional hypoxic tolerance and exquisite management of blood O2 stores underlie their extraordinary diving capability. Despite numerous behavioral and ecological diving studies and a growing body of physiological data, we lack a clear understanding of how diving behavior affects energy expenditure in air–breathing vertebrates. To begin to unravel these relationships, we analyzed dive profiles and classified O2 utilization according to dive type (overall function of dive: transit, foraging, food processing/rest), linking fine scale behavior with in vivo O2 measurements for the first time in a free–diving animal at sea. In routine dives of elephant seals, the blood O2 store was significantly depleted to a consistent level for dives of the same duration irrespective of dive function, indicating that all dive types have equal costs. Thus, although elephant seals appear to devote one major task to a given dive, thereby separating dive functions into distinct dive types, each of these bears the same sizeable expense. This strategy may optimize O2 store utilization and recovery, consequently maximizing time underwater and allowing these animals to take full advantage of their underwater resources. Additional studies integrating dive behavior and physiology will provide a more complete understanding of the ecology and conservation needs of these animals. This may be especially important to species like the elephant seal that operate regularly at considerable cost, particularly in determining their ability to cope with unpredictable environmental perturbations.
50.3 MERNER, M.J.*; BERENDZEN, P.B.; Univ. of Northern Iowa; mernerm@uni.edu

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.

S7–1.6 MERRITT, DJ*; 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 the 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 L:D exposure to peak during the day. Nevertheless, in L:D environments, individuals don’t 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 the limited food availability and lower temperatures that are associated with winter. Temperate insects enter diapause in response to the short day lengths 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.

50.4 MERRICKS, J.A.*; GERHARDT, H.C.; Univ. of Missouri; Columbia; jawf2@mail.missouri.edu

Sexual plasticity and mate recognition in the pine woods treefrog, 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 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.
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).

MIDDLETON, KM*; COATS, BR; University of Missouri, mkmiddleton@missouri.edu

Energy metabolism of small muscle phenotype mice compared to inbred strains in response to exercise

In recent years, studies of the skeletal system have revealed that it occupies a central role in whole–organism energy regulation via interactions with the autonomic nervous and endocrine systems. Much of this interaction is mediated by the adipocyte–derived hormone leptin, which has broad activity on appetite, energy expenditure, reproduction, and the skeletal system. Although the leptin–bone–insulin pathway has been extensively studied in leptin or leptin receptor knockout models, selection experiments may provide a novel system in which to address similar questions. We compared physiological parameters between an inbred line of high activity mice that exhibit a small muscle mutation and two inbred strains of mice that exhibit high and low bone mass phenotypes. The high activity mice were derived from a long–term selection experiment for high levels of voluntary wheel running. We divided mice from three strains into activity and stationary groups (n = 8 each) and recorded daily wheel activity for 10 weeks. Insulin and fasting glucose levels were assayed post wheel access, while circulating leptin was assayed both before and after wheel access. Insulin was significantly lower in the activity group but did not differ among strains. In contrast, fasting glucose did not differ between strains or treatments. Mini–muscle mice showed significantly higher initial leptin levels than the other strains, and were significantly lower in exercise groups. Leptin levels were more variable in sedentary mice across strains compared to the activity group. We conclude that mice with the small muscle phenotype exhibit a similar response to exercise as has been shown in other strains and that these mice might be an appropriate model for simultaneous studies of exercise, skeletal morphology, and energy physiology.

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.

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 by propulsive contractions of their elastic bell. 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.

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 by propulsive contractions of their elastic bell. 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.
**107.5 MITCHELL, J.S.; The University of Chicago; mitchells@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 skew, 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, L.; 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; mitchbiny@post.bgu.ac.il**

**Novel chitin binding proteins with suggested role in organization of a cuticular cuticular chitin spur in the arthropod cuticle**

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 domain 2 domains (ChtBD2), 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. Gastrotheca are cuticular structures formed by the crayfish Cherax quadricarinatus during premolt, as transient calcium deposits. However, unlike the exoskeleton, gastrotheca are relatively homogenous in composition, making them excellent research candidates for cuticular assembly. Two novel, strong chitin-binding proteins containing three ChtBD2 domains, were identified from C. quadricarinatus gastrotheca. Their transcripts were fully sequenced based on RNA from the gastrotheca–forming epithelium, and designated C. quadricarinatus gastrotheca 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 gastrotheca 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; nmllot@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.
Antarctic notothenioid fishes display a suite of adaptations to their habitat, including proteins that function optimally in the cold. Studies of enzymes have shown that adaptation to temperature is driven by subtle changes in primary structure that lead to changes in conformational flexibility. We have focused on the Ca$^{2+}$ binding protein parvalbumin (PV) to determine if the enzymatic paradigm of thermal adaptation applies also to non–enzymatic proteins. Characterization of PV from white muscle of Antarctic notothenioids and from temperate zoge teleosts reveals that the pattern of thermal sensitivity for PV Ca$^{2+}$ dissociation constants ($K_0$) parallels that of $K_m$ for many enzyme systems: At common measurement temperatures, PVS from Antarctic fish have a higher $K_a$ than temperate counterparts, but at physiological temperatures function is conserved. Attributing this observation to specific amino acid substitutions is a difficult task as notothenioids are highly diverged from most temperate fishes, meaning that accumulated neutral substitutions can confound a simple analysis by sequence alignment. Accordingly, this work employs ancestral sequence reconstruction and three–dimensional modeling to pinpoint residues possibly responsible for functional adaptation. Reconstruction and modeling suggested that just two amino acid substitutions can lead to the current Ca$^{2+}$ binding thermal profile of notothenioid PVs. Expression and characterization of the ancestral Antarctic and temperate PVs supports this hypothesis. Hence, thermal adaptation of PV follows the paradigm established for catalytic proteins: The evolutionary loss of just two hydrogen bonds is sufficient to explain the observed thermal phenotype of Antarctic notothenioid PVs.

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, 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 amplitude and faster response supporting predictions from the model and whole–nerve recordings. Variable–latency afferent signals may provide a sufficient and low–delay preconditioned control input to the neuromechanical system of the cockroaches as demonstrated from the correspondence between the time course of the population response and the turning kinematics.
35.1 MORRIS, J.S. *; BRANDT, E.; University of Utah; j.s.morris@utah.edu

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.

10.5 MOROZ, L.L.; University of Florida; moroz@whitney.ufl.edu

Genomic Bases for Independent Origins of Neurons and Complex Brains: New Insights from RNA−seq and molecular sequencing of basal metazoa, basal deuterostomes and molluscs

The origin of neurons and complex centralized brains are two major evolutionary transitions in the history of animals. How many times might complex brains or neurons have evolved? Polyphyly (e.g. the presence of a centralized nervous system in urbilateria) vs polyphyly (multiple origins by parallelization nervous systems within several lineages) are two historically conflicting scenarios to explain such transitions. To reconstruct the parallel evolution of nervous systems, genomic and metabolomic approaches have been implemented to probe enigmatic neurons of basal metazoa (including 8 ctenophores) and basal deuterostomes, as well as 23 species of gastropod and cephalopod molluscs (including Nautilus, Sepia, Loligo, Octopus). 1) Recent phylogenomic and cladistic analysis of RNA−seq data suggests that complex brains may have independently evolved at least 9–11 times within different animal lineages. Indeed, even within the phylum MolUsca cephalization might have occurred at least 5 times. 2) Cladistic, genomic and metabolomic analyses imply that neurons themselves evolved more than once (e.g. Ctenophores vs other animals). Emerging molecular data further suggest that at the genomic level neural specification might have been achieved by changes in expression of just a few transcriptional factors not surprising since such events might happen multiple times over 700 million years of animal evolution. Ancestral polarized secretory cells were likely involved in coordination of ciliated locomotion in early animals, and these cells can be considered as evolutionary precursors of neurons within different lineages. Under this scenario, the origins of neurons can be linked to adaptations to stress/injury factors in the form of an integrated regeneration−type cellular response with secretory signaling peptides as early neurotransmitters.

38.1 MORROD, C.C. *; REDMOND, N.E.; PICTON, B.E.; ALLCOCK, A.L.; SIGWART, J.D.; MAGGS, C.A.; Queen’s University Belfast, NMNH, Smithsonian Institution, National Museums Northern Ireland, Dept. of Zoology, Ryan Institute, National University of Ireland Galway; christinemorrow@gmail.com

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 Dictyonellidae 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 results show 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.
51.3 MORSE, MPATR; Univ. of Washington, Friday Harbor Labs; mpmorset@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 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. Morse 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 curtailed 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.

64.3 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 lifespans. 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 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 affects of collisions.

7.2 MOUCHKA, M E*; LEHNERT, E M; BURRIESCI, M S; SCHWARZ, J; PRINGLE, J R; Cornell 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 mannose−binding lectin serum 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.

135.1 MOUSTAKAS−VERHO, JE*; ZIMM, R; CEBRA−THOMAS, J; SEPPäLä, NK; KALLONEN, A; MITCHELL, KL; HäMäLäINEN, K; SALAZAR−CIUDAD, I; JERNVALL, J; GILBERT, SF; Institute of Biotechnology, University of Helsinki, Biology Department, Millersville University, Department of Physics, University of Helsinki, Biology Department, Swarthmore College, Department of Chemistry, University 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 the loss 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.

January 3–7, 2013, San Francisco, CA
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 which of 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 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 birds typically fly faster, migrate more frequently and migrate longer distances than bats.

Hawkmoths of Ender: Navigational decision policies for obstacle navigation in Manduca sexta

Insects flying within complex environments avoid obstacles by making decisions primarily on the basis of visual information. To study how the availability of visual information about obstacles affects course planning, we constructed a virtual flight simulator in which tethered Manduca sexta hawkmoths were able to control their trajectories through a virtual 3–D forest environment by applying yaw torques measured by a torquemeter. We investigated how visual information regarding local obstacles influenced navigational decision policies by using the display software to reduce contrast between obstacles and the background on the basis of their virtual distance from the moth, effectively introducing a virtual fog into the environment. For each subject, we applied five levels of virtual fog at two flight speeds, with three replications for each combination, for a total of thirty trials per subject. For 8 subjects a variety of behaviors were recorded, including obstacle avoidance and attempted landings on virtual trees. Heavy virtual fog limited navigation for all subjects, showing evidence of short range planning. Trajectories gathered for very long visibility ranges did not exhibit obvious differences compared to medium visibility trials. Our virtual reality system demonstrates a viable platform for investigating decision making on the basis of visual information, broadly applicable to a wide range of biological subjects and capable of easily generating extraordinarily rich datasets.

Does thermal specialization accompany environmental differentiation in a diverse clade of Caribbean Anolis lizards?

Despite lacking physiological heating and cooling, vertebrate ectotherms can be found across a wide spectrum of thermal environments. The degree to which ectothermal diversification along thermal gradients is accompanied by evolution in thermal physiology remains a pervasive question in evolutionary biology. The adaptive radiation of Anolis Caribbean lizards in the Greater Antilles has been most often studied along a single axis of morphological and behavioral adaptation to microhabitat (i.e., the ecomorphs). However, most of the species richness of these anoles occurs through within–ecomorph radiations along a separate axis of specialization that corresponds to macrohabitat gradients. The cybotoids are a clade of Hispaniolan trunk–ground anoles that present the most extreme case of radiation along macrohabitat gradients. Members of this group are found from sea level to almost 3,000 meters and span a wide gamut of thermal environments. In this study we use environmental niche modeling (ENM) to quantify diversification in the thermal niche among seven species of Dominican cybotoids. We employ a phylogenetic framework to measure the extent to which diversification in the thermal environment has been accompanied by differentiation in the thermal sensitivity of three metrics: the critical thermal minimum (CTmin), critical thermal maximum (CTmax), and the mean field–active body temperature (Tb). We find that environmental diversification is accompanied by thermal specialization in some, but not all, physiological traits, and likely reflects tradeoffs between optimal performance and performance breadth in variable thermal environments.
Low hydrogen peroxide production in mitochondria of the long–lived Arctic 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 H$_2$S, anoxia/reoxygenation 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 H$_2$O$_2$ 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 H$_2$O$_2$ 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. can 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 metazoan 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–seq on different stages of skin appendage 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 &beta;–catenin, the earliest known molecule expressed in feathers. Our preliminary evidence suggests &beta;–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.
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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 area). To avoid 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 Dialisus 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.

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Reflections and 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 survived 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, Carlson 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–ha!) 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 Earths climate and ecology continue to change, forcing wild animals to face new challenges to survival and reproduction.

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

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 anatomical 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.
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.

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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 Usambari Orange Baboon tarantulus (Pterinochilus murinus) (body length: 1.1±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±4.81° 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: 13.4±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 in addition to locomotory role, while the fourth set of limbs maintain a primarily propulsive function.

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Evolutionary morphology of the prehensile tail in syngnathid fishes: from pipefish 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 armor 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 (Halichthys 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 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 trout–like flow structures which are shed off of the fin ventrally along the heave axis. The eel–like flowing wave of the fin adds momentum to the fluid longitudinally along the surge axis, reorienting the ventrally 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.

Anthropogenic ocean warming and acidification is potentially detrimental to the sensitive early life stages of benthic marine invertebrates. Most studies have focused on the effects of ocean acidification as a single stressor on calcifying planktotrophic larvae with a paucity of data on species with alternate non–calcifying developmental strategies, the early juvenile stage and, on the interactive effects of warming and acidification. To address these knowledge gaps, the development of the non–calcifying echinoderm larvae of the sea star Meristema scalaris and the echinulithic juvenile of the sea star Parusulastra exigua were investigated in the setting of predicted ocean warming (+2–4°C) and acidification (−0.4 –1.0 pH units) for 2100 and beyond. For M. scalaris, pH had a greater negative effect on embryos reaching the hatched gastrula stage than larvae. Mortality and abnormal development in larvae increased significantly even with a +2°C warming and, larval growth was impaired at +4°C. Negative effects on P. exigua juveniles occurred only at −1.0 units pH at units where there was an increase in mortality and abnormal development. There were no interactive effects of temperature and pH across all stages monitored for either species. For M. scalaris, warming not acidification was the dominant stressor. In contrast, juvenile P. exigua were resilient to projected near future ocean (ca. 2100) acidification and warming. Heat shock protein expression 70 kDa (hsp70) in the embryos and adults of M. scalaris indicated that the developmental stages do not elevate expression of this protein in response to thermal spikes, but the adults do as a potential defensive strategy to warming in their tide pool habitat.

Histamine functions and distribution in gastrulation and skeletogenesis of the sea urchin S. purpuratus

Earlier studies established a novel function of histamine signaling (HA) in metamorphic competence of the sea urchin Strongylocentrotus purpuratus. Preliminary results suggest that several neuron like cells synthesize HA also in gastrulation and phuteus formation. Here we tested the distribution and function of this important neurotransmitter in gastrulation and skeletogenesis. Our data show that HA is required for proper gastrulation in sea urchin embryos based on the inhibition of histamine receptor protein. Furthermore our data suggest that neuron like cells in the region of the developing apical ganglion produce HA post–gastrulation. When we tested a previously proposed link between HA and programmed cell death (PCD) we found that PCD is not required for gastrulation and HA does not appear to regulate this process in early embryogenesis. Our data further emphasize the importance of HA as a signaling molecule in sea urchin development and suggest that paracrine signaling may play an important role in sea urchin gastrulation in addition to transcriptional regulation.
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**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 its ability to survive and potentially increase its fitness. In this study, we aimed to dissect the genetics of cold tolerance in fruit flies (Drosophila melanogaster). The fly species was exposed to a cold environment at 4ºC, and individuals who survived the exposure were selected for further studies. These selected individuals were then crossed with a control line to produce F1 offspring, which were then crossed with the parents to produce F2 offspring. The F2 offspring were then subjected to cold stress at 4ºC, and those who survived were selected to produce the F3 generation. The process was repeated for 3 generations, and the results were compared to the control line to identify the genes responsible for cold tolerance.

With declining sea ice availability, walruses are increasing their use of terrestrial haul-outs, which can deplete localized prey resources. Estimates of carbonic demand and techniques for monitoring body condition are required for assessing the potential for population level effects on walruses. Carbonic intake and body condition (length, girth, and blubber thickness) were measured for 29 individuals from four populations over one year from non-reproductive female walruses housed at Indianapolis Zoo (n = 5; T<sub>water</sub> = 14.2 ± 0.1°C), Six Flags Discovery Kingdom (n = 8; T<sub>water</sub> = 13.9 ± 2°C), Point Defiance Zoo and Aquarium (n = 2; T<sub>water</sub> = 13.8 ± 7°C), and Discovery Kingdom (n = 10; T<sub>water</sub> = 13.9 ± 4.5°C). 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 ± 4,499 kcal dy<sup>−1</sup> (wild = 16.3 ± 3.5 kcal dy<sup>−1</sup>), 758 kcal dy<sup>−1</sup> (wild = 29,403 ± 4,474 kcal dy<sup>−1</sup>). Based on our published bioenergetics model, these caloric intakes represent 61%, 47%, 35%, 45%, and 29% 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.
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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.

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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, 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.

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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 toolkit, 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, 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 whole mount in situ hybridization, identifies a group of neurosensoric cells, which might function as a main light sensory organ. In addition, expression of clock genes has been detected in adult tissues.
Dabbling, gracing 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 quadrato. Within Anseriformes, upper bill−quadrato 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).

Hormones regulate decision−making strategies, in particular by translating an individuals physiological state into decisions on major behavioural and life−history processes, such as reproduction. Corticosterone is a glucocorticoid hormone that has been gaining attention as a mediator of reproductive effort, and experimentally elevated corticosterone concentrations have been shown to disrupt reproduction in avian species. Here, we tested whether individual variation in corticosterone concentrations is related to the decision for brood abandonment in free−living great tits, Parus major. Because of harsh environmental conditions, many adults abandoned their first broods in 2010, enabling us to ask which physiological, environmental and individual characteristics increased the probability of nest desertion by both males and females. The best predictors of nest desertion were high stress−induced corticosterone levels in males and low average nesting mass. Furthermore, high stress−induced corticosterone levels in 2010 appeared to represent plastic responses to environmental conditions and reproductive investment: individual males that abandoned their nests in 2010 had higher stress−induced corticosterone concentrations and produced nestlings with lower average mass than in 2009, when nesting successfully. Females that abandoned their nests in 2010 had higher baseline corticosterone concentrations than in 2009, when nesting successfully. Also, males that renested after abandonment in 2010 had lower stress−induced corticosterone concentrations and nestlings with higher mass. Finally, pairs that abandoned but renested later in 2010 had similar fledging success at the end of the season as those that did not abandon. These results indicate that an individuals reproductive decision is the result of a plastic modulation of the corticosterone stress response that influences reproductive decisions according to environmental conditions.

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 handling 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.

The role of titin in force enhancement along the length−tension curve

Force enhancement is when steady state muscle forces are larger after stretch and can result in muscle forces that exceed isometric force at Lo, even on the descending limb. This muscle property is not well explained by the sliding filament theory; however, many studies suggest a role for titin in force enhancement via calcium activation of titin. To study titin's contribution to force enhancement, we used an MDM mouse model in which mutant mice have a deletion in the N2A region of their titin protein and exhibit different active and passive properties compared to wildtype, including grazing, diving and dabbling. This morphological diversity 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 quadrato. Within Anseriformes, upper bill−quadrato 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).
The predominant biological view of the evolution of flight is that it is preceded phylogenetically by a gliding stage. Support for this hypothesis has mainly rested on what is presumed to be easier or necessary based on models. The hypothesis can be empirically tested by examining the comparative phylogenetic positions of gliders and flyers. The three known clades of living and extinct vertebrate flyers are far removed from the 15 known clades of living and extinct gliders. The problem is particularly acute with bats, which are far removed from all eight clades of mammalian gliders, and are nested within a clade that contains only terrestrial and fossorial forms. We used phylogenetic analyses of major clades of bats, and the extinct chiropteran outgroups of crown–group bats, to assess ancestral states for ecological characters related to locomotion, echolocation, diet, and habitat. The ancestor of crown–group bats likely was insectivorous, echolocated as most bats do, could climb quadrupedally, and had poor terrestrial locomotory skills; the ancestral habitat is difficult to determine. Inferences about stem–group bats involve character states of fossil bats. Flight phylogenetically preceded advanced echolocation; the most basal stem–bats could climb, but their habitats are difficult to specify. No outgroups to bats are or apparently were bipedal; thus the forelimbs of bats could only be freed to evolve powered flight if standard quadrupedal locomotion was modified. Ontogeny also speaks against gliding in bat precursors. Bat wings develop by hypertrophy of the manus and chiropatagium (the thrust–producing part of the wing), not the medial part of the wing (brachiopatagium) that produces lift in gliding.

Multiple climate change variables interact to reduce the physiological performance of sea urchin larvae in future oceans

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 metabolically. 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 estritol 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 that had 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.

Evidence for links between ecology, immune function, and life–history strategy remains contradictory; especially regarding the pace–of–life ecocrinology 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 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 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.
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 similar across species. Cephalopod mollusks include two distinct clades of squid that harbor closely related strains of luminous bacterial symbionts within their eyes and photophores. To confirm this hypothesis, 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.

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.
S10–1.3 PASSAMANECK, Y.J. *; MARTINDALE, M.Q.;
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Opsins in brachiopod embryos and larvae

In the larvae of most protostome invertebrates, detection of directional light is facilitated by simple pigmented eyes containing rhodomeric 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 finding provide novel models for understanding the increase in complexity during the course of eye evolution.

S1–3.1 PATTERSON, B.W.; ABRAHAM, A.; MCLEAN, D.;
PATANKAR, N.A.; MACIVER, M.A. *; Northwestern University; maciver@northwestern.edu

Vision versus electrosense: Mechanics and sensing in prey capture behavior in larval zebrafish compared to electric knife fish

We have collected motion capture data on a non-visual hunter, the weakly electric knife fish (Apteronotus albifrons) as well as a visual hunter, the larval zebrafish (Danio rerio) during prey capture behavior. Kinematic analyses have provided a detailed picture of how both fish hunt their prey. We have also analyzed their biomechanics through a combination of computational fluid dynamics, particle imaging velocimetry, and biomimetic robotics. What do these distinctively different animals and prey, differing in size by two orders of magnitude and using very different sensory systems, tell us about the biomechanics and sensory constraints of prey capture? I’ll talk about a few of the emerging lessons, highlighting differences between the sensory volumes and mechanics of these two fish.

S1–2.4 PATEK, S. N. *; DEVRIES, M. S.; MURPHY, E.A.K.;
University of Massachusetts Amherst, University of California Berkeley, University of Virginia; patek@bio.umass.edu

What is fast?

Predators are often assumed to be the fastest organisms and being fast is typically associated with speed. However, the notion of fast involves multiple kinematic parameters, such as duration, speed and acceleration, and not all of these parameters are necessarily relevant for particular predatory strategies. In the context of this symposiums focus on the motor systems underlying predatory attacks, this study examines the definition of fast, the macroevolution of fast organisms, and addresses which facets of fast are actually relevant to predatory movements. In addition, we examine mantis shrimp (Stomatopoda), a group of extreme marine predators that exhibit substantial variation in the kinematics, morphology and strategies of prey capture. The results of these analyses show that the fastest movements are not synonymous with classic notions of predatory attack and that using the appropriate kinematic measure is key to correctly interpreting the function of fast movements.

S1–2.5 PENDAR, H. *; SOCHA, JJ; Virginia Tech; hpendar@vt.edu

The mechanism of tracheal collapse in beetles: a multi-linked system

Many insects are known to augment their respiration via rhythmic tracheal compression and reinflation. 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 tenebrioid 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 tracheal 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).
Differential physiological tolerance to low salinity exposure in two color morphs of the green crab, Carcinus maenas

The European green crab, *Carcinus maenas*, is variable in ventral carapace coloration. Crabs are green after molting and become dark red after prolonged intermolt. Previous studies have shown that red morphs are weaker osmoregulators and have poorer tolerance to low salinity exposure than green morphs. Cellular data to complement this organismic response is lacking. We exposed crabs to 10 ppt seawater to assess hemolymph osmolarity, oxygen consumption, righting response and treadmill running endurance. Changes in mRNA expression were assessed for ion transporters (carbonic anhydrase, Na⁺/K⁺-ATPase, Na⁺/K⁺−2Cl⁻ cotransporter, and Na⁺/H⁺ antiporter), stress marker (HSP70) and indicators of cellular energy status (AMPK, arginine kinase). At 10 ppt red morphs exhibited lower hemolymph osmolarity and poorer whole animal performance. Concurrently, greens morphs exhibit a greater upregulation of genes responsible for ion regulation, cellular stress response and cellular energy status. Whereas red morphs crabs show minimal if any upregulation in these genes. To test the hypothesis that the red morphs reached a physiological limit of ion regulation at 10 ppt, suggested by higher morality, green morphs were exposed to 10 ppt and red morphs to 12 ppt, resulting in a similar hemolymph osmolarities of 750 mOsm in both morphs. After matching the hemolymph osmolarity both morphs showed similar mRNA upregulation. Therefore, the two color morphs seem to have different ion regulatory capacities and reach a critical point of no longer being able to upregulate the respective transporters at different salinities. Funded by NSF IOB0640478 and DGE0841361.

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 the 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 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; peluda@wfu.edu
Citius, altius, fortius: jumping kinematics and kinetics in two distantly related tetrapods
Many fish stranded on land will use axial movements to generate C−jumps in efforts to return to water. However, mangrove rivulus, 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@usc.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 fasting 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.

72.5 PETERSON, K.*; DUDLEY, R.; FEARING, R.S.; Univ. of California, Berkeley; kevingp@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 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 curial 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 pupuratus. 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.

57.4−1.5 EPSPENI, M.H.; Indiana University; mpespeni@indiana.edu
Evolutionary and ecological genomics in a changing world: integrating Next−Gen data with environmental variation to reveal local adaptation
Understanding how populations respond to and are shaped by their environment is of fundamental importance to revealing the mechanisms of local adaptation in general and for predicting the impact of a rapidly changing climate in particular. Species distributed across heterogeneous landscapes present rich opportunities and challenges for uncovering the targets of natural selection, particularly when there is substantial gene flow among populations, as is the case in many marine, plant, insect, and microbial species. These ecologically interesting species have until recently been without the genomic resources needed to comprehensively explore their physiological and genetic means of persistence in complex ecosystems and changing environments. Here I highlight a recently developed pipeline for generating and analyzing RNAseq data. Using several case studies in the purple sea urchin, Strongylocentrotus purpuratus, I illustrate how polymorphism, gene expression, gene function, and environmental data can be integrated to identify physiological phenotypes while simultaneously testing for signals of natural selection. This broad melding of very different data sets identifies adaptive phenotypes in gene regulation as well as signals of selection in specific genes across environmental mosaics. This approach detected extensive selection on innate immunity proteins in areas of elevated disease incidence, showed strong population differentiation of biomineralization proteins in response to elevated CO2, and showed distinct gene regulatory adaptations in different coastal populations. Collectively, these efforts illustrate how genomic, transcriptomic, and environmental data can be integrated to reveal the targets of natural selection in complex environmental mosaics and can help evaluate the possibility of future evolution to climate change.

January 3−7, 2013, San Francisco, CA
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%), hematoctrit 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 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 stroke and does not detach and shed into the wake. An experimental investigation was conducted to investigate the potential effect of wing aspect ratio on the stability of the LEV. Experiments were accomplished with a custom-designed, mechanical flapping-wing apparatus (the ‘Flutterator’) 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.

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.

Effects of limb autotomy on locomotor performance of ghost crabs

Autotomy, or limb loss, is a mechanism frequently used in response to aggressive inter- and intra-specific interactions, despite the possibility of negatively impacting fitness by hampering an animals ability to run, walk, or swim. Although Atlantic ghost crabs (Ocypode quadrata) are decapods, they use only eight of their ten legs when running and maneuvering. Differential use of the 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 for laboratory−based performance studies. Each

Autotomy, or limb loss, is a mechanism frequently used in response to aggressive inter- and intra-specific interactions, despite the possibility of negatively impacting fitness by hampering an animals ability to run, walk, or swim. Although Atlantic ghost crabs (Ocypode quadrata) are decapods, they use only eight of their ten legs when running and maneuvering. Differential use of the 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.
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.

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 bauplan. 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 a 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.

Why does immunity vary? Linking phylogenetics and life history traits to immunity in reef-building corals
Changes associated with global climate change are affecting ecosystems through the planet, an example in the oceans are coral reefs. Increased sea surface temperatures are favoring the emergence of coral disease and environmental stressors in these ecosystem engineers. Disease outbreaks and frequent fluctuations in temperature have resulted in reduced coral cover and community shifts to either less sensitive coral species and/or algae. Basal immune levels, as well as inducible immune responses, have proven variable and species-specific suggesting that this variability might be associated with both interspecific genomic differences and evolutionary histories. Recently the phylogeny of corals have been under review thanks to the advent of molecular technique and the development of both molecular and population genetics markers. The most current analysis recommended a reorganization of the scleractinian phylogeny at several taxa, which resulted in a relatively accepted new classification of most families and genera. Based on this new taxonomic organization, our endeavor here is to analyze constitutive immune levels and explore its relation with the current classification, across distinct scleractinian groups (i.e. well defined families and genera). Initial results suggest that constitutive immunity in reef-building corals has a significant relation with their evolutionary history. Although, within each group other biological factors, such as reproduction (hermaphrodites vs. gonochoristic) and growth form (massive vs. branching), might provide an advantage to certain species to fight and overcome current challenges from pathogenic infections and/or environmental stressors.
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.

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.

Assessments of immuno- and inflamm-aging following a photoperiodic regime that delays female reproductive aging in Siberian hamsters
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 diseased 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.

Assessments of immuno- and inflamm-aging following a photoperiodic regime that delays female reproductive aging in Siberian hamsters
Age and reproductive senescence are thoroughly intertwined, as evidenced by the ability of photoperiod 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-aging 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.
S10.1-4 PLACHEZKI, 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@bhorn.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.

61.3 PORRO, L.B.*; IRIARTE–DIAZ, J.; O'Reilly, J.; Ross, C.F.; University of Chicago, IL; lporro@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 Uromastyx. 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 Uromastyx 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 Uromastyx during feeding are substantially higher than those recorded in mammalian crania. These results shed new understanding on cranial biomechanics in Uromastyx during feeding and will be used to validate and improve the accuracy of previous computer models.

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 positioning 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 Melanochlamys diomedea, 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.
**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 resulted 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.

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**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 created by the wings of the other birds within the flock. A fixed wing containing unique features that exist in no other animals. These features include a specialized ommatidial region, intraretinal filtering of photoreceptors, and receptors devoted to polarized light detection. The most complex stomatopod eye type contains 16 physiologically different photoreceptor classes, although there is variation in eye complexity among species. In order to investigate this visual system diversity and complexity at the molecular level, transcriptomes have been sequenced from 4 species exhibiting variations in eye design. Transcripts from genes involved in visual signal transduction were identified from assembled transcriptomes using sequences of full−length genes from the *Drosophila melanogaster* genome as queries. The stomatopod species investigated vary in the number of arthropod visual−pigment (R−Type) opsin genes expressed from 12 (*Hemisquilla californiensis*) to 25 (*Neogonodactylus oerstedii*). Based on these results we hypothesize that the diversity of opsin genes has increased during the evolution of the group, with the largest expansion of copy number occurring in the short−wavelength sensitive opsin classes. In all four species sequenced (*H. californiensis, N. oerstedii, Squilla empusa, and Pseudosquilla ciliata*) more opsin genes are expressed than physiologically documented photoreceptors present in the visual system; preliminary in situ hybridization work in *N. oerstedii* shows that many photoreceptor types express multiple opsin genes. Additionally, there is variation among species in the number of expressed transcripts of other key cascade components, including G−proteins and visual arrestins, suggesting further complexity in visual signal transduction.

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**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 biologists analyze landscapes and the 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.
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, found the engulfment rates of the prey are much higher than measured by tags deployed on humpback whales (horizontally lunging towards fish). On the other hand, fish-entrainment costs become smaller and more realistic. One major axis of their divergence is trophic specialization, which is driven by the costs of both feeding and non-feeding transport. A crucial input for non-feeding travel, diving and prey-approach simulations 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 on the body shapes 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, body and boundary layer modeling and sensitivity on body shape details (including tail flexion).

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 increasing incidence and/or severity of some of these diseases. 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 health benefits of zebrafish as a model for human disease. Recent modeling has shown how these are met, thanks to high body streamlining and efficient hunting (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 limb bud and heart development, and may mediate bmp4 and lbh. Expression of lbh, which characterizes this linkage, was re-sequenced in the East African cichlid species. The other alternately fixed SNP was shown to be fixed in the East African cichlids, exhibiting a rapid and extensive adaptive radiation. One major axis of their divergence is trophic specialization. With respect to kinetic and kinematic data (Goldbogen et al 2012 Funct. Ecol.; Potvin et al. 2012 PLoS One; Weidenmann et al. 2011 Ecol. Model.) that mediate this process, a combination of morphological and morphological data (Goldbogen et al 2012 Funct. Ecol; Potvin et al. 2012 PLoS One) indicate that lunge feeding on krill is a very high mass of water. Particularly with regards to the metabolic power of fish, the engagement of fish size in limiting the amount of prey available (i.e., 50 rather than 80% gape) 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 of fish size characteristic of krill-feeding. 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.
81.2 PRAVIN, S*; KOEHL, MAR; REIDENBACH, MA; University of Virginia, Charlottesville, University of California, Berkeley; sp8yb@virginia.edu

Simultaneous sampling of flow and odorants in a turbulent plume can aid tracking behavior by aquatic organisms

Odors are dispersed across aquatic habitats by turbulent water flow as filamentous, intermittent plumes. Many crustaceans take discrete samples of odors by flicking their olfactory antennules. These antennules, in addition to containing chemo-sensors, also contain mechanosensors that can detect water motion in the surrounding fluid. We examined correlations between fluctuating odorant concentrations and turbulent flow that can provide cues for plume tracking. Laboratory flume experiments utilized a combined planar laser-induced fluorescence (PLIF) and particle image velocimetry (PIV) system to simultaneously measure the flow and odorant concentrations within a turbulent plume. In addition, a numerical model of an odorant release within a boundary layer flow was constructed to simulate the impact of bed geometry and ambient velocity on odorant transport. Results from the laboratory experiments show correlations between high energy eddies and odorants that are actively being stirred, while numerical simulations show that these correlations between flow and odorants change in systematic ways with distance from the source. Detection and use of these correlations by aquatic organisms may enhance tracking behavior across aquatic habitats.
Paracellar absorption of nutrients in bats is high during intestinal luminal perfusions

Water-soluble nutrients can be absorbed across enterocytes via protein-mediated transport, or paracellularly through the tight junctions between enterocytes. Previous in vivo measurements of bats that were orally dosed with carbohydrate probes have shown that bats absorb larger proportions of nutrients paracellularly than similarly-sized non-flying mammals. While this could indicate greater paracellar permeability of the intestinal epithelium, it could also be caused by longer retention time or slow gastric evacuation. We sought to determine if bat intestines are particularly permeable to nutrient-sized molecules. We performed in situ intestinal luminal perfusions on Tadarida brasiliensis and Myotis lucifugus. We cannulated the intestine and recirculated an isomotic buffer containing 10−75 mM D−glucose, 10−75 mM proline, and two carbohydrate probes that are only absorbed paracellularly, 1 mM L−arabinose, and 1 mM lactulose, and radioisotope tracers for these molecules. Absorption of arabinose (MW 150) was nearly double that of lactulose (MW 342), demonstrating a similar molecular size sieving effect as has been seen previously for various species in vivo. At low molarity proline conditions, paracellar absorption (assessed by arabinose clearance) can account for at least 44% of total proline absorption. At 75 mM proline, paracellar absorption accounts for a majority of proline absorption. These data demonstrate that insectivorous bats rely heavily on paracellar absorption for the uptake of nutrients and confirms the high intestinal permeability suggested by whole-animals studies. Supported by NSF Award 1025886.
41.1 QIAN, F*; GOLDMAN, D/I; 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; cristinurade@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 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 Cyprinoidea and sailfinns 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 chemical cues
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; ragland@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.
RAINWATER, E*; FASSBINDER-ORTH, C; Creighton University; ellecia@creighton.edu
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.

RAMIREZ, D*; OAKLEY, TH; Univ. of California, Santa Barbara; ramirez@ufl.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, dorsal 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 α and ϑ. 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 opsins–expressing PSNs are octopus dispersed photoreceptor cells 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.

Ramsay, J.B.; WILGA, C.D.; University of Rhode Island; jasonramsay@my.uri.edu
Preorbitalis and quadratomandibularis 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 quadratomandibularis (QM) and the lower jaw. The PO is considered to function as a jaw protractor and also may assist the QM in adducting the jaws. However, manual depression of the hyomandibulae and lower jaw results in anteroventral rotation of the PO muscle. 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 feeding. PO and QM are passively lengthened during prey processing the PO and QM are passively lengthened during the expansive phase and actively shorten 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.

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 beetle
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 marker loci [5 allozymes, 5 microsatellites, and a 550 bp region of mitochondrial COII] shows significant differentiation among montane drainages along a 75 km transect from the King's River in the southwestern Sierra to Rock Creek in the central Sierra. Geographic variation along this transect is much greater for the allozyme phosphoglucose 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 critical to energy metabolism, may contribute to population persistence in the face of rapid environmental change.
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 margeali and Harmelinella mariannae which disperse only as adults. At the Mediterranean scale, our phylogeographic study based on several mitochondrial and nuclear molecular markers revealed that H. margeali 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. margeali, 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. margeali 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.

Wing shape characteristics exaggerated by RNA interference modulate aerobic performance in fruit flies

The diversity in the 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 aerodynamic 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.

Harmelinella mariannae

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.
10.1 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.

134.2 REICHARD, D.G.; RICE, R.J.; SCHULTZ, E.M.; KETTERSON, E.D.; Indiana Univ., Bloomington, Univ. of California, Davis; dreichad@iu.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 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 for 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 ² or ³ and ², respectively. Given the critical dependence of interactions between Tm and tropomin–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 quantitate 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.
**Circadian clock of the starlet sea anemone Nematostella 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 *Nematostella 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.

**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.

**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 cry (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 re-investigated 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.

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**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.

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**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 *Nematostella 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.**
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 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; HEIMLIER, Jon; BONAPACE–POTVIN, Michelle; ZHANG, Kurt; University of North Dakota; turk.rhen@email.und.edu Genemics, 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/tem) 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 DSeq 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.; clr77@cornell.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 difficulties of linking plasticity and 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 retroposon family in the flowering plant, Arabidopsis thaliana. I will present an update on our work charts the genetic behavior of SADHU element epigenic alleles, as well as an investigation of the impact that this epigenetic variation exerts at both the genomic and phenotypic level.
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 goslings in part because Canadas 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 Canadas, and that there were interspecific differences in compensatory growth that were explained by their digestive physiology. Although phenotypic flexibility in forage 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 a degree species-specific.

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 convoluted nature 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 semi-aquatic carnivorans (coyote, 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 regarding respiration 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 airflow performance. Supported by NSF grants IOS–1120375 (to BAC), NSF I0B–0517748 (to BVV), and NSF IOS–1119768 (to BVV).

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 0.01ml O2/g/hr at 2&degC to 0.29ml O2/g/hr at −20&degC. We also held AGS in steady state torpor at 0&degC–10&degC, −10&degC–0&degC, and 0&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 0.36ml 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 and 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.
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.

Coral–macroalgae dominance shift may impact flow–mediated recovery from bleaching

In the last decade, coral bleaching has emerged as one of the most pressing issues facing tropical coral reef ecosystems, a process that frequently results in a community dominance shift on the reef from a coral– to macroalgae–dominated system. Recent studies have shown that increased water flow enhances recovery from bleaching by reducing the boundary layer thickness and increasing mass flux between the coral and water column. We characterized the water flow profile and oxygen concentration immediately over the surface of both a healthy, coral–dominated and a bleached, algal–dominated specimen of Siderastrea siderea, by utilizing a Nortek Vectrino II velocimeter, particle image velocimetry, and an oxygen microelectrode. We coupled this to photosynthetic yield of the coral using in–situ pulse amplitude–modulated fluorometry. With this experimental setup, we quantified a significant effect on momentum boundary layer thickness over the coral due to macroalgal presence, which influenced oxygen flux at the coral surface–water interface and altered photosynthetic activity compared to healthy coral. As bleaching is often attributed to photosynthesis and oxidative stress on the coral host, these results will likely have implications for recovery potential from a bleaching event.

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 of the size of a song 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.
Gene expression differences underlying sexual dimorphism in ostracod eyes: Insights from transcriptomics

The genetics of convergent evolution and switchback evolution is largely unknown. The assumption is that latent gene regulatory networks are redeployed to recreate an ancestral tissue or cell-type. However, the specifics of this are unknown, for example: At what level is the pathway suppressed? How was the network maintained over the evolutionary history of the group? Is the same redeployment strategy used in convergently evolved species? To begin to answer these types of questions we are using transcriptomics, comparative gene expression analysis, and developmental biology to examine a likely case of switchback evolution the lateral compound eyes in myodocopid ostracods. Our study species, Euphilomedes carcharodonta and E. morini, are of particular interest in that they exhibit dramatic sexual dimorphism of eye morphology. Males have large compound lateral eyes while females have only a tiny rudimentary eye lacking ommatidia. In this way females may represent the ancestral case with eye development suppressed throughout their development while males escape this suppression. Here, we examined the transcriptomes of both embryos and developing male eyes and found 11 of 82 developmental eye genes. After confirming the identity of these genes via phylogenetic methods, we compared gene expression in developing males and females via qPCR and in situ hybridization. We found phototransduction and eye differentiation genes expressed in both male and female eyes, but eye differentiation genes were typically lower in developing female eyes while phototransduction genes showed similar expression levels.

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−naïve 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.

Luminescence reduces the fate of a scale worm Harmothoe imbricata when attacked by crustacean predators.

The luminescent scale worm Harmothoe imbricata is found in abundance in the intertidal and subtidal habitats of coastal Maine. Luminescence occurs in the elytra (scales), which emit light when both attached and detached from the body. Worms can also exhibit whole−segment autotomization, with the posterior half luminescing and the anterior half staying dark, presumably to escape and regenerate the lost segments. Although the luminescence has long been postulated to provide an increase in survivability upon predation attempts, the role luminescence plays on survivorship has yet to be quantified. Using low−light CCD cameras with infra−red (IR) illumination, a night vision device with an IR barrier filter, and a photomultiplier, we recorded the interactions of dark−adapted H. imbricata with crustacean predators having different visual capabilities. The eyes of green crabs (Carcinus maenas) and American lobsters (Homarus americanus) were painted with a matte−black or clear polish, or left unpainted. We found H. imbricata were 15% more likely to escape after the first attack eliciting luminescence with visually unimpaired predators than with blind predators. Upon multiple attacks by the same predator, the trend increased, with worms escaping 25% more from predators able to see the luminescent displays than from blind predators. These data indicate that the luminescent behavior of the worms does play a role in escaping predation. In order to further determine the role of light for defense, we will discuss how computer−controlled LED displays mimicking scale worm displays affected predator behavior in the absence of any other sensory modality.

Using biophysics and Dynamic Energy Budget theory to investigate how a large mammal responds to varying environmental conditions

Multiple factors affect where species can survive and persist across the landscape. Climate limits a species range and abundance directly via physiology, activity constraints, and mortality in extreme events and indirectly, by affecting food availability. We have developed and linked two mechanistic and individual−based models to investigate how populations of red kangaroos (Macropus rufus) respond to varying climate and nutritional conditions. Biophysical models are a powerful tool for predicting an animals metabolic and water requirements based on how their physiology, behavior, and morphology interact with microclimate conditions. However, biophysical models do not fully capture what energy (and water) is available and how this energy is allocated to different metabolic purposes. Such insight can be granted by metabolic theory, such as the Dynamic Energy Budget (DEB) theory, which considers how animals allocate energy (and mass and nutrients) to maintenance, development, growth, and reproduction throughout the animals lifespan. We used the output from a biophysical model (NicheMapper) to calculate maintenance requirements of red kangaroos for a DEB model, and coupled the models with estimated food availability, based on spatial and temporal data on pasture growth. We found that the northern range boundary of the red kangaroo is limited by heat tolerance, which constrains foraging time. We also show how body condition and temporal changes in food availability interact with climate to affect reproductive output. Such a fully mechanistic approach is a novel and powerful tool for investigating how range limits and population vital rates are affected by varying nutritional and climatic environments.
S1–3.3 ROBINSON, H.E.*; KOEHL, M.A.R.; Univ. of California, Berkeley; eroebinson@berkeley.edu

Sessile predator–prey: 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 elegansissima, 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.; Hilibish, T.J.; Univ. of South Carolina, Columbia; rangelogstad@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 extraordinary 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; rodnekenn@isu.edu

Does glucose metabolism limit rainbow cardiac performance in rainbow trout at elevated 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 cardiomyocytes 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, Q10 = 2.1). 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 energy metabolism. We also explored the possibility that endogenous glycogen and glycogenolysis play significant roles in supporting contracting cardiomyocytes. 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.

32.3 Rollan, C.*; Dohhanik, A; Krueger, C; Hallgrimsson, B; University of Calgary; cprolian@ucalgary.ca

Observing skeletal evolution in real time: preliminary results from an artificial selection experiment in laboratory mice.

Vertebrates show tremendous diversity in the morphology of the postcrania!al skeleton. This diversity is the long–term result of evolutionary forces acting on population–level skeletal variation. However, this variation is not random or uniformly distributed across traits. Instead, the direction and magnitude of phenotypic variation across the skeleton is patterned by normal processes of organismal development, in turn affecting the evolvability of individual traits. Here, we report on the first few generations of an artificial selection experiment targeting increases in tibia length in the mouse. The experiment comprises two Selected lines and one Control line of CD1 mice, each set up into 14 families. In the Selected lines, mice are tagged and x–rayed, and littermates with the longest tibiae relative to body mass are chosen as breeders for the following generation, and out–bred to top–ranked individuals from other litters. Control mice are paired randomly. After six generations, tibia length has increased 7.3% in Selected vs. Control mice, while the change in body mass is not significant. Other limb bones have increased significantly in length, though not to the same extent, leading to significant changes in limb proportions. These early results show that despite strong phenotypic covariation with other limb bones and overall body mass, targeted selection on a single quantitative skeletal trait can produce relatively independent evolutionary change in individual skeletal traits.
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 cumulative 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)

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 (Meckel's 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 Cell Profiler 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.

A newly identified IGFBP in crayfish: another piece in the insulin–like androgenic hormone's puzzle?
In malacosarcan 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 sex–reversal changes ranging from de–masculinization to even male sex–reversal were induced and also maintained by a secreted insulin–like androgenic hormone's puzzle?

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61.4 ROSS, C.F.*; HERREL, A.; PORRO, L.B.; EVANS, S.E.; FAGAN, M.J.; MURRAY, K.D.; University of Chicago, CNRS/UMN.H.; University College London, University of Hull; rossc@uchicago.edu
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.

136.5 ROUSE, GW*; WILSON, NG; VRIJENHOEK, RC; Scripps Institution of Oceanography, Australian Museum, Monterey Bay Aquarium and Research Institute; grouse@ucsd.edu
First Xenoturbella spp. (Xenoturbellida) from the Pacific
Xenoturbella is an enigmatic bilaterian taxon of animals that currently contains two nominal species, Xenoturbella bocki Westblad 1949 and Xenoturbella westbladi Israelsson 1999, both from shallow waters off the Swedish west coast and reaching about 3 cm in length. Evidence from mitochondrial cytochrome C oxidase I sequences suggest that these two in fact represent a single species, Xenoturbella bocki. Following initial placement as close to aceol flatworms, the position of Xenoturbella amongst Metazoa has varied considerably. They have been considered to be derived molluscs, deuterostomes, or with aceols as basal bilaterian animals. The most recent study places Xenoturbella and Acoelomorpha as a clade that is sister to Ambulacaria (Hemichordata and Echinodermata) among the deuterostomes. Here we report the discovery, via Remote Operated Vehicles, of three new species of Xenoturbella from deep waters of the eastern Pacific Ocean. One species is closely related to Xenoturbella bocki and is of a similar size, and was found near a whale fall at 600 m depth in Monterey Canyon (California). The second species is much larger (~10 cm), and was found in a vesicomyid clam field at ~3000 m depth in Monterey Canyon. This species was also found at 2000 m. in the Guaymas Basin (Gulf of California, Mexico). The third species, also large, was also found in the Guaymas Basin at 2000 m. Evidence from live observations, morphology and molecular sequence analyses are presented. It is likely that this dramatic expansion in the known diversity of Xenoturbella will provide further data to stabilize their systematic placement within Metazoa.

105.6 ROWE, A.*; XIAO, Y.; ROWE, M.; CUMMINS, T.; ZAKON, H.; The Univ. of Texas at Austin, Indiana Univ. School of Medicine, Sam Houston State Univ.; ahrowe@utexas.edu
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 mice [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 mice 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.

140.6 ROWELL, TR*; SEALE, LA; SEALE, AP; BANUELOS, GS; GRAU, EG; RILEY, LG; Fresno State Univ., Univ. of Hawaii, USDA–ARS; temperance15@mail.fresnostate.edu
Effects of Selenium–enriched meal on growth performance, endocrine control of growth and selenoprotein expression in tilapia (Oreochromis mossambicus)
Selenium channels express 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).
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, odor 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 incurrent 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.
Ontogenetic shifts in oxygen uptake of Common Mudskipper (<em>Periophthalmus kalolo</em>) 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 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⁻¹ h⁻¹, respectively). Aerial mass-independent oxygen uptake in juvenile 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.

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 *Ochradienes 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 vital 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.
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, Hylobatidae 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 sympathy 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 North Carolina, Chapel Hill; 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 phylogenies, 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, luvar) and scombroids (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.; ROBINSON, A.; HEDRICK, T.L.; Georgia Institute of Technology, Univ. of North Carolina, Chapel Hill; 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 flap 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.
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 tritrophic 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.

133.4 SCHMITZ, L*; MOTANI, R; OUFIERO, CE; MARTIN, CH; MCgee, MD; GAMARRA, AR; LEE, JJ; WAINWRIGHT, PC; Claremont McKenna, Pitzer, and Scripps Colleges, Univ. of California, Davis, lschmitz@kecksci.claremont.edu

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 species 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 revisited 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.

106.2 SCHNITZLER, CE*; PANG, K; POWERS, ML; REITZEL, AM; RYAN, JF; SIMMONS, D; TADA, T; YOKOYAMA, S; HADDOCK, SHD; MARTINDALE, MQ; BAXEVANIS, AD; NHGR/NIH, Sars International Centre for Marine Molecular Biology, Monterey Bay Aquarium Research Institute, Woods Hole Oceanographic Institution, Kewalo Marine Laboratory/Univ. of Hawaii, Emory University, Monterey Bay Aquarium Research Institute; christine.schnitzler@nih.gov

Ctenophore photocytes express a light-sensing opsin as well as bioluminescent proteins 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 photocytes. 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.

140.5 SCHMIDT, K.L*; MACDOUGALL-SHACKLETON, E.A.; MACDOUGALL-SHACKLETON, S.A.; Western University, London, ON; kschnitzler@nih.gov

The Long-term Effects of Early-Life Stress on Metabolic Rates, 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-raised 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.
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.

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 in some species of fish suggesting the possibility for adaptive evolution in these traits in response to anthropogenic environmental change.
59.6 SCHWAB, D.B.*; KIJIMOTO, T.; MOCZEK, A.P.; Indiana University – Bloomington; schwabdb@indiana.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 diversity 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.

122.3 SCHWAGER, E.E.*; MENG, Y; EXTAVOUR, C.G.; Harvard University; eschwager@oeb.harvard.edu

Spriafasta is required for early embryogenesis but not for germline specification

Metazoans specify their germline either early in development by maternally transmitted cytoplasmic factors (inheritance), or later in development by signaling factors from neighboring tissues (induction). The molecular principles of the inheritance mode have been thoroughly studied in model organisms such as flies, worms and fish, whereas the molecular basis of induction is only known from two vertebrates, mouse and salamander. Nevertheless, induction is hypothesized to be the ancestral mechanism of germline determination. Still currently we are lacking molecular and functional descriptions of inductive germ cell specification from protostomes. Arthropods are one of the metazoan clades that exhibit both induction and inheritance. We therefore examined germ line development in the spider Parasteatoda tepidariorum, an emerging chelicerate model organism. Even though spiders have repeatedly been the subject of classical embryological research, there have been only vague descriptions of putative spider germ cells to date. Our results, based on gene expression patterns of the germline marker genes vasa and piwi, and using spider-specific antibodies against Vasa and Piwi proteins, show that germ cells in the spider are likely formed by induction: neither Vasa nor Piwi protein appear localized before primordial germ cell clusters emerge as paired segmental clusters in opisthosomal segments 2–6. To investigate the molecular basis of the inductive germ cell specification in the spider, we next examined the function of the vasa gene in this process. Maternal vasa knockdown led to embryos that died shortly after initiating gastrulation. To circumvent this maternal effect of the vasa gene, we next knocked down vasa zygotically. Our experiments show that these embryos develop normally and still form germ cells, implicating that vasa is not required for germ line specification.

38.5 SCHWALBE, M.A.B.*; WEBB, J.F.; University of Rhode Island; mberghstrom@uvrui.edu

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141.1 SCHWARTZ, TS.*; BRONIKOWSKI, AM; Iowa State University; schwartz@iastate.edu

Plasticity and evolution of life-history phenotypes

The complex molecular network that underlies physiological stress response is comprised of nodes (proteins, metabolites, mRNAs) whose regulation is conserved across species, but the role of sensory biology in these points in the network upon which natural selection may act. Our aim is to identify variable nodes that will reveal how the molecular stress network may evolve among populations, and how it might impact 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 transcription of mitochondrial RNAs. As well, the phenotypes diverged at multiple nodes: overall 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 secrete and oosmotregulate 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 gonad 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.

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**1.4 SECOR, S.M.; University of Alabama, Tuscaloosa; ssecor@biology.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 then can transcend multiple levels of design.

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**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.

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**135.4 SEFTON, E.M.*; PIEKARSKI, N.; HANKEN, J.; Harvard University; esfton@eeb.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 fate 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.

**128.3 SETTE, CM*; VREDENBURG, VT; ZINK, AG; San Francisco State University; carla.sette@gmail.com**

**Temporal and spatial variation of cythridiomycosis 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 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.

**SI0–2.3 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–type eyes 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 (rhodomic or r–) opsin, 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.
Novel muscle and connective tissue design controls engulfment volume in lung−feeding whales

Euphylax−feeding 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 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 aperture 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.

Dual function of a putative epidermal growth factor receptor in the decapod crustacean Macrobrachium rosenbergii

Epidermal growth factor receptors (EGFRs) are highly conserved members of the tyrosine kinase receptor superfamily found in all multicellular organisms. In arthropods, EGFRs have been found to be involved in proper development of embryos and of adult wings, legs, ovaries and eyes, as well as to affect body size. In search for genes involved in growth and development in our model organism, the decapod crustacean Macrobrachium rosenbergii, we used next generation sequencing to create a comprehensive transcript library of larvae and juveniles. We have identified the expression of several genes assigned to the cross−talking signal transduction pathways activated by EGFRs and insulin receptors, including a transcript coding for an M. rosenbergii EGFR (Mr−EGFR). The deduced protein showed sequence similarity to other arthropod EGFRs. The gene was found to be expressed in most, but not all, tissues. We examined its role in juvenile animals using functional genomics methods, by temporary silencing of the Mr−EGFR transcript through weekly injections of double−stranded Mr−EGFR. This resulted in a significant reduction in growth, a delay in the appearance of a male secondary sex character (appendix masculine). The Mr−EGFR silenced animals developed abnormal eyes which included irregular organization of the ommatidium, unorganized receptor cells occupying large area of the dioptric portion and lack of the crystalline tract layer. However, all portion of the optic ganglion appeared to have normal morphology. To our knowledge, this is the first report of an EGFR identified in crustaceans, and its proven involvement in decapod growth and development demonstrates its significance.

Distal−less and dachshund pattern both plesiomorphic and apomorphic structures in chelicerates: RNAi 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 RNAi interference protocol for this species. We silenced the leg gap genes Distal−less (Dll) 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 Dll 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 Dll dsRNA additionally do not develop the preoral chamber formed from pedipalpal and leg coxopophyses, or the osculium, a dorsal outgrowth that bears the eyes. A single embryo injected with dac dsRNA was observed to lack the proximal segment of the chelicera, a plesiomorphic podomere wherein dac is expressed in wildtype embryos.
S6−1.7 SHELDON, B.C.; University of Oxford; ben.seldon@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 the environment are constrained by (i) spatial variation, and (ii) temporal dissociation of breeding decisions from the phenological events that cause selection. These effects will act in different ways, with the common effect of constraining the evolution of plasticity. 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 SHELTON, RM*; JACKSON, BE; HEDRICK, TL; Univ. of North Carolina, Chapel Hill; rmshelton@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 beetles, 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 (~70 ms) 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.

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 = 3 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 constraints, 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.

35.6 SHAWKEY, MD*; D’ALBA, L; VINTHER, J; AHMED, M; LIU, S; University of Akron, College of Wooster, University of Bristol, Lawrence Berkeley National Lab; shawkey@uakron.edu
Melanin chemistry and color in feathers
Melanin has great potential as a uniquely multifunctional material because of its high light absorption and conversion efficiency, its physical toughness that enables it to persist for millions of years in unaltered form and its likely high refractive index (estimated at ~1.8~2.0) that enables it to produce strong optical effects. However, our understanding of the chemistry of melanin remains limited, primarily based on samples from human hair and squid ink sacs and stuck in an overly simplified eumelanin/pheomelanin paradigm. Avian melanosomes have an unparalleled diversity of form that almost certainly mirrors a diversity in chemistry. However, their chemistry remains virtually unstudied, even though it is critical to understanding questions of both fundamental and applied interest. We are using Vacuum Ultraviolet Laser Desorption Mass Spectrometry (VUV−LDMS) to determine the chemical structure of melanin from samples of melanin non−iridescent (black, brown, grey) and iridescent feathers. The mass distributions of these samples are determined on an imaging mass spectrometer coupled to VUV synchrotron radiation, and the probable chemical arrangements and structure determined by comparing fragmentation patterns upon varying photon energy and using bioinformatics and electronic structure calculations. While there is considerable variation, the spectral data for each of the color categories are relatively consistent (see Fig. 3), indicating that they have distinct chemical signatures. These data suggest a direct correspondence between molecular color and structure in avian melanin and suggest that our method is useful for reconstructing color of fossilized feathers.

January 3–7, 2013, San Francisco, CA
63.2 SHERIDAN, M.A.; North Dakota St. Univ.; mark.sheridan@ndsu.edu
Coupling of animal growth: Where are we and where do we go from here?
Since the description of the secretotrophic action of growth hormone (GH) and the emergence of the dual effector theory of growth control in mammals, the study of non-mammalian model organisms, particularly teleost fish, has advanced our understanding of how organismal growth is regulated. In particular, the unique structures of the pituitary and pancreatic endocrine (Brockman body) of teleosts have lent themselves to the study of GH and pancreatic hormone secretion (e.g., insulin, somatostatins), and the interaction of these hormones in growth control. Teleosts also have provided novel insight into peripheral modulation of GH and insulin-like growth factor (IGF) sensitivity as well as of GH and IGF action. As a result of teleosts having undergone a genome duplication event during their evolution (ca. 320 MYA), they possess multiple genes encoding major elements of the growth control system (GH receptors, IGF receptors, etc.), which provides a unique opportunity to examine the functional significance of duplicated genes. Moreover, teleosts provide an opportunity to examine the molecular basis of GH multi-functionality and to resolve its anabolic (growth promoting) and catabolic (lipolytic) actions.

26.6 SHERO, M.R.*; PEARSON, L.E.; GOETZ, K.T.; ROBINSON, P.W.; HUCKSTÄDT, L.A.; COSTA, D.P.; BURNS, J.M.; Univ. of Alaska Anchorage, Univ. of California Santa Cruz, Univ. of California Santa Cruz; msrhero@alaska.edu
How Weddell seals stay in shape: Using morphometric and isotopic dilution techniques to assess seasonal changes in body condition
Adult Weddell seals (Leptonychotes weddellii) haul-out on the ice in Oct/Nov for their pupping and breeding period and remain relatively inactive for ~4 months until their molt in Jan/Feb. Because phocid seals rely on stored lipid reserves for fuel across periods of reduced foraging, seasonal changes in body composition are indicative of past foraging success and energy allocated towards reproduction. In this study, body composition was assessed via morphometric (truncated cones) and isotopic dilution (H2O) techniques for pre-breeding (Oct/Nov; 34F; 5M) and post-molt (Jan/Feb; 51F; 11M) seals. Nine females were handled in both seasons. Blubber mass estimated by morphometric models was significantly correlated with lipid mass estimated by isotopic dilution (P<0.001). However, morphometric models overestimated body mass by 20.6±0.6%, indicating that this method cannot be used as an unbiased estimate of Weddell seal mass or condition, as in other pinniped species. Therefore, seasonal comparisons were based on lipid content estimated via tritiated water. While there was no seasonal difference in lipid stores (% body mass) in the cross-sectional study (P=0.691), individual animals that were handled in both seasons were larger (kg) in October (lipid mass increased 33%, lean mass 22%). These findings suggest that animals lose both lipid and lean mass during the summer reproduction and molt periods, but regain it during the winter months. In addition, larger and fatter Weddell seals made significantly longer dives during the 8 weeks following tagging in Jan/Feb (P<0.001), likely affecting the Weddell seal’s ability to regain mass after the breeding period.

56.1 SHERIFF, MJ*; LOVE, OP; University of Alaska Fairbanks; mjsheriff@alaska.edu
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 environmental context 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).

89.1 SHINE, C*; MCGOWAN, C; ROBBINS, C; NELSON, L; University of Idaho, Moscow, Washington State University, Pullman, Washington State University, Pullman; shino0453@vandals.uidaho.edu
Unique movements of Ursidae: kinematics of the forelimb in walking grizzly bears.
Bears (family Ursidae) are large, quadrupedal, plantigrade animals and represent an unusual evolutionary branch; few animals are plantigrade and none that are the size of bears. Also unique to this group is an unusual rotation of the wrist and position of the elbow during locomotion. The cause and/or effect of this movement are as yet unknown; however, preliminary data from skeletons suggests that the wrist movement may be due to a more ancestral elbow joint structure. Specifically, the articulation surface of the olecranon is extended and curved to form an S-shape, which likely causes rotation with respect to the humerus during flexion and extension. In this study, we aimed to quantify the movement of the joints via high speed video. We recorded two adult female grizzly bears (Ursus arctos horribilis) at slow to moderate walking speeds with three high speed cameras. The videos were digitised and used to generate 3-D coordinates for points on the shoulder, elbow and foot of the left forelimb. Preliminary results show that at ground contact the lateral edge of the foot contacts first at an angle of 34.3±1.7 degrees, relative to the ground. The elbow is unusually adducted during stance, with a frontal plane angle of 20.1±5.3 relative to vertical, and the forefoot have a substantial medial deviation (67.6±3.7 degrees, relative to the direction of travel). Future research will include more detailed kinematics during both swing and stance coupled with ground reaction force data to establish a comprehensive understanding of the relationship between the novel elbow joint morphology and the resulting walking mechanics of bears.
Mechanisms of Metamorphic Remodeling in Hydrodies elegans (Polychaeta).

Larvae of the serpulid polychaete Hydrodies 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 filier-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.

Are you positive? Discrimination between poles of electric fields by elasmobranch fishes.

Elasmobranch fishes use electrorception 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 electrorception, we employed behavioral assays to test whether the yellow stingray (Urolophus 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.

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 (Barcelo 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.

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 include multiple exemplars of all 8 classes diversification of molluscs started immediately in the early Cambrian and was far more rapid and more complex than previously appreciated. Extensive evolutionary plasticity by heterochronic shifts in development and multiple convergent adaptations, as demonstrated in extant mollusc, were already within the evolutionary potential of their Cambrian forebears, and continue today.
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 evolutionarily 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.

The Imaginal Discs of Manduca sexta

The imaginal discs are progenitor cells in holometabolous insects such as Manduca sexta and Drosophila melanogaster, which are destined to form 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 pupation 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 PTTH 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.

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53.5 SKIBIEL, A.L.; SPEAKMAN, J.; HOOD, W.R.*; Harvard University, University of Aberdeen, Auburn University; wrhood@auburn.edu
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 the probability of maternal survival or future reproduction. However, 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.

58.1 SLATER, GJ*; FRISCIA, AR; Smithsonian Institute, Univ. of California, Los Angeles; gslater@ucla.edu
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 assembled 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. Simpson's 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 molurus) are intermittent feeders, capable of surviving prolonged fasts punctuated by periods of voracious feeding. The postprandial period in P. molurus is characterized by a rapid and significant increase in metabolic rate and a several-fold increase in oxygen consumption. Tasked with meeting elevated O2 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 animals). 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, CA

As populations of a species decline, an understanding of the regional variation in population health can be vital in informing 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 dry in late summer; turtles and native anurans do not require permanent water, but Bullfrog larvae usually take two years to metamorphose.

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 nestling’s CORT. Behavioral observations at supplemented and control nests confirm adults 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.
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.

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 P50, 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 P50 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.

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 covariation 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.
S2−1.7 SNELL−ROOD, EC; University of Minnesota; emilies@umn.edu

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.

I23.6 SNYDER, S*; KOHIN, S; CHILDERS, J; FRANKS, P.J.S.; Scripps Institution of Oceanography, UCSD, Southwest Fisheries Science Center; snmsnyder@ucsd.edu

Thermal Physiology of albacore tuna, Thunnus alalunga, 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 tunas and the surrounding water temperature was estimated. Incorporating this parameter into a heat budget model, the predicted body temperature given only the heat loss due to the temperature gradient was calculated. 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.

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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, phosphorous 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.

65.3 SOBOLEWSKI, ME*; BROWN, JL.; MITANI, JC; University of Michigan; mesobole@umich.edu
Anticipatory Stress, Territoriality and Hunting in Wild Chimpanzees
Territoriality and hunting are energetically and psychologically demanding aspects of male chimpanzee behavior. The stress response allows an individual to quickly alter its physiological and behavioral profile to successfully navigate such behaviors. The discrete nature of these competitions permitted us to investigate any anticipatory urinary hormone variation associated with these behaviors in the Ngogo chimpanzee community, in Kibale National Park, Uganda. Here, we investigated the correlation between cortisol, a stress hormone, territorial and hunting aggression. Our results indicated that territoriality and hunting are facilitated by increases in adrenal activity and cortisol production. More importantly, these data showed that cortisol increases before any aggression transpires. In an earlier study, we found that male chimpanzees display anticipatory increases in testosterone in advance of territorial behavior but not hunting. Therefore, we investigated two correlates of territorial behavior, large male party size and location in territory, in an attempt to identify cues associated with these anticipatory hormone increases. However, neither correlate explained the increases in anticipatory hormone concentrations. Being on the periphery of their territory was not associated with elevated cortisol or testosterone concentrations. Group size was not associated with testosterone variation and cortisol levels, contrary to expectation, were higher when males were in smaller groups. The potential cues that explain the observed anticipatory increases in cortisol are still unknown.
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 notothenioid fishes. Discovery that lactate dehydrogenase (LDH) orthologs of notothenioids 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.
1.5 SPEAKMAN, J.R.; Rowett Research Institute; J.speakman@adbn.ac.uk

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.

106.1 SPEISER, DI*; OAKLEY, TH; Univ. of California, Santa Barbara; dispensier@gmail.com

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.

116.7 SPERLING, EA*; FEUDA, R; ROTA–STABELLI, O; ROBINSON, J; PETERSON, KJ; PISANI, D; Harvard University, NUI–Maynooth, Fondazione Edmund Mach, Dartmouth College; sperling fas.harvard.edu

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–Stabelli and Telford, 2008, MPE 48:103) on three different datasets. Analyses with outgroups that were ranked objectively 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.

131.1 SPONBERG, S*; DYHR, JP; HALL, R; SALCEDO, M; DANIEL, TL; Univ. of Washington; bergy@uw.edu

Background luminance alters tracking performance of freely flying hawkmoths revealing variable delays in optomotor processing

Does the context in which sensory signals are acquired and processed alter the performance of motor control tasks? Hawkmoths, Manduca sexta, hover and track moving flowers during natural foraging in variable, low light environments. Neural recordings of motion sensitive optic lobe cells have shown interspecific differences in spatiotemporal tuning properties that correspond to different preferred luminance levels for foraging. These results are consistent with a sensing strategy that integrates visual cues at low light levels. Such a strategy raises the possibility that reducing luminance could increase the time delay for integrating sufficient visual information. Hence performance of motion tracking tasks may vary with the background sensory environment. We tested this hypothesis with freely flying moths feeding from an actuated artificial flower under luminance levels of 0.3 or 300 lux. Flower motion was composed of the superposition of multiple sine waves (0.2–20 Hz), allowing reconstruction of the moth’s frequency response. By calculating the gain, phase delay, and coherence at each frequency, we discovered that moths reliably track at frequencies exceeding 5 Hz. As predicted, we observed significantly lower phase lags between the moths response and the flowers movement under high luminance conditions. This phase difference corresponds to a 16 ms reduction in processing delay at high luminance. At low luminance, moths actually overcorrected, with gains significantly above 1 at peak tracking frequencies (1–2 Hz), possibly due to longer integration delays. The background sensory environment significantly alters the performance of an ecologically–relevant tracking behavior as predicted from sensory neurophysiological mechanisms.

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Burrowing biomechanics of the ghost crab.

Burrowing encompasses a wide range of behaviors, including substrate liquefaction, crack propagation, and lateral–undulatory swimming and variants of digging, where animals manipulate the substrate with teeth, limbs or head. Digging to construct permanent or semi–permanent burrows can involve a combination of specialized postures, locomotion in confined environments, and goal-directed control of the substrate. Here we present the first description of such a behavioral suite for free excavation in damp sand (gravimetric water content: 0.16) by the ghost crab, Ocypode quadrata. Observations enabled by a novel method of X–ray imaging with detailed leg and body markers showed that crabs excavated circular burrows using a hook–and–pull motion at average rate of 0.65 cm/min, corresponding to an average mass transport rate of 10 g/min. During excavation, crabs employed a particular posture to anchor themselves within the burrow by pressing against burrow walls with their chela and the rear of the cephalothorax. Crabs rotated up to 180° within the sagittal plane while excavating. After the substrate was collected, crabs manipulated and transported the sand with both the chela and walking legs. Sand packets, to be transported to the burrow entrance or compacted within the burrow, were carried by these limbs or passed under the body. Results not only quantify the biomechanics of excavation, but also reveal new insights relevant to the field of mobile manipulation. Further experiments, using the techniques we have developed will likely lead to a new generation of bio–inspired robots capable of excavation and subterranean, confined space locomotion.

Dietary effects on enzymatic immunity of migrating Mormon crickets

Migration is often associated with movement away from scarce nutrients or other resources, and yet migration itself is energetically demanding. Migrating Mormon crickets lack nutrients, and supplementation of deficient nutrients slows migratory movements 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 18–24 h later. Crickets fed protein moved fastest, those without diet or only vitamins moved less, and those fed carbohydrates or P+C moved the least. Standard intake trials also indicated that the Mormon crickets were deficient in carbohydrates. Consistent with a previous study, anti–bacterial activity was greatest in those fed carbohydrates, and there was no difference between those fed water, protein, or P+C. Total PO activity also differed between treatments and was greatest in those fed protein and least in those fed water or vitamins only. In a second experiment, we fed crickets from the same migratory band a diet treatment for 1 h and then held them in captivity until blood was drawn 4–24 h later. Dietary effects on total PO activity were not different between captive and migrating crickets, but to have a dietary effect on anti–bacterial activity the crickets had to be migrating freely. Thus a direct compromise between migratory and anti–bacterial activities is evident, whereas PO is compromised by poor protein nutrition independent of migratory activities.

Estrogen Dose Influences Medullary Bone Quantity and Density in Female Pine Siskins

Medullary bone is a non–structural type of bone tissue that can serve as labile calcium reservoir for the production of calcified eggshells. Previous research has shown that medullary bone formation precedes eggshell formation and is influenced, in part, by rising estrogen levels. In the current study, we examined the effect of estrogen (E2) treatment on medullary bone quantity and mineralization in female Pine Siskins (Carduelis pinus). Over a five–month period, females received one of three treatments: high dose E2 (n=4), low dose E2 (n=3), or no E2 (n=8). After sacrifice, high resolution (10 µm) micro–computed tomography scanning (Scanco Medical, SUI) was done on the femora and humeri to determine average medullary bone quantity (BV/TV) and its density (mg HA/ccm) across the two bones for each bird. In the 15 females examined, medullary BV/TV ranged from scant (3%) to abundant (83%) and minimally (490.0 mg HA/ccm) to highly (1184.6 mm Hg/ccm) mineralized. We found that the E2 dose had a significant effect on the average medullary BV/TV and average density for each bird (p<0.05), with the high estrogen treatment group having the greatest average medullary BV/TV (78.6%) and the highest average density (1161.9 mg HA/ccm). We are currently investigating the relationship between bone measures and ovarian development and future studies are needed to examine the timeline of medullary bone formation and resorption in greater detail.
31.3 STAHLSCHEIDT, ZR*; ROLLINSON, N; ACKER, M; ADAMO, SA; Dalhousie University; yrs@dal.ca

Are reproductive traits equal? Food availability and the fitness tradeoff between reproduction and immunity

Reproduction and self-maintenance (e.g., immune function) are critical processes, but organisms can rarely optimize both of these traits. Such reproduction-immunity tradeoffs may be facultative and appear only when resources are scarce, or they may be obligate and occur regardless of resource availability due to underlying physiological mechanisms. While the role of resource availability in reproduction-immunity allocation tradeoffs has been studied, measuring resource allocation alone may be insufficient when gauging the fitness consequences of reproduction-immunity tradeoffs. Thus, we used the Texas field cricket (Gryllus texensis) to provide the first test of whether resource availability influences a fitness tradeoff between these two traits that is, how does chronic food limitation and immune challenge affect lifetime fecundity and reproductive success? We used a 2 x 5 design to manipulate food availability and immune status throughout adulthood in a factorial fashion. We demonstrate that reproduction-immunity tradeoffs are obligate in crickets because immune challenge resulted in reduced fecundity and reproductive success regardless of food availability. Food availability significantly affected fecundity, reproductive success, and hatching size where females with ad libitum access to food produced more abundant and larger hatchings. There was no effect of food availability or immune status on egg size, egg phenoloxidase activity, incubation duration, hatching success, or hatching energy stores. In sum, we clarify the independent and interactive roles of two widespread environmental factors (food availability and immunogen exposure) on the dynamics of reproduction. Future work will investigate the underlying role of immune-induced oxidative damage in reproduction-immunity tradeoffs.

S4−1.6 STAJICH, JE*; JONESON, S; ABRAMYAN, J; AHRENDT, S; RAMAMURTHY, R; SAIN, D; SHIU, SH; ROSENBLUM, EB; Univ of California, Riverside, Univ of Wisconsin – Waukesha, Univ of British Columbia, Michigan State Univ, Univ of California, Berkeley; jason.stajich@ucr.edu

Tools and pipelines for comparative genomics with application to evolution in fungi

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 FungDB – 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 study systems 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 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.

27.1 STARK, A.Y.*; NIEWIAROWSKI, P.H.; DHINOJWALA, A.; BADGE, I.; Integrated Bioscience Program, The University of Akron, OH, Department of Polymer Science, The University of Akron, OH, Department of Polymer Science, The University of Akron, OH. avy3@zips.uakron.edu

The Effect of Water on the Gecko Adhesive System

As we move through nature, we have seen an increase in studies focused on the nano, 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 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.

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Pheromone Evolution and Reproductive Isolation in Dusky Salamanders

Conspecific mate recognition signals can delimit species boundaries and structure communities. However, signals and mate choice are evolutionarily labile, and few studies have examined the impact of signal discordance on lineage diversification in adaptive radiations. Salamanders produce highly variable, proteinaceous courtship pheromones. Dusky salamanders of the genus Desmognathus are endemic to eastern North America, and display dramatic disparity in ecology, body size and life history. However, some distantly related species are highly convergent in these traits, and behavioral studies have shown varying degrees of prezygotic isolation among divergent, yet ecologically similar species. In this study, we analyze the transcripts of pheromone genes (plethodon modulating factor and sodefrin precursor factor) in Desmognathus. We specifically test how signal discordance affects species recognition of two widespread environmental factors (food availability and immunogen exposure) on the dynamics of reproduction. Future work will investigate the underlying role of immune-induced oxidative damage in reproduction-immunity tradeoffs.
S1−3.2 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 predator's 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 approach kinematics of a predator fish in light and dark conditions 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 vectorial 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 Gymnotoidei), 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.
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, I'll 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.

87.5 STRATHMANN, R.R.*; BRANSCOMB, E.S.; VEDDER, K.; Univ. of Washington, Friday Harbor; rstrath@u.washington.edu
Plasticity in Hatching in Response to Predators and Individual Variation in Duration, Frequency, and Seasons of Brooding in the Barnacle Balanus glandula

Hatching in response to predation reduces a potential cost of holding larvae until conditions in the plankton are favorable. Broods of barnacles hatch when the clumps of embryos (lamellae) are dissected into smaller groups. Predation on brooding barnacles can have a similar effect. Escape or death of brooded offspring depends on the predator. In the laboratory, when crabs (Cancer oregonensis) ate adult barnacles (Balanus glandula), the barnacles tests were broken, and nauplii hatched from broods; in contrast, when the whelk Nucella ostrina ate barnacles, the barnacles wall plates and opercula remained in place, and fewer or no nauplii were released. In some cases numerous nauplii were trapped within the test of the killed mother. At a field site with abundant whelks, many dead barnacles had opercular plates in place. Hatching of some barnacles is also known to occur when phytoplankton induces the parent to stimulate hatching of its brooded larvae. To examine synchrony and variation in brooding among individuals of B. glandula, we non-destuctively observed late-stage (dark-colored) broods in individuals that had settled on glass plates. For the first brood of the year, first appearances and disappearances of late-stage broods were consistent with a synchronizing environmental stimulus for hatching. The dates that broods reached advanced stages varied more than the dates that they were released. An exception to synchronizing among individuals was that a few of the broods that reached advanced stages early also hatched early. In subsequent broods (later spring and summer), advanced stages were held more briefly. Either an environmental stimulus for hatching was not needed later in the season or it was more frequently present. Individuals appeared to vary greatly in number of broods per year.

103.5 STORZ, J. F.*; NATARAJAN, C.; PROJECTO–GARCIA, J.; MORIYAMA, H.; WEBER, R. E.; FAGG, A.; Univ. of Nebraska, Lincoln, NE, Aarhus Univ., Aarhus, Denmark; jstorz2@unl.edu
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.

107.3 STREICHER, J.W.*; MEIK, J.M.; SMITH, E.N.; FUJITA, M.K.; Univ. of Texas, Arlington; streicher@uta.edu
Limits and opportunities of diversification in barking frogs of the Craugastor augusti complex

Craugastor augusti is among the most widely distributed direct-developing frogs in North America, occurring from the southwestern United States to the Isthmus of Tehuantepec in southern Mexico. Across this distribution, C. augusti exhibits relatively low genetic diversity but extensive phenotypic variation in color patterns, integumentary characteristics, and breeding vocalizations. Furthermore, these frogs inhabit diverse habitats from deserts to tropical forests, and are the only Craugastor species to have invaded a temperate biome. These patterns are uncommon in vertebrates with low vagility such as amphibians, which often exhibit high endemism and habitat specialization. These generalist attributes make C. augusti an ideal system for investigating limits and opportunities of diversification. Here we describe preliminary phylogeographic patterns in this complex and relate them to patterns of morphological diversity. Using mitochondrial and nuclear DNAs (a total of 2064 bp) we recovered eight geographically circumscribed clades, each of which has distinctive patterns of morphological variation. We also used canonical correlation analysis and mantel tests to evaluate the importance of various bioclimatic variables as predictors of morphology, while controlling for spatial autocorrelation. We discuss these results in the context of the evolutionary history of these frogs as unique direct-developing colonizers of xeric habitats.
35.3 Summers, M.M.*, Rouse, G.W.; Scripps Institution of Oceanography, UCSD; msummers@ucsd.edu

Unraveling 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@sfu.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 biogeochecmistry: 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 (d13C) and nitrogen (d15N) 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 d13C and quadratically related to d15N. 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.*; Johnsen, S.; Gagnon, Y.; Morse, D.E.; Stramski, D.; University of Pennsylvania, Duke University, Scripps Institute of Oceanography, UCSD; alisonsw@physics.upenn.edu

Jurassic marine photonics: Squid dynamic iridescence and predation by large extinct marine reptiles

Dynamic iridescence in Loligo squid 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.
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.
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 myostisis (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 +/- 3.5 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.

Developmental mode, poecilogony, and population structure of the pyramellid nudibranch Boonea impressa

Poecilogony, the expression of more than one developmental mode in a single species, is usually not viewed as an evolutionarily stable strategy. Poecilogous species are typically considered transitional states between discrete developmental modes. However, poecilogony 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, poecilogony is difficult to confirm in many cases, and only a few poecilogous species are known. Many suspected poecilogous 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 poecilogony among Gulf coast populations of the marine snail Boonea 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 poecilogous species. Together these results show that intraspecific variation in developmental mode contributes to the diversification of marine invertebrates.
19.6 TEPOLT, CK*; SOMERO, GN; Stanford University; 
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Carcinus thermal tolerance and acclimatory plasticity in diverse 
populations of the invasive green crab, Carcinus maenas

Widespread invasive species successfully enter a broad range of 
troubling novel habitats, often over short time scales, and exhibit remarkable 
abilities to thrive under new conditions, e.g., of temperature. These 
qualities make them ideal systems for examining traits underlying 
success in novel environments. Carcinus maenas, the green crab, 
ranges from Morocco to Norway in its native range and is globally 
invasive. Thus, this eurythermal species offers an opportunity to 
study the thermal traits that facilitate success across a wide range 
of temperatures, and how those traits vary among populations of a 
wide range of species. We characterized thermal tolerance and 
acclimatory plasticity for seven populations of C. maenas across 22 
degrees of latitude in the native and invasive ranges. Using 
non-invasive cardiac physiology, we measured high and low 
temperature tolerance of cardiac activity (critical thermal maxima 
and heart rates at 0°C, respectively) for field-derived adapted and 
for crabs given 3-4 weeks of laboratory acclimation at 5°C or 25°C.

We show that the species has a high heat tolerance compared to other 
temperate species, with critical maxima of 30.8-37.0°C depending 
on source and acclimation. Both heat and cold tolerance were plastic; 
cold-acclimated crabs had heart rates at 0°C (3-3.5) times higher than 
their warm-acclimated counterparts. High and low temperature 
tolerances appear to be coupled, with higher heat tolerance 
accompanied by lower cold tolerance in both adults and juveniles. 
We discovered some inter-population differences in thermal tolerance, potentially 
due to genetically different stocks. However, across all populations 
sampled, C. maenas maintains high thermal tolerance and 
acclimatory plasticity, even in populations with low genetic diversity 
due to sequential founding bottlenecks.

44.5 THAWLEY, C.J.*; ROBBINS, T.R.; LANGKILDE, T.; 
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Survival at what cost?: Consequences of a native lizard's 
adaptations to invasive fire ants

Anthropogenic environmental change, including introductions of 
non-native species, imposes novel selective pressures on native 
and invasive species. A population's 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 
neonatal 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 
highlight 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 population fitness and the persistence of biodiversity.

17.3 THEOBALD, J. C.*; CABRERA, S; Florida International 
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Flying fruit flies correct for visual sideslip using motion parallax cues

Fruit flies possess tiny brains, but still depend on sophisticated flight 
skills to navigate to food, mates, and oviposition sites. A tenet of 
stable flight is the ability to correct for deviations from an intended 
flight path, such as by a gust of wind. One means by which flies do this 
is optic flow stabilization; when the visual world abruptly seems to 
move to the left, flies steer to the left to compensate. In previous 
experiments with static flies immersed in moving flow fields of 
points, forward motion had no effect on these side corrective 
responses. In other words, flies that appeared to be moving forward 
slowly, quickly, or even backward responded identically to 
sideways visual perturbations. However, with forward 
flight is a mix of images that seem to move faster or slower depending 
on their distance. When just the faster, seemingly nearer 
points move sideways, flies respond more robustly than when just the 
slower, seemingly farther points move, and this holds regardless of 
absolute forward speed. This result is consistent with the theory that 
flies, which cannot use binocular or accommodation cues for 
deep space, use motion parallax to attend to nearer, more relevant features 

January 3–7, 2013, San Francisco, CA
E13.8 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 (aDLD) 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 (11.7±0.36 g/dL) which increased in large pups (15.7±0.32 g/dL) and juveniles (18.1±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/100g 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.

119.2 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 raccoon 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 (Macrochelys 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.

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 of turrle species are often seen in many taxa as they transition from aquatic to terrestrial environments. This is often seen in various species 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 (aDLD) 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 (11.7±0.36 g/dL) which increased in large pups (15.7±0.32 g/dL) and juveniles (18.1±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/100g 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.
Phenotypic plasticity of jaw morphology as a response to diet in two cichlid species and their hybrid

To explain the very high rates of speciation of cichlids in the East–Africa Lakes several hypotheses have been suggested. The decoupling of the oral and pharyngeal jaws is considered most important key innovation, but it has been found that several other factors may also play a role in their adaptive radiation. Local adaptive responses, resulting from phenotypic plasticity, may allow cichlids to rapidly adapt to environmental changes during their lifetime and through processes like genetic assimilation such a response has the potential of becoming a heritable trait. Genetic studies have also confirmed that hybridization has occurred in the wild and that this potentially leads to novel phenotypes through transgressive segregation. We investigated phenotypic plasticity in response to different feeding modes in two cichlid species from Lake Victoria: Haplochromis piceatus, a suction feeder and H. fischeri, a biter. We raised groups of both species and their hybrid on food with the same nutritional quality, but different physical characteristics, simulating different feeding modes: (1) suction feeding from the water column, (2) scraping food and (3) biting on hard pellets. To visualize the plastic response we performed a geometric morphometric analysis of head morphology and we also compared feeding performance based on morphological proxies (theoretical bite force, KT,&). Furthermore we focused on the lower jaw, one of the most important elements in the oral apparatus. Based on micro–CT scans we compared ossification patterns and analyzed shape differences using 3D morphometrics. To some degree, the observed morphological variation between treatments seemed to be related to improving the imposed mode of feeding.

Environmental Stress Proteomics of Blue Mussel (Genus Mytilus) Congeners

The warm–adapted Mediterranean blue mussel species Mytilus galloprovincialis invaded southern California during the last century and displaced 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.

Notch signaling during neural development in the annelid Capitella teleta

Central nervous system development begins with fate specification of neural precursor cells, which generate the brain and nerve cord. Comparisons between vertebrates and arthropods have provided important insights into neural development, but studies in spiralian systems are still lacking. To understand the evolution of nervous systems, we are investigating brain development in the spiralian annelid Capitella teleta. C. teleta has a dorsal anterior brain that has several hundred cells. Brain development begins at the end of gastrulation with the ingestion of single cells from localized areas of anterior ectoderm. During ingestion, cell divisions are restricted to apical cells in the anterior ectoderm, while neural differentiation markers are basally localized. In both vertebrates and arthropods, proneural BHLH genes and Notch signaling play a role in neural fate specification and differentiation, although their function seems to be somewhat different between organisms. Based on expression of the proneural gene homologs Ct–ash1 and Ct–ngen, and preliminary functional analysis of Ct–ash1, we hypothesize that cells expressing the highest levels of proneural genes ingress and then differentiate into neurons. Furthermore, Ct– notch and Ct–delta are expressed in the region of the developing brain. To test a possible function of Notch signaling in specifying neural fate or in preventing neural differentiation, we treated embryos with the gamma secretase inhibitor DAPT, which blocks cleavage–mediated activation of Notch. Despite apparent phenotypes in other tissues, notably the developing foregut, we did not see a strong phenotype in the developing nervous system. If true, these results would provide an interesting contrast to neural development in other animals.
**40.1 TYTELL, E.D.; Tufts Univ.; eric.tytell@tufts.edu**

The intrinsic dynamical properties of muscle are self-stabilizing for rhythmic gaits

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. Floquet theory, a branch of nonlinear dynamics, includes ways to analyze how such rhythmic systems respond to perturbations. We analyzed the dynamics of a mathematical model of lamprey muscle and developed several robust ways of estimating the Floquet 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, as in 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.

**31.1 UHRIG, E.J.*; FRIESEN, C.R.; MASON, R.T.; Oregon State University; uhrig@science.oregonstate.edu**

Endoparasitic infections in the red-sided garter snake, Thamnophis sirtalis parietalis

Garter snakes have been model organisms for numerous studies of reproductive behavior, endocrinology, and chemical ecology. Such aspects of biology are known to be affected by parasites in a variety of other organisms yet parasite-mediated effects have been little studied in garter snakes. Indeed, even the composition of parasite communities has not been well described for most Thamnophis species including the red-sided garter snake. Our current study presents data on the prevalence and intensity of endoparasitic infections in red-sided garter snakes, specifically two distinct populations in Manitoba, Canada; thus we are able to make both inter- and intrapopulational comparisons. Snakes from both populations harbor at least five genera of endoparasites including nematodes (Rhabdias sp.) and trematodes (Lechriorchis sp.) in the lung, cestodes in the digestive tract, and trematode mesocercariae concentrated in the visceral fat deposits (Fibricola sp.) and the tail tissue (Alaria sp.). We investigate patterns of parasite distribution including potential variation in infection prevalence and intensity based on host sex and body size. We also examine whether measures of infection are correlated with host fat stores and/or reproductive structures. Of particular interest is our finding that, in at least one host population, the presence of Lechriorchis trematodes is negatively associated with ducxus deferens mass suggesting potential implications for male reproductive investment. The results of this study provide an important basis for future work investigating parasite-mediated fitness effects in garter snakes.

**S10—1.5 ULLRICH-LUTER, Esther; ARNONE, Maria Ina*; Univ. of Bonn and Natural History Museum, Berlin, Stazione Zoologica Anton Dohrn, Napoli, mariarome@izan.it**

Watch your steps! Opsins and photoreceptors in sea urchin tube feet

Sea urchins, due to their derived morphological body plan, have long been considered to be of limited value regarding the reconstruction of ancestral deuterostome character states. In contrast, recent molecular findings show that the animals exhibit a huge variety of vertebrate and even mammalian gene orthologs, including such essential for function and development of photoreceptors. We recently demonstrated that one of the six sea urchin opsin (photopigment) proteins is expressed within microvillar, r-opsin expressing photoreceptors cells (PRCs). These PRCs are located in the animals numerous tube feet and, surprisingly, lack any associated screening pigment. Indeed, one of the tube foot PRC clusters may account for directional vision by being shaded through the opaque calcite skeleton. Since juveniles display no phototaxis until skeletal completion, we suggest a model in which the entire sea urchin, deploying its skeleton as PRC screening device, functions as a huge compound eye. Moreover, we are currently investigating on another sea urchin photoreceptor system, expressing a c-type opsin, phylogenetically clustering with chordate and protostome ciliary opsins. Specific antibodies and mRNA detection revealed expression in the sea urchin dermis and internal nervous system as well as in spines of other echinoderms. Analysis of the observed expression patterns does not indicate involvement of c-opsin in sea urchin directed vision. However, the c-opsin expressing cells might comprise the corresponding receptor for the long proposed dermal light sense and might have a function in shadow responses of echinoderms. Investigating the echinoderm c-opsin system is promising regarding information about c-opsin function at the base of deuterostomes.

**6.1 USHERWOOD, JR; The Royal Veterinary College; jushewood@rvca.ac.uk**

The basic mechanics of pronking, bounding or frog-hopping the costs of pitching accounts for much of the diversity of fast quadrupedal gait.

Quadrupeds show a fascinating range of gaits, both between species and across speeds. Accounting for 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 for food: multimodal sensory fusion in freely flying fruit flies

The ability to find food by tracking wind–borne odor plumes to their source is one of the most critical yet difficult tasks an insect performs. In a natural environment, turbulent air breaks apart the odor distribution in a plume, resulting in packets of high concentration interspersed with clean air. The visual sense, however, provides continuous information about where objects are, but very little about what they are. Thus, it would seem prudent for an animal to integrate the two sensory cues to maximize their ability to localize food sources. In this study we focus on the fruit fly, and how they are able to track a time varying plume of an attractive odor 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.

Fluctuations in Historical Oxygen Levels Impacted Insect Body Size and Physiology

Fluctuations in atmospheric oxygen over the last 500 million years has 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 hypoxeric 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

Photoperiod 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 buried 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°C, 30°C 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.

Freshwater transitions and the evolution of osmoregulatory function in alewifes (Alosa pseudoharengus)

Among fishes, ecological transitions into freshwater environments are often associated with episodes of diversification and adaptive radiation. The functional changes that accompany these transitions have rarely been characterized. In this research, we identify evolutionary shifts in osmoregulatory capacity and ion regulation associated with freshwater transitions in populations of alewife (Alosa pseudoharengus), some of which maintain the ancestrally anadromous migratory habit and some of which have become landlocked. Juvenile landlocked and anadromous alewifes were experimentally challenged with a range of salinities both in situ and in the laboratory. We detected differentiation between population types in salinity tolerance and osmoregulatory performance, as well as in the expression of candidate genes for osmoregulation (Na+, K+, 2Cl− cotransporter (NKCC), and cystic fibrosis transmembrane conductance regulator (CFTR)) and Na+, K+ ATPase activity. Overall, evolutionary changes upon restriction to freshwater include enhanced osmoregulatory function in freshwater and reduced osmoregulatory function in seawater, as well as a diminished response of several salt-secreting pathways.
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 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 reef clades.
92.4 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.

92.9 VON BUSSE, J.R.S.*; MOSTOWY, M.; BRUCE, H.; SWARTZ, S.M.; Brown University; rhea_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 videoographed 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.

59.2 VON DASSOW, G*; EMLET, RB; MASLAKOVA, SA; University of Oregon; dassow@uoregon.edu
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 Polygordius, 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 the cryptomonad Rhodomonas. We used high-speed video to describe the feeding mechanism of Micrura's pilidium. Flow generated by the primary ciliated band brings food particles past the band margins. 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 ejectionsomes, 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 its own way to eat, the pilidium converged upon strategies used by Venus' fly trap, a FACS, and the baleen whales.

92.2 VONWETTBERG, E.J.B.; Florida International University; ericvonwettberg@yahoo.com
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 university serving a large diversity of students. Although I find some improvement in student performance on test materials following the adoption 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.

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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, 38.4ºC) 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 37.4ºC. 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 riparian 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, & ³–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 in migratory birds to facilitate hyperphagia and lipogenesis, and that further elevation of CORT in response to acute stress is suppressed. 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 ³–hydroxybutyrate also varied among years, but this was not consistently associated with high or low water levels.
**118.1 WALKER, J.F.*; ZANIS, M.J.; Purdue University; jfwalker@purdue.edu**

The evolution of mononucleotide repeats and gene stability in eukaryotes

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 were 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 then 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.

**S11–1.5 WALSH, M. R.; Univ. of Texas Arlington; matthew.walsh@uta.edu**

Environmental influences on plasticity in sexual investment in *Daphnia*

Sex and dormancy are directly connected in organisms that engage in asexual 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*.

**70.5 WARNER, R. W.; KIRSCHMAN, L. J.*; CREPSI, E. J.; BRUNNER, J. L.; Southern Illinois University, Washington State University, Washington State University; lj.kirschman@siu.edu**

**STRESS EFFECTS ON IMMUNE FUNCTION AND DISEASE EMERGENCE IN AMPHIBIANS**

Environmentally 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.

**88.2 WARNER, S E*; HENRY, V; HUTCHINSON, J R; Royal Veterinary College; swarner@rvc.ac.uk**

**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.
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**Anthropogenic stressors and the evolutionary potential of amphibian populations**

Virtually all habitats on Earth have been affected by human activities. Understanding and mitigating the ecological consequences of anthropogenic habitat modification require addressing how multiple stressors interact to affect the long-term viability of populations. In addition to diminishing population numbers, exposure to anthropogenic stressors can lead to the evolution of increased tolerance via natural selection. However, the evolution of tolerance to one stressor may compromise a populations ability to tolerate or adapt to different stressors in the future. To address how natural selection imposed by different stressors may impact a populations evolutionary potential, I investigated genetic variation in tolerance to two different stressors as well as the genetic correlations between tolerances to these different stress regimes.

91.9 WATERS, JS*; HARRISON, JF; Princeton University, Arizona State University; jswaters@princeton.edu

**Metabolic and behavioral variation with colony size and age: a manipulative test of the size-dependence theory of metabolic allometry**

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 organisms 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 hypometry 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.

94.1 WEBB, JF*; GILLIS, JA; University of Rhode Island and MBL, Woods Hole, Dalhousie University and MBL, Woods Hole; jwebb@uri.edu; jacqueline_webb@mail.uri.edu

**Lateral Line Morphogenesis in Chondrichthyan vs. Osteichthyan Fishes: New Perspectives on an Old Problem**

The morphology of the lateral line system (LL) differs significantly in chondrichthyan and osteichthyan fishes, so we hypothesized that the pattern of its development would also be distinct in these two gnathostome lineages. We have shown that in the little skate (Leucoraja erinacea), migration/elongation of LL placode-derived primordia, differentiation of neuromasts, and morphogenesis of LL canals are not discrete, sequential processes as in bony fishes. SEM revealed that the surface of the shallow grooves that define the paths of the migrating/elongating LL primordia on the head and trunk is characterized by small epithelial cells with dense apical microvilli. We used CM-DiI to trace the fate of LL placode-derived cells (from the anterodorsal and posterior placyodes) to clarify the relationship between the LL primordium, microvillus epithelial cells, and the unique longitudinal pocket associated with LL development on the trunk (Johnson, 1917). DiI+ placode-derived cells were found below the microvillus epithelial cells found in the cranial grooves and rostral to the entrance to the pocket and below the epithelial cells that line the pocket on the trunk. Gillis et al. (2012) had shown that LL placode-derived cells contribute to neuromasts and canal walls in older embryos. Thus, we hypothesize that placode-derived cells found below the epithelium subsequently intercalate among the microvillus cells and differentiate into the hair cells of the canal neuromasts and the cells of the walls of the lateral line canals. An on-going analysis with finer temporal resolution will allow an accurate description of the processes of neuromast differentiation and canal morphogenesis in chondrichthyan fishes. Supported by URI (JFW) and a Allen/Bang/Colwin Summer Research Fellowship from the MBL, Woods Hole (JAG).
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Osteohistological differences between marsupials and placentals
mammals 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 placentals bone histology,
leaving 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.

S9−2.3 WHITEHEAD, A.*; PILCHER, W.; MAYER, G.;
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Integrative biological footprint of the Deepwater Horizon oil spill in
the laboratory and field

Large populations of silifish 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
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.

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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 expands 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 reduced 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 automatization, 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 *S. alatus*–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.
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.
Behavioral plasticity mediates life history trade-offs in response to habitat disturbance

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.

Phenology of hibernation and reproduction in free-living arctic ground squirrels

Climate warming is predicted to lengthen the growing season, particularly at high latitudes, which provides increased foraging opportunities, although biological interactions can also be disrupted due to intra- and inter-specific variability in the response to climate forcing. We developed a method of using patterns of core body temperature in free-living arctic ground squirrels to precisely determine the timing of key seasonal events including hibernation, mating and parturition, and immigration and emergence from the hibernacula. Long-term data collected from two arctic ground squirrel populations living 20 km apart in northern Alaska indicate that individuals respond plasticly to environmental conditions with earlier reproduction at the site characterized by earlier snow melt. The timing of parturition was tightly linked to the termination of heterothermy and subsequent emergence from the hibernacula. Long-term data collected from two arctic ground squirrel populations living 20 km apart in northern Alaska indicate that individuals respond plasticly to environmental conditions with earlier reproduction at the site characterized by earlier snow melt.

Continuous metrics for classification of bipedal gait and predictions of gait transition fine structure in turkeys

An accurate method for differentiating walking and running bipedal gaits is presented and applied to experimental data from turkeys. It is known that bipedal walking and running gaits can be distinguished based on the phase difference of the kinetic and potential energy of the center of mass. It has also been suggested that the energy stored in the legs may also differentiate these gaits. It is, however, conventional to use a discrete estimate of these phase differences (such as the relative timing of peaks in these energies). Such estimates are prone to error, especially during non-steady locomotion, and are of limited utility when examining gait transitions which typically occur over short time scales (one or two strides). It is the short time scale of transitions that makes them interesting, as it is likely that energy cost is of diminished importance. Other factors such as stability and robustness may play a greater role in the form of transitions than in ordinary locomotion. To investigate these issues, we need a continuous-in-time classification of gait. We present and discuss a continuous-in-time classification of the gait of turkeys (n=5) on a treadmill. Gait classification was constructed by applying continuous-time phase extraction techniques to kinematic data. We show that the resulting gait classifier has a high performance, average 93% correct from a testing set with at least 16 strides per bird, and can correctly classify partial strides. We will discuss the potential application of this classifier to investigating locomotor dynamics and transition fine structure.

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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.

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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 bioindicators 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 Loratadine (p < 0.05), however, productivity was not significantly reduced by the presence of Triclosan, 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.

S3–1.6 WILSON, JM*; CHEW, SF; IP, YK; CIMAR, Porto, Portugal, Nanyang Tech. Univ., Singapore, National Univ. Singapore, Singapore; wilson.jm.cimar@gmail.com

Metabolic and osmoregulatory challenges of emersion in fishes

The climbing perch (Anabas testudineus), combtooth 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 ionic 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 volatilizing ammonia through its intestine using facilitated NH₄⁺ excretion while in the gill NH₃ excretion by a different Rhc–H⁺ – ATPase coupled mechanism is up regulated. This work was partially supported by FCT grant POCTI/BSE/47585.
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 5Hz L1 pseudoorange 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 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 fine grained behaviour 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 cheetah 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.

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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 diI 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 diI to define specific cells that arose from these regions. The anterior pole largely gives rise to basopinacocytes that adhere to the substrate during settling, while sclerocytes derive from the posterior pole. Interestingly, the osculum, the terminus of the aequiferous 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 metazoans.

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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.

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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 incur 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 that head stabilization may play an important role in insect flight control.

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 incur 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.
Phylogenomics of non-bilaterian animals: pitfalls and challenges

Deep-level metazoan relationships have long been controversial issues. Especially a well resolved and supported phylogeny of non-bilaterian animals is needed to provide a robust framework for reconstructing early metazoan evolution. Expanding molecular (phylogenomic) datasets are increasingly being used to unravel these relationships. However, important nodes remain notoriously difficult to resolve. For example, some recent large-scale metazoan phylogenomic analyses contrary to classical conceptions found clenophores to be the sister-group to the remaining Metazoa and favored a sister-group relationship between sponges and cnidarians, while other analyses suggest that the Placozoa are the sister-group to the remaining Metazoa or that sponges are a paraphyletic assemblage that share a grade of construction rather than common ancestry. From these hypotheses, many claims have been made with far reaching implications for the early evolution of animals. An overview about the current state of the debate will be given, especially with respect to the monophyly of sponges and their position in the animal tree of life. Several novel phylogenomic analyses of non-bilaterians will be used to address the underlying causes of the incongruences observed among deep-level metazoan phylogenies. However, even using large phylogenomic datasets, some non-bilaterian relationships remain difficult to resolve as they are highly dependent on taxon- and gene sampling, evolutionary model selection and outgroup choice. Additional sequence-independent data might be required to unequivocally resolve the branching order of all non-bilaterian groups.

Attachment ability of a clamp-bearing fish gill parasite, Diplozoon paradoxum (Monogenea)

An effective attachment system is crucial for the survival of monogeneans, which are mainly fish ectoparasites. Monogeneans use various types of haptoral (posterior) attachment devices to attach themselves onto their hosts. However, there is no study done to assess the efficiency of their attachment devices. The present study aimed to determine (1) the attachment forces of a paired adult Diplozoon paradoxum from the fish gills, (2) the contribution of muscles action to the clamp movements and (3) the distribution of a resilin-like protein in clamp sclerites. An average force of 6.1 ± 2.7 mN (about 246 times the animals weight) is required to dislodge a paired D. paradoxum vertically from the gills of the fish Abramis brama. When the monogeneans were treated in three different solutions, the widths of the clamp openings differ significantly in each treatment. The widest clamp openings were observed in the monogeneans treated in 2.5% glutaraldehyde (74.52 ± 28.31 µm), followed by the those treated in 20 mM MgCl₂ (37.91 ± 7.58 µm), and in filtered lake water (20.16 ± 8.63 µm). Results from the toluidine blue staining and spectral analyses of the blue autofluorescence, exhibited by the clamp sclerites, indicated that the sclerites contain a rubber-like protein similar to resilin of Arthropods. Our results suggest that the closing of the clamps is not due to the continuous contraction action of muscles, but rather due to the elasticity of the clamp material. The presence of the resilin-like protein likely improves the attachment efficiency and the lifespan of the clamp sclerites.
13.10 WOODS, H.A.*; WILSON, J.K.; Univ. of Montana; art.woods@msu.montana.edu
Dynamics of thermal shock illuminate the evolution of homeostasis
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 of transmitters and receivers, the performance of any one homeostatic system influences information processing in all other homeostatic systems. This dependence implies that multiple homeostatic systems, embedded within individual organisms, 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.

116.6 WULFF, J.L.; Florida State University; wulff@bio.fsu.edu
Sponge recovery after extreme mortality events: Taxonomic and morphological patterns in regeneration vs. recruitment
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 dynamics to be quantified with respect to biomass, number of individuals, and species. These data revealed an earlier mortality event and documented the early stages of recovery, both on the community level and also for every individual sponge. Differences in the degree to which the 54 sponge species suffered mortality ranged from complete loss to no effect, resulting in immediate significant alterations in community composition. Groups of species defined by higher taxa or by morphology not only experienced mortality very differently, but also recovered differently, with some showing efficient regeneration after partial mortality, others adding small individuals by recruitment, and still others not recovering at all. And because each taxonomically or morphologically defined group of sponge species also contributes differently to ecosystem services, such as water column filtration, hoisting inquilines, feeding spongirobes, stabilization of broken corals, and improved coral survival, differential mortality and recovery has caused shifts in how adequately these functional roles are played. Rapid changes in representation of taxonomically-defined groups, at levels from species to order, provide additional strong impetus for continuing efforts aimed at thorough understanding of sponge systematics.

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Are two parents better than one? Examining the effects of biparental care in a stomatopod crustacean
Although social monogamy and biparental care have been extensively studied in birds, mammals, and fish, few studies have been conducted on invertebrate species. Social monogamy is characteristic of several marine crustaceans, while biparental care is only known in a single genus of monogamous stomatopod crustaceans, Pullosquilla. In Pullosquilla litoralis, males and females spend statistically equal amounts of time aerating eggs with their pleopods and removing fouled eggs from clutches. Under certain conditions, P. litoralis is also capable of double-clutching. Based on laboratory observations, we suspected that biparental care also occurs in Pullosquilla thomassini, a congener with very similar ecology and behaviors. Through observational studies and experiments conducted at Lizard Island Research Station, Queensland, Australia, we characterized parental care in P. thomassini and examined the effects of uniparental and biparental care on the survival and development of egg clutches and weight gain in parents. We found that parental care behaviors in P. thomassini are similar to those of P. litoralis and that males and females provide similar amounts and types of care. We observed two double-clutches in the field. We found that there were no clear benefits of biparental care over uniparental care, but that any form of parental care decreases the amount of weight lost by developing egg clutches. There were also no significant differences in the survival of egg clutches between care provided by males or females. These results suggest that biparental care is not evolutionarily maintained simply by short-term fitness gains in egg development and survival in P. thomassini. Instead, it may be selected for with other life history traits, such as double-clutching, that increase lifetime reproductive success, but do not affect the size or developmental outcome of individual clutches.

139.6 YANCEY, P.H.*; GERRINGER, M.E.; CAMERON, J.; HARDY, K.; CHASTAIN, R.; BARTLETT, D.H.; Whitman College, DEEPSEA CHALLENGE, Scripps Institution of Oceanography; yancey@whitman.edu
High contents of methylamines and scyllo-inositol as potential piezolytes (pressure counteractants) in muscles of amphipods 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 perturbations of proteins by hydrostatic pressure. Trimethylamine oxide (TMAO) is a prime candidate. 1) It counteracts pressure effects on protein activity and stability in vitro, better than other osmolytes. 2) Muscle TMAO content increases with depth in marine bony fishes (analyzed to 7 km depth). 3) In marine decapods (osmoconformers with a fixed osmolyte total), muscles in 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 content increases with depth (to 1.4 km) in freshwater Lake Baikal amphipods, which do not need osmolytes. Here we report organic osmolytes in amphipods (Hirodelleu 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, glycerophosphoholine and dimethylglycine, plus the polypol scyllo-inositol (SI). Though only TMAO has been tested with pressure, all are potential piezolytes 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.
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 predators 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.

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 adjust 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.

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−tr), and thiamin pyrophosphokinase with its seven splice variants (tpk_tv1−7). The transporters are critical for cellular and body Th uptake, and the enzyme generates the active Th, H−Th. The expression of thtr1, thtr2, thde−tr, and tpk_tv1 with two–three tpk_tv transcripts 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 thtr2 transcripts peaked in yolk–sac fry stage, while thtr2 transcripts gradually increased toward the swim–up stage. Notably, tpk_tv 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; thtr−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, thtr−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_tv mRNA expression might be important in ovary and in embryogenesis; and 3) in TD, thtr2, thtr−tr and tpk appear to be down-regulated.
YUSA, Yoichi*; SAWADA, Kota; YAMAGUCHI, Sachi;
The small individuals on background. To test mosquitoes ability to navigate using detection, suggesting convective tracking may require the do not exhibit bias toward the heated 2
sylvia.zamudio.69@my.csun.edu
Streblospio benedicti
Aedes aegypti
P. damicornis
Pocillopora damicornis
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S. benedicti
O. lowei
ZAKAS, C*; ROCKMAN, M.V.; New York University;
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) in a darkened wind tunnel (1 m long, 0.33 m wide) in detect radiant heat at these distances. Our observations suggest and the falloff of radiant heat, it remains unlikely that the mosquitoes landed on the heated rods. Given the low radiation of the heat source showed no side preference. All exhibited search behaviors, but none absence of CO2, selectivity between two heat sources. Our data suggest that, in the navigation signal. Experiments suggest that thermosensation is gated (black body) heat, making convective (windborne) heat a likely 2
varying radiative emissivity suggest they are not sensitive to radiative a pair of thermosensory organs on the distal end of each antenna. The signals such as CO2 by CO2, P. damicornis experiment using small individuals of O. lowei suggested that those transplanted on conspecifics emphasized male−function than those on plastic plates. Overall, our study shows 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.

Mosquitoes do not track warm plumes in the absence of CO2
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 radiative sensitivity 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 thermosensation is gated by 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 element. 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.

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 phenotypic 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 larval 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.
This research focuses on the velocity of in–plane dynamic hexapodal 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 legs 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 step 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.

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. Furthermore, we modeled the distribution of material properties on wings based on experimental measurements from wings of selected species, and used computational simulation to explain the major types of dynamic deformation observed in flight performances characteristic of different sized wings.

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 decanalized, destabilized or distingintegrated. 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.

Locomotion with Winglets in Stick Insects

Flight with Winglets in Stick Insects

Using Terradynamics to Understand the Role of Limb Morphology in Legged Locomotion on Granular Media

Locomotion Analysis of Dynamic in–Plane Hexapod

Flight with Winglets in Stick Insects

Plasticity of a complex, integrated structure: The impact of diet on mandibular form
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.