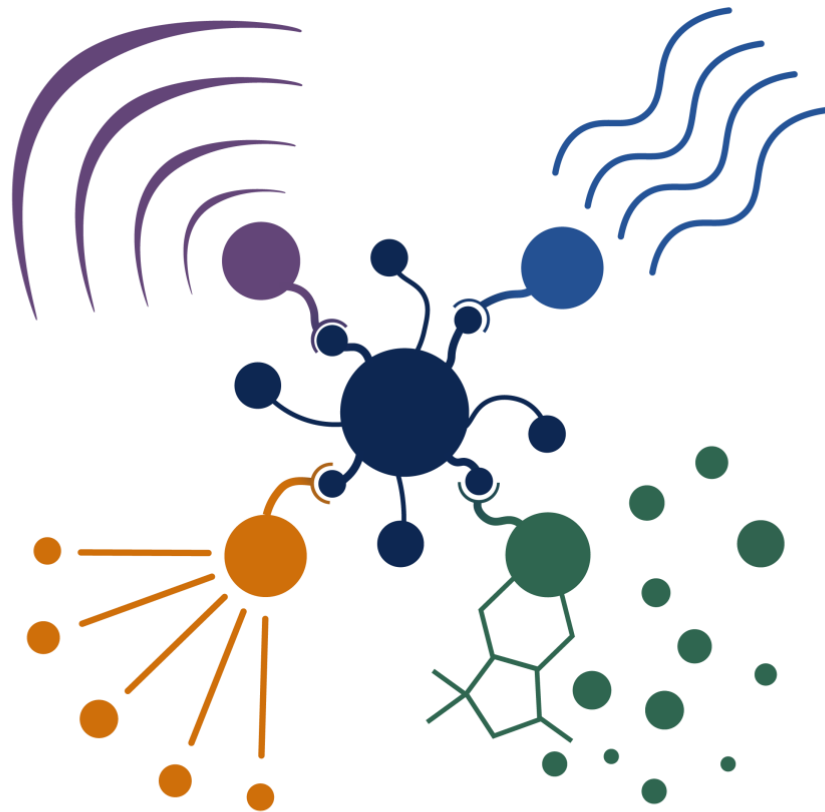




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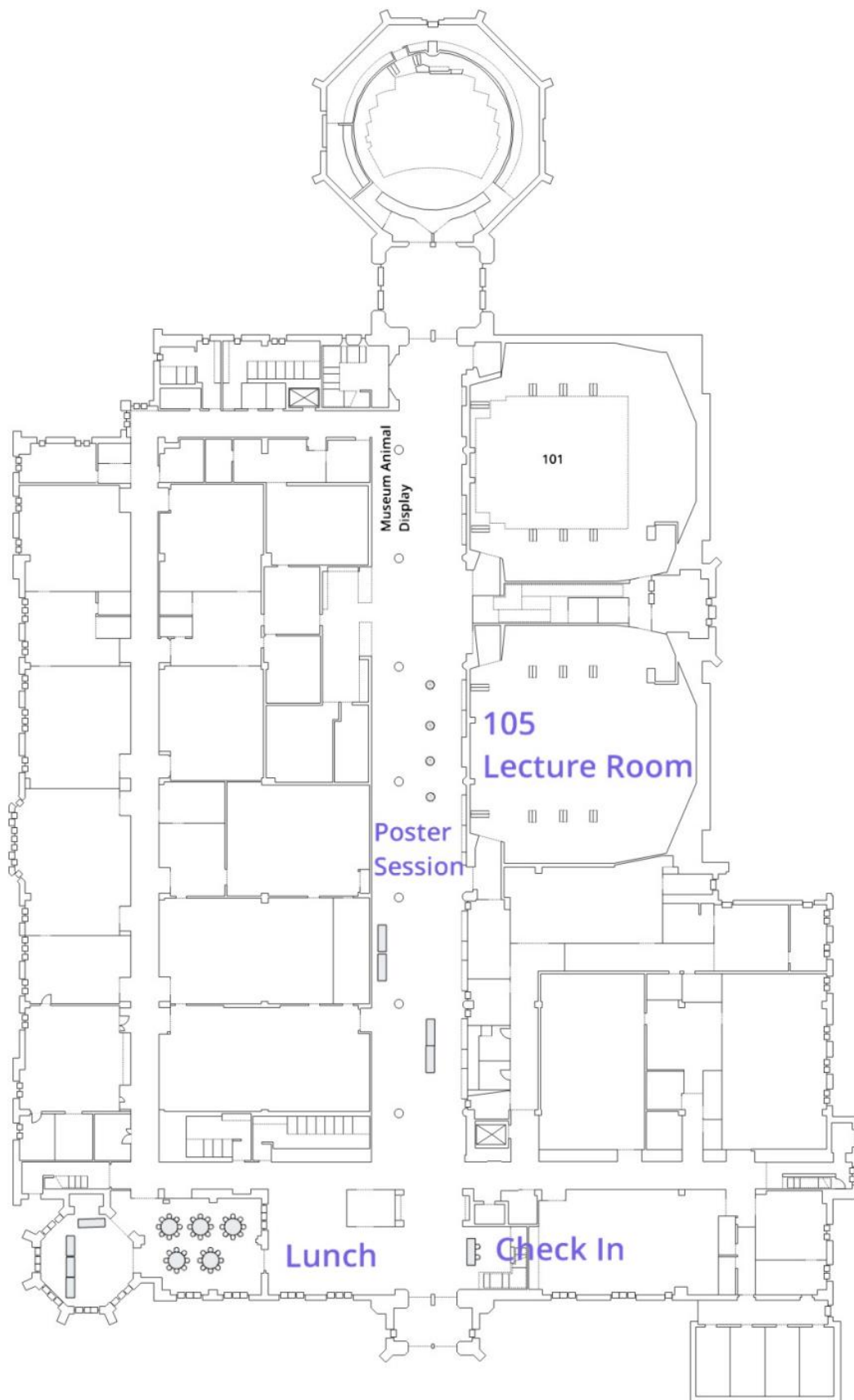


Saturday, October 17

Time	Speaker / Event	Presentation Title
8:45	Registration and coffee	Main Hall, Jordan Hall of Science
Visual Environments and Sensory Ecology Lecture Room 105, Jordan Hall of Science		
9:15	Introduction	
9:30 T01	Emma Thureau University of Notre Dame	<i>Deciphering the relationship between leaf color and nutritional content in the diet of a folivorous primate in Kibale National Park, Uganda.</i>
9:45 T02	Shane Guenin Purdue University	<i>High contrast and temporal vision in two species of New World Vulture: challenging assumptions on the visual capabilities of large birds</i>
10:00 T03	Yash Sondhi Case Western Reserve University	<i>Evolution of dim light vision in moths and insect phototaxis</i>
10:15 T04	Harold Gridley University of Notre Dame	<i>Evolution of the Neotropical Convict Cichlid (<i>Amatitlania siquia</i>) visual system in Crater Lake Apoyo</i>
10:30	Coffee break	Main Hall, Jordan Hall of Science
Sensing the Physical Environment Lecture Room 105, Jordan Hall of Science		
11:00 T05	Eric Gulson-Castillo University of Illinois	<i>Activation of a putative magnetoreceptive brain region, Cluster N, in New World migratory passerines</i>
11:15 T06	Ivan Mendez Gonzalez Northwestern University	<i>Evolution of thermosensory circuits and behaviors in flies of the genus <i>Drosophila</i></i>
11:30 T07	Kosisochukwu Onyeagba University of Cincinnati	<i>Hygrosensation through the Haller's Organ shapes oviposition site selection and reproductive success in ticks</i>
11:45 T08	Patrick Casto Bowling Green State University	<i>Wind direction predicts refuge homing success in a nocturnal whip spider</i>
12:00	Lunch	Reading Room, Jordan Hall of Science
Sensory Evolution and Adaptation Lecture Room 105, Jordan Hall of Science		
1:30 T09	Cesar Bertinetti Max-Planck for Biological Intelligence	<i>From SNPs to foraging performance: a key gene underlying local adaptation in color vision</i>
1:45 T10	Andressa Viol University of Michigan	<i>Sensory innovation and the ecological diversification of snakes</i>
2:00 T11	Sofia Sheikh University of Chicago	<i>A shared supergene but distinct dynamics regulate mimicry polymorphisms in closely related <i>Papilio</i> species</i>

2:15 T12	Tyler Hunt Purdue University	<i>QuantOD: an automated deep learning workflow for cone photoreceptor quantification in vertebrate retinae with oil droplets</i>
2:30	Coffee break	
Sensory Pollution Lecture Room 105, Jordan Hall of Science		
3:15 T13	Nina Hall Purdue University	<i>Novel sensory constraints on predation: noise and acoustic host-seeking in a frog-biting mosquito</i>
3:30 T14	Jabez Shin Purdue University	<i>Combined sensory pollutants alter physiology but not morphology in American toad tadpoles</i>
Plenary Lecture Lecture Room 105, Jordan Hall of Science		
4:00	Amanda Melin University of Calgary	<i>How wild primates find and select foods</i>
5:00	Poster session	Main Hall, Jordan Hall of Science
6:00	Banquet	Main Hall, Jordan Hall of Science
Sunday, October 18		
Time	Speaker / Event	Presentation Title
Sensory Signals and Communication Lecture Room 105, Jordan Hall of Science		
9:30 T15	Nathan Morehouse University of Cincinnati	<i>Sensory drive selects for increased salience of courtship color and motion in <i>Habronattus</i> spiders</i>
9:45 T16	Katja Kochvar Princeton University	<i>Call variation is associated with behavioral context but does not influence courtship in a North American Hummingbird</i>
10:00 T17	Trevor Price University of Chicago	<i>Cumulative cultural evolution transforms an avian vocalization</i>
10:15 T18	James Higham New York University	<i>Primate adaptive coloration: a sensory ecology approach</i>
10:30	Coffee break	Main Hall, Jordan Hall of Science
Plenary Lecture Lecture Room 105, Jordan Hall of Science		
11:00	Angeles Salles University of Illinois	<i>Neuroethology of social behavior in bats</i>
12:00	Lunch / end of meeting	Reading room, Jordan Hall of Science

Jordan Hall of Science Floorplan



Abstracts

Plenary Lectures

Saturday, 4:00–5:00 PM

How wild primates find and select foods

Amanda Melin

University of Calgary

As the interface between animals and their environments, senses are critical for guiding food detection and selection behaviours. However, sensory ecology research on wild mammals is sparse, limiting our understanding of forces shaping their foraging behaviours under natural conditions. Here, I discuss my research over the past 2 decades studying the sensory ecology of three sympatric Costa Rican primates (*Alouatta palliata*, *Ateles geoffroyi* and *Cebus imitator*). I discuss within- and between-species variation in sensory behaviours, and factors that may explain this variation. Overall, my research seeks to improve understanding of sensory system evolution and plant-frugivore interactions.

Sunday, 11:00 AM–12:00 PM

Neuroethology of social behavior in bats

Angeles Salles

University of Illinois

Bats are gregarious animals with well-developed audio-vocal systems. They use ultrasonic vocalizations to navigate their environment and produce social communication calls that vary in complexity, form, and function. My lab studies the neuroethology of auditory processing and social behavior in bats, working at the intersection of behavioral ecology and neural systems and combining laboratory and field work across behavior, acoustics, neuroanatomy, and electrophysiology. In this talk, I will focus on what drives social cohesion and roost fidelity, how bats distinguish roost mates from strangers, and how context modulates behavioral responses to communication sounds. Additionally, I will share our work on the neural circuits underlying contextual modulation, including the role of the auditory cortex and amygdala in shaping auditory processing at the inferior colliculus. Finally, I will also discuss how our work informs our understanding of auditory communication in mammals, including humans, and their relevance to disease ecology and conservation.

Oral Presentations

Session 1: Visual Environments and Sensory Ecology

Saturday, 9:30–10:30 AM

T01. Deciphering the relationship between leaf color and nutritional content in the diet of a folivorous primate in Kibale National Park, Uganda.

Emma Thureau, Kim L. Valenta, and Jessica M. Rothman

City University of New York, University of Notre Dame, University of Florida, Uganda Wildlife Authority, Kampala, Uganda

Much of the research on plant color has focused on color as a mutualistic signal to pollinators or frugivores; however, color can also act as a cue that may be exploited by folivores to detect nutritional quality. Primates as a group exhibit a wide diversity of color vision phenotypes including trichromatic vision, which may allow folivorous primates to discriminate between nutrient-rich reddish young leaves from mature green leaves. Here, we tested whether leaf colors acts as a nutritional quality and whether trichromatic vision enhances food discrimination and select by a folivorous colobus monkey, the guereza (*Colobus guereza*) in Kibale National Park, Uganda. We combined six months of behavioral observations of leaf selection with reflectance spectroscopy, color vision modeling, and nutritional assays of 73 leaf samples across 25 species. We assess color and nutritional composition across three comparisons: (1) among species, (2) within species and (3) across leaf maturity. Proportion of greenness, redness and the red: green contrast varied to nutrients but appeared to be related to measures of fiber, protein and energy. Trichromats were better able to detect chromatic contrasts between consumed and unconsumed foods across all three comparisons (Wilcoxon signed-ranked test for all nutrients $p < 0.05$) and we found that color was important for selection by guereza when selecting young leaves (versus mature leaves). Together, these findings suggest that color can act as a cue that is used by guerezas to detect young leaves among mature leaves and therefore is an important facet to primate adaptations and feeding ecology.

T02. High contrast and temporal vision in two species of New World Vulture: challenging assumptions on the visual capabilities of large birds

Shane Guenin, Tyler Hunt, Patrice Baumhardt, Esteban Fernandez-Juricic

Purdue University

Black Vultures (*Coragyps atratus*) and Turkey Vultures (*Cathartes aura*) are the two most common New World Vulture species present in North America. Members of their family, Cathartidae, are thoroughly underrepresented in the literature for several aspects of visual physiology and capability. We have characterized two aspects of the visual systems of these vultures, their achromatic contrast sensitivity (the ability to detect objects in low light and other low visibility scenarios) and temporal visual resolution (the “speed” of an animal’s vision, and ability to track moving objects). Birds typically have lower achromatic contrast sensitivity than other vertebrates. However, both of these New World vultures demonstrated higher achromatic contrast sensitivities than have ever been previously reported in a bird species. Similarly, the temporal visual resolution of both species, in some contexts, outpaces that of any previously reported bird (>150 Hz). This high temporal resolution is especially

pronounced for red and green light. We will describe these results, and our hypotheses on the life history mechanisms by which they may have arisen, as well as continuing experiments to describe why obligate scavengers may have such a unique visual ecology.

T03. Evolution of dim light vision in moths and insect phototaxis

Yash Sondhi

Case Western Reserve University

Standing outside and watching the sun set, you may not realize that light levels drop more than ten times in just ten minutes. A moonlit night is about a million times darker than a sunny afternoon. In the dark, it is harder to discriminate color, contrast, or fast motion, but most animals must deal with dramatically changing light conditions. Animals can be nocturnal (night), crepuscular (dusk or dawn), or diurnal (day), often referred to as “diel-niche”. No group better embodies these light extremes than butterflies and moths. They are close relatives, famously active in profoundly different light conditions and have more than a hundred recorded diel-niche switches. Relatively more is known about their natural history and evolutionary relationships than any other insect order, yet our understanding of their visual system is limited to a few species. In this talk, I explore how light environment has shaped the evolution of visual genes, behaviour and circuits across butterflies and moths. We provide a novel explanation for short range light entrapment of insects and explore how we will unravel neural basis of insect’s light entrapment.

T04. Evolution of the Neotropical Convict Cichlid (*Amatitlania siquia*) visual system in Crater Lake Apoyo

Harold Gridley, Julián Torres-Dowdall

University of Notre Dame

Vision mediates critical ecological interactions from prey detection, mate choice, and predator avoidance. Matching visual performance to local photic environments may therefore be important for survival and reproduction. The Nicaraguan lake-system contains two contrasting photic environments; shallow, highly turbid, red-shifted Great Lakes and deep, clear crater lakes. The convict cichlid (*Amatitlania siquia*) occurs about both lake types and can modify opsin gene expression to match local photic conditions. In 2018, a population of convict cichlids was first recorded in Crater Lake Apoyo, providing an opportunity to investigate visual-system divergence following recent colonization of a novel light environment. ddRAD SNPs indicated that the Apoyo population does not derive from any sampled Nicaraguan population, although it is genetically closer to Nicaraguan fish than to populations from Honduras or Costa Rica. Its origin therefore remains uncertain, with introduction through the ornamental fish trade as one possibility. Here we used qPCR to compare opsin gene expression patterns among four lacustrine populations of convict cichlid from two clear water lakes and two turbid lakes in Nicaragua, with focus on the recently established Crater Lake Apoyo population. We then compared each wild-caught fish with laboratory-reared descendants from each population to identify the extent to which population differences in opsin expression are environmentally induced or persist under a common rearing environment. Wild-caught Apoyo fish expressed a short-wavelength-shifted opsin palette, including adult expression of the UV-sensitive *sws1*, matching the clear-water environment. This pattern persisted in laboratory-

reared descendants, suggesting an inherited component and indicating either colonization by a clear-water-adapted lineage or rapid evolution following establishment in Lake Apoyo.

Session 2: Sensing the Physical Environment

Saturday, 11:00 AM–12:00 PM

T05. Activation of a putative magnetoreceptive brain region, Cluster N, in New World migratory passerines

Eric Gulson-Castillo, Corinna Langebrake, Benjamin Van Doren, Miriam Liedvogel, Dominik Heyers, Henrik Mouritsen, Benjamin M. Winger

University of Illinois

Despite decades of research, the mechanisms that birds use to detect magnetic fields remain mysterious. We studied magnetoreception comparatively by stimulating brain regions associated with putative magnetoreceptive organs. Cluster N is a visual brain structure that is active at night and known to mediate visual magnetoreception. Cluster N has been identified in night-migratory songbirds by comparing day/night brain neuronal activation patterns. We tested for Cluster N activation in a phylogenetically diverse set of bird families (Tyrannidae, Vireonidae, Turdidae, and Passerellidae) under controlled magnetic conditions and during day and night. Each bird family putatively represents an independent evolution of migration. Importantly, Tyrannidae lack cryptochrome 4, a candidate magnetosensor protein with strong empirical support, suggesting that flycatchers may differ in their magnetoreception sensory responses. We found Cluster N activation at night in all four bird families but responses to magnetic stimulations depend more on the control region used than Cluster N itself. Our findings reveal that cluster N activation is associated with nocturnal migration and night vision in all major passerine radiations. However, cluster N activation in Tyrannidae suggests that the relationship between Cluster N and magnetoreception is more complex than previously thought. Cluster N activation cannot be triggered by cryptochrome 4 in flycatchers, indicating 1) that magnetoreception-dependent activation in Cluster N does not require this protein, or 2) that this brain region only serves other vision functions in flycatchers. These complexities show that further exploration is required to understand the functionality and evolution of magnetoreception in birds.

T06. Evolution of thermosensory circuits and behaviors in flies of the genus *Drosophila*

Ivan D Mendez Gonzalez, Michael Alpert, Yuquing Su, Nan Ding, William L. Kath, Alessia Para, Marco Gallio

Northwestern University

From boreal forests to hot deserts, flies of the genus *Drosophila* occupy a remarkably broad range of habitats. This has been facilitated, in part, by the evolution of behavioral adaptations that enable these small poikilotherms to cope with diverse, even extreme, thermal conditions. Amongst other responses, rhythms of sleep and activity in *Drosophila* are regulated by changes in external temperature. Here, we explore how the daily alternation between periods of activity and midday siesta sleep is regulated by temperature in *D. melanogaster* and, for comparison, in two

southwestern desert endemic species, *D. mojavensis* and *D. mettleri*. Our results suggest that evolutionary changes in the activation threshold of a specific thermoreceptor gene are sufficient to explain changes in the length of mid-day siesta sleep in response to hot conditions in the desert species. Deserts of the southwest are characterized by a prolonged daily heating cycle, where intense solar radiation builds extreme heat that lingers well past sunset. Shifting the time and structure of daytime sleep-activity cycles may thus be critical to exploit the rather short windows of favorable thermal conditions.

T07. Hygrosensation through the Haller's Organ shapes oviposition site selection and reproductive success in ticks

Kosisochukwu Onyeagba, Pia U. Olafson, Holly D. Gaff, and Joshua B. Benoit
University of Cincinnati

Following detachment from the host, gravid female ticks must locate oviposition sites that provide environmental conditions favorable for egg development and larval survival. Although humidity sensing through the Haller's organ has been implicated in water balance regulation in unfed ticks, its role in post-feeding behavior and the selection of oviposition sites that promote egg and larval survival remains unclear. Here, we demonstrate that fed females of multiple tick species actively select humid microhabitats for oviposition and that disruption of humidity detection impairs this behavior. Mechanical interference with the Haller's organ through wax occlusion, cauterization, or foreleg removal significantly reduced attraction to humid environments and resulted in egg deposition under suboptimal moisture conditions. Transcriptomic analyses revealed enrichment of sensory-related genes in the forelegs, including the hygrosensory ionotropic receptors *Ir25a* and *Ir93a*, supporting a specialized role of the Haller's organ in humidity detection. Egg viability experiments showed that survival was strongly dependent on relative humidity, with maximal hatching occurring at $\geq 93\%$ RH, while natural egg clustering partially buffered eggs against desiccation stress. Chemical disruption using DEET similarly impaired humidity-guided behavior. Semi-field studies demonstrated that impairment of humidity sensing substantially reduced larval recruitment. Collectively, our findings demonstrate that humidity detection through the Haller's organ is essential for oviposition site selection, egg viability, and subsequent larval recruitment, and suggest that disrupting hygrosensory pathways may provide a novel strategy for suppressing tick populations.

T08. Wind direction predicts refuge homing success in a nocturnal whip spider

Patrick Casto, Verner P. Bingman, Eileen A. Hebets, Daniel D. Wiegmann
Bowling Green State University

How does a nocturnal animal find its home shelter in a complex natural environment? Amblypygids, or whip spiders, appear to use olfaction during navigation, but the role of wind-borne cues during homing under natural conditions remains unclear. We tested whether *Phrynos marginemaculatus* shows refuge fidelity and the possible interaction between wind direction and homing success after displacement. We marked 75 individuals and surveyed their daytime refuges over three subsequent nights. Site-faithful individuals were then displaced 2 m approximately upwind or downwind of their refuge; procedural controls were handled without displacement. Nearly 84% of marked individuals were repeatedly resighted near their original home

refuge. Following displacement, 74% of downwind-displaced individuals were resighted at their refuge, compared with only 25% of upwind-displaced individuals, and 89% of controls were resighted at their refuge. Greater success after downwind displacement is consistent with wind-borne odors from the refuge area aiding navigation. However, upwind-displaced individuals also returned more often than expected by chance, which is inconsistent with a rigid, direction-specific anemotactic rule, although a directional bias remains possible. The overall data suggest flexible, cue-guided homing that may involve multiple sensory modalities.

Session 3: Sensory Evolution and Adaptation

Saturday, 1:30–2:30 PM

T09. One gene, many lakes: how one transcription factor shapes color vision across a cichlid radiation

Cesar Bertinetti, P. Nührenberg, M. Li., A. Jordan, Axel Meyer, Julián Torres-Dowdall
University of Notre Dame

Color vision shapes how animals perceive and exploit their environment, but the genetic basis of its evolutionary tuning remains poorly understood. In Midas cichlid fish, foraging performance is locally adapted to water clarity: fish from clear lakes outperform those from turbid lakes under clear conditions, and *vice versa*; with this difference being linked to divergent cone opsin expression. To uncover the genetic basis of this divergence, we performed an interspecies genetic cross paired with gene expression analysis (eQTL), identifying a strong QTL and pinpointing the transcription factor *rx1* as a key candidate gene. Using retinal transcriptomes from over 150 cichlid species, we show that *rx1* expression is linked to violet/blue and red/green opsin usage, suggesting this gene has been repeatedly co-opted to drive opsin tuning during adaptive radiations. Together, these findings trace a path from ecological phenotype to transcription factor variant to altered gene regulation, revealing how a single regulatory change can fine-tune sensory systems to local environments.

T10. Sensory Innovation and the ecological diversification of snakes

Andressa Viol, Alison Davis Rabosky

University of Michigan

To successfully invade a habitat, an organism must be able to perceive and interpret environmental cues within their new environment. In this way, sensory systems mediate the accessibility of novel habitats. The invasion of new habitats, a process which may in turn generate new species, phenotypic innovations, or entire adaptive radiations, must therefore be facilitated by the sensory and neural system. The evolution of “hard parts” for feeding and locomotion is increasingly well-understood, but it remains poorly known how “soft parts” like sensory and brain anatomy may facilitate habitat invasions. We leveraged computed tomography (CT) scanning of preserved museum specimens to test a set of hypotheses on ecological diversification across >60 independent invasions of subterranean, arboreal, and aquatic habitats in snakes (Squamata: Serpentes). We found that convergence is widespread in both peripheral sensory organs and differential brain investment, with some regions of morphospace accommodating surprising overlap among ecological specialists, while other regions are dominated by only a single ecology. We also recovered potential trade-offs between sensory systems, such as visual and

chemosensory, suggesting that investment in some specialist morphologies comes with constraints. Interestingly, we also found that relationships among sensory structures can be complicated by the type of habitat specialization, with both fossorial and arboreal species showing reverse correlations to other ecologies. Finally, we asked if these patterns of sensory and brain anatomy covariation can predict phylogenetic transitions at deep time scales. Our results showed that the evolutionary integration of stimulus-sensing organs and processing brain regions can provide unprecedented insight into the drivers of among-clade variation in successful habitat invasions.

T11. A shared supergene but distinct dynamics regulate mimicry polymorphisms in closely related *Papilio* species

Sofia I Sheikh, Nicholas VanKuren, Meredith Doellman, Marcus Kronforst

University of Chicago

Despite the fact that sexes share the vast majority of their genomes, males and females can develop not only distinct morphologies, but also multiple alternate phenotypes suited to particular life histories and selective pressures. Sex-limited polymorphism – the ability of one sex to develop multiple discrete morphs – thus represents a striking and widespread case of adaptive phenotypic variation. Such polymorphisms are often controlled by supergenes, which are sets of tightly linked genetic elements or loci that together function to instruct the development of alternate phenotypes. However, the evolutionary origins of supergenes and the mechanisms through which supergene alleles shape distinct developmental programs remain poorly understood. The *doublesex* (*dsx*) supergene controls batesian mimicry polymorphism in several *Papilio* butterflies, where divergent *dsx* alleles switch between mimetic and non-mimetic female wing patterns. Using comparative genomic approaches, we characterized relationships and patterns of variation among mimetic and non-mimetic *dsx* alleles across several species and find signatures of both shared ancestral variation and extensive divergence between mimetic *dsx* alleles. To investigate the functional basis of *dsx* mimicry, we compared antibody staining and RNA-seq data from representative species of two subclades that diverged approximately 11 million years ago. Mimetic *dsx* alleles have species-specific spatiotemporal expression patterns and unique effects on the transcriptomes of developing wings. Collectively, our findings suggest that despite the shared use of *dsx* among closely related species, the mimicry switch operates through distinct developmental mechanisms.

T12. QuantOD: An automated deep learning workflow for cone photoreceptor quantification in vertebrate retinæ with oil droplets

Tyler Hunt, Patrice E. Baumhardt, Sara E. Cloft, Patrick A. Zollner, Marisa Erasmus, Gregory S. Fraley, Deana Jones, Javier Garcia, Darrin Karcher, Esteban Fernández-Juricic

Purdue University

The retinæ of many vertebrate groups (e.g., fish, birds, turtles, lizards, and some mammals) contain distinct oil droplets within the photoreceptors that function as spectral filters, improving color discrimination. In taxa where each photoreceptor type has a unique oil droplet, oil droplets can provide a means to estimate relative photoreceptor density, a key visual modeling input, without taxon-specific

immunolabeling. However, current methods require counters to quantify oil droplets across hundreds of images, per retina, per individual, representing significant time investments that limit sampling intensity and breadth. Here, we present QuantOD, a deep learning object detection pipeline that integrates two YOLOv12 models trained to classify oil droplets under brightfield and epifluorescent imaging, mirroring how humans use both illumination modes to make oil droplet classifications. Trained on >3000 images from domestic chicken retinæ, QuantOD shows high precision and recall (>95%) across all oil droplet types and practical equivalence with human counters. Running locally on a standard computer, QuantOD can process a complete chicken retina (300-600 images), a task that formerly took months, in less than 6 minutes. QuantOD could enable denser spatial sampling within retinæ and broader sampling across individuals, improving statistical power, reproducibility, and facilitating robust phylogenetic comparisons of photoreceptor distribution.

Session 4: Sensory Pollution

Saturday, 3:15–3:45 PM

T13. Novel sensory constraints on predation: noise and acoustic host-seeking in a frog-biting mosquito

Nina Hall, Richa Singh, Ximena E. Bernal

Purdue University

Animals are increasingly exposed to anthropogenic noise such as road traffic. Although animals have developed strategies to cope with natural noise, the effects of excessive anthropogenic noise on insects with flagellar ears remains largely unknown. In this study, we focused on *Uranotaenia lowii*, a unique species of mosquito that relies on auditory cues to locate anuran hosts, to examine how traffic noise affects their ability to respond to frog calls and their strategies to overcome this sensory pollutant. One mechanism that could allow *Ur. lowii* to overcome noise is Spatial Release from Masking (SRM), a phenomenon where listeners can detect sounds when they originate from different spatial locations than competing background noise. We hypothesized that these frog-biting mosquitoes are affected by noise and use SRM to improve their ability to detect and respond to frog calls. To test how *Ur. lowii* females are impacted by anthropogenic noise, we performed behavioral experiments using road traffic noise and frog calls presented at different signal-to-noise ratios. We also used speakers broadcasting frog calls and traffic noise from spatially distinct directions to test the use of SRM as a mechanism to improve their ability to find frog calls. Mosquito responses, response latency, and flight trajectory were quantified to further analyze the effects of noise on host-seeking behavior. Investigating how *Ur. lowii* are impacted by noise and the mechanisms underlying hearing in noisy conditions can deepen our understanding of urbanization effects on species interactions.

T14. Combined sensory pollutants alter physiology but not morphology in American toad tadpoles

Jabez S. Shin, Stiwat A. Cataño, Ana M. Ospina-L., Jonathan Lopez, Caitlin R. Gabor, Ximena E. Bernal

Purdue University

Urbanization transforms landscapes, exposing species to traffic noise and artificial light at night (ALAN). These pollutants can disrupt adult physiology and morphology, yet their effects on development are less understood. We examined the effects of traffic noise and ALAN on the physiology and morphology of American toad (*Anaxyrus americanus*) tadpoles, testing the combined effects of traffic noise and ALAN as well as the independent effects of ALAN. We assessed the glucocorticoid (GC) profile, measured as corticosterone, the primary GC in amphibians, to evaluate physiological coping capacity. By measuring baseline, stress-induced, and recovery corticosterone, we gain insight into the ability to maintain homeostasis and regulate physiological processes. To simulate sensory pollution, we used playbacks of traffic noise paired with white light to create a “phantom road”. To examine the effects of two common sources of light pollution, we also tested “white” and “yellow” ALAN. We hypothesized that these stressors differentially disrupt development, resulting in changes in tadpole physiology and morphology. Tadpoles growing in the control/natural environment showed a normal predicted coping capacity, while tadpoles exposed to the phantom road treatment exhibited a delayed and prolonged activation of the HPI axis despite no morphological effects. White and yellow ALAN did not influence coping capacity or morphology. These findings provide insights into how combined sensory pollutants affect developing amphibians and inform mitigation strategies in urban environments.

Session 5: Sensory Signals and Communication

Sunday, 9:30–10:15 AM

T15. Sensory drive selects for increased salience of courtship color and motion in *Habronattus* spiders

Nathan Morehouse, David Morris, Abhinav Madabhushi, Sebastian Echeverri, David Outomuro, Imogen Watts, Daniel Zurek, Wayne Maddison

University of Cincinnati

Sensory drive theory posits that sensory systems and associated signaling traits should co-evolve under selection for increased efficacy, such that evolutionary trajectories reflect adaptation to divergent signaling environments. Evidence for this process is well established in aquatic systems, but results from terrestrial taxa remain mixed. Using *Habronattus* jumping spiders, we tested the sensory-drive-based prediction that male courtship elements have evolved to be most salient in their own environments by 1) comparing color contrasts of focal species in their home environments to those across environments of all other species in our study, and 2) comparing parameters of courtship movements to motion characteristics of backgrounds in native habitats. For color ornaments, we find a consistent pattern of higher salience in home environments compared to heterospecific microhabitats. For courtship movement, we reveal a strong signature of habitat motion suggesting a history of selection for increased motion salience. Taken together, our work reveals a

key role for sensory drive in the evolution of courtship elements in this terrestrial animal group.

T16. Call variation is associated with behavioral context but does not influence courtship in a North American Hummingbird

Katja Kochvar, Jessica Wang, Cassie Stoddard

Princeton University

Acoustic communication is uniquely suited to dynamic, interactive exchanges, as individuals can easily modify acoustic signals on short timescales. Calls provide a prime example; variation in timing, spacing, and sequence structure can be rapidly adjusted in response to changes in environmental context or receiver behavior. Our study focused on the function of variation in “chip” calls of breeding Broad-tailed Hummingbirds (*Selasphorus platycercus*) in Gothic, Colorado. Based on recordings of 376 bouts across behavioral contexts, we found that calls could be clearly grouped into singlets, doublets, or triplets based on their spacing (i.e., within-bout call interval). The relative frequency of each grouping within a bout varied markedly by behavioral context, with males producing more doublets and triplets in high intensity situations like vigilance and pursuit and females producing more doublets and triplets when receiving male courtship. We tested whether variation in female calls influences male courtship by presenting 40 territorial males with playback of female bouts containing differing proportions of singlets, doublets and triplets. Although males did not differ in responsiveness to the experimental treatments, some males were consistently more responsive to female calls than others. These differences may be driven by intrinsic factors like male flight ability or extrinsic factors like background noise level. Overall, our work highlights the dynamic nature of acoustic signals and provides a framework for testing the function of call variation in other taxa.

T17. Cumulative cultural evolution transforms an avian vocalization

Trevor Price, Pratap Singh, Per Alström, Kavya Pandeya, Vignesh Chandran, Mark Kirkpatrick

University of Chicago

Cumulative cultural evolution is the process whereby innovations arise in a series of small steps building one on another, and at a rate which can be much faster than genetic evolution. Such evolution has been often considered a property of humans. We describe evolution of a bird vocalization across an entire species, achieved in 40 years. Evolution happened in at least six sequential steps. Present-day individuals scarcely respond to the ancestral form whereas more recent innovations promote strong responses, demonstrating why evolution was necessarily cumulative, rather than occurring as a single major innovation, as is the case also for human language. We build a model to show how biologically realistic large dispersal distances can indeed transform an entire species vocalization in such a short time (in contrast to human languages, whereby lower dispersal distances have resulted in diversification). We implicate urban noise as triggering the process. Such rapid, widespread, changes may be more common than appreciated given novel environments.

T18. Primate adaptive coloration: a sensory ecology approach

James P Higham

New York University

Primates exhibit some of the most striking color phenotypes among mammals, from radiations exhibiting remarkable face patterns, to the presence of bright orange and yellow babies in species where the parental coats are dark. Here I describe our work combining visual models with experiments with live primates to elucidate the function and evolution of some of these phenotypes.

Poster Presentations

P01. Influence of habitat background motion on short-range courtship in *Habronattus pyrrithrix*

Abhinava Jagan Madabhushi, Katelyn Wright, Eden Crawford, Tyler Ching, Ellie Jacobs, Gowthami Vidya, David Morris, Daniel Zurek, Nathan Morehouse

University of Cincinnati

Animals live in noisy **environments** that can affect signal perception by receivers. Research in vertebrates reveals that signalers often modulate motion signals in response to background motion. However, little is known about how background motion shapes signals in invertebrates. We examined the influence of background habitat motion on *Habronattus pyrrithrix* jumping spiders' courtship. *H. pyrrithrix* has a multicomponent visual display with distinct long- and short-range phases. The long-range phase consists of alerting foreleg waves functioning to capture female attention. Previous research has found that males move closer to females against noisy backgrounds during long-range phases of their displays. This effectively increases the perceived visual angle of waves by the females, making them more salient against background motion. The short-range phase consists of tarsal and knee movements whose motion also plays an important role in capturing and maintaining female attention. We thus predicted that males would increase the visual angle and/or velocity of tarsal movements in the short-range phase in response to background motion. We recorded male courtship displays to a conspecific female against two backgrounds (still habitat image, habitat video with motion). We tracked display motions in 3D and compared the kinematics of tarsal movements as perceived by the focal female in the two background conditions. Our research demonstrates the role of background motion noise in shaping displays of a charismatic invertebrate taxon.

P02. Substrate temperature preference during egg-laying in *Drosophila*

Alexandria Snyder, Leisly Bahena, Zexin Zeng, Iván D. Méndez González, Alessia Para, Marco Gallio

Northwestern University

Ectotherms like the fruit fly *Drosophila* rely on behavioral strategies to avoid temperature extremes and to maintain their body temperature within a suitable thermal range. In addition, female flies select egg-laying substrates with suitable

temperatures, favoring conditions permissive for embryo development. The specific sensory neurons and central circuits that guide this behavior are not known. Here, we describe a specific 2-choice behavioral assay to study egg-laying substrate temperature preference in *Drosophila melanogaster* and other *Drosophila* species adapted to divergent thermal environments. We show that egg-laying substrate temperature preference is species-specific and, in *D. melanogaster*, we utilize this assay to screen selective driver lines to silence candidate sensory and central circuits, looking for candidate cell types involved in this behavior. In this poster, I will present preliminary data from this ongoing work.

P03. Effects of artificial light at night (ALAN) on *Glossina* transcriptome, physiology, and behavior

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University of Cincinnati

Urbanization has transformed ecosystems worldwide, introducing new forms of sensory pollution that directly affect organisms. Among these, Artificial Light at Night (ALAN) has steadily increased, becoming a pervasive anthropogenic stimulus. As an unnatural light source, ALAN disrupts the natural light–dark cues essential for regulating biological processes. The tsetse fly (*Glossina*) is the primary vector of African trypanosomiasis and relies strongly on environmental cues to regulate its daily rhythms. Under a standard 12:12 light–dark cycle, male *Glossina* display the expected U-shaped activity pattern with peaks at dawn and dusk. However, exposure to ALAN disrupted this bimodal rhythm, and comparisons of activity proportions revealed that ALAN-exposed males spent a greater proportion of time active relative to control males. ALAN exposure also altered sleep architecture, with exposed males exhibiting decreased total sleep duration. To further investigate the effects of ALAN, a male competition assay was conducted with ALAN-exposed and control male paired with a female. Control males performed more mating attempts than ALAN-exposed males, but no differences were noted in latency to first attempt or total time attempting to mate compared to ALAN-exposed males. RNA-seq analysis was performed to identify differentially expressed genes between the two groups, which show increased expression profiles underlying metabolic function in ALAN-exposed males. These findings provide insight into how anthropogenic light pollution may alter behavior, reproduction, and transcriptional responses in tsetse flies with consequences for vector ecology and disease transmission.

P04. The effects of traffic noise and artificial light at night (ALAN) on frog choruses

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Urbanization transforms landscapes and reshapes sensory environments through artificial light at night (ALAN) and traffic noise. These sensory pollutants can disrupt acoustic communication by interfering with signal production, signal transmission, and receiver responses. Although research has increasingly examined how animals adjust signaling behavior in response to noise or ALAN independently, far less is

known about their combined effects, despite their frequent co-occurrence in urban habitats. Moreover, most studies focus on responses by individual signalers, leaving unclear how these sensory stressors scale up to influence chorus-level dynamics. Frog choruses are emergent social systems in which timing, participation, and acoustic energy relate to mating opportunities and reproductive success. Here, we investigated the independent and combined effects of ALAN and traffic noise by experimentally introducing these sensory pollutants to natural choruses. We quantified short-term changes in the number of detections and the probability of the chorus being active through time when exposed to light and noise independently or combined. We predicted that traffic noise would filter out species with low-frequency calls, which are more prone to acoustic interference. Due to changes in perceived predation risk, ALAN is expected to alter calling motivation and reduce chorus participation. Simultaneous exposure to both stressors could magnify disruptions to chorus dynamics beyond the independent effects of each sensory pollutant. This study provides insights into how sensory pollutants affect chorus dynamics in rapidly changing environments. Short-term signaling adjustments, such as those investigated here, may allow frogs to cope with sensory disturbances. Further studies examining persistent chorus disruption are necessary to evaluate how these changes ultimately influence breeding dynamics in urbanized environments.

P05. Blue-green sensitivity dominates the retinal response in the eyes of kissing bugs, *Rhodnius prolixus*

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Kissing bugs are nocturnal, blood-sucking hemipteran insects that serve as vectors of trypanosomes in the Americas. Vision is a key sensory modality required for many aspects of insect behavior, yet little is known about the visual systems of kissing bugs. To thoroughly examine kissing bug vision, we used transcriptomics, phylogenetics, and electrophysiological extracellular electroretinography (ERG) analyses of photoreceptors to identify and characterize opsins and related visual processes in the kissing bug compound eyes. RNA-seq of the eyes and in situ hybridization confirmed two putative visual opsin genes (UV and blue-green), one of which is highly expressed in the eyes, and phylogenetic analysis indicates that this opsin belongs to the blue-green-sensitive class. To investigate opsin spectral sensitivity, we assessed spectral responses using electroretinograms from adult *R. prolixus* compound eyes and measured photoreceptor responses to monochromatic light stimuli from 300 nm to 700 nm (in 20 nm steps). Spectral sensitivity analysis predicted a peak sensitivity at approximately 496 nm. Further, we assessed opsin wavelength sensitivities using photoreceptor bleaching experiments with UV (365 nm), blue (460 nm), and orange (605 nm) light stimuli. All wavelengths attenuated the entire ERG response, suggesting a dominant functional opsin in the visual system. Together, our results indicate that both long-wavelength and UV opsins are expressed in the *R. prolixus* compound eye. However, only a blue-green opsin accounts for most of the response to light stimuli. Understanding the spectral classes of photoreceptors in kissing bugs is critical to understanding their nocturnal ecology and could identify novel targets to control their spread.

P06. Applications of hyperspectral imaging to modeling animal visual environments

Kristina Fialko, Mary Caswell Stoddard

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Animal signals and behaviors are situated within complex sensory environments. The visual properties of these environments contain both spatial and spectral information, which shape the evolution of animal perceptual systems. However, capturing the properties of natural scenes has typically required a tradeoff between spectral and spatial resolution. Hyperspectral imaging offers an approach to quantify the visual complexity of natural environments by recording hundreds of wavelength bands at each pixel, allowing both fine-scale color and scene structure to be collected together. Here, we use an outdoor hyperspectral imaging system to document natural landscapes and pilot an analytical pipeline that extracts spectral and spatial features to model the information available to animal visual systems. We apply this method to ask how Broad-tailed hummingbirds respond to changes in the "colourscape" of alpine wildflower meadows – the color and spatial distribution of flowers. Working across alpine wildflower meadows at the Rocky Mountain Biological Laboratory (Colorado, USA), we show how shifts in floral phenology reshape the visual "colourscape" of each meadow as different flowers come in and out of peak bloom. This approach provides a tool to model how environments appear to animal observers and to compare habitat differences that may shape sensory and signaling evolution.

P07. Variation in sensilla type, distribution, and morphology among lepidopteran proboscises predicts feeding habits

Kendall Myers

Case Western Reserve University

The proboscis of butterflies and moths (Lepidoptera) is a highly specialized feeding appendage consisting of two elongated c-shaped galeae that form a food canal for feeding. The external morphology of the proboscis varies between lineages and species; however, species with functional proboscises are typically lined with sensory structures that aid in food sensing and acquisition, which vary in form, abundance, and their distribution across the proboscis surface. These sensory structures, known as sensilla, also vary in type, with six commonly found: styloconica (gustatory), chaetica (tactile), basiconica (gustatory), filiformia (vibrotactile), coeloconica (gustatory), and campaniformium (proprioceptive). Using scanning electron microscopy and confocal laser scanning microscopy, we compare the type, abundance, density, and morphology of sensilla among sixteen species of moths. Based on patterns observed among the studied lineages, as well as patterns identified in the literature, we found that sensilla can be used to help infer feeding habits among lepidopterans. Flower visiting species tend to have shorter, fewer, and less dense sensilla than non-flower visiting species. Extremely specialized species, such as vampire moths and honey feeding death's head moths, lack styloconica, with sensilla shapes and distributions that more closely match those of flower visiting moth species. Our findings suggest that the morphology of lepidopteran proboscis sensory structures can be used to infer function and ecological roles.

P08. A novel type of oil droplet in the Turkey Vulture (*Cathartes aura*) retina

Patrice Baumhardt, Tyler Hunt, Shane Guenin, Esteban Fernández-Juricic
Purdue University

The typical single cone photoreceptor in birds is composed of an inner segment and an outer segment with an oil droplet organelle positioned between the two. Oil droplets in birds function as optical filters that can modify the spectral sensitivity and photon-catching ability of the photoreceptor they are within. All bird species measured to date have spherical oil droplets throughout the retina. However, we recorded for the first time in the retina of Turkey Vultures (*Cathartes aura*) an oil droplet that is fusiform in shape with a strong orange coloration. This type of oil droplet was only observed in the dorsal retinal region, producing an orange coloration on the retina that is visible to the naked eye. These fusiform oil droplets seem to completely replace the yellow-type oil droplets on the medium-wavelength sensitive (MWS) photoreceptors in this portion of the retina. Microspectrophotometry confirmed that the fusiform oil droplets were associated with the MWS opsin visual pigment with a peak sensitivity near 500 nm. Transmission electron microscopy revealed that they are aligned on their long axis within the cone photoreceptors. The potential function of these oddly shaped oil droplets, isolated into a single region, remains unknown but could be related to their ability to scavenge for food while soaring.

P09. Syringeal innervation patterns: An unexplored anatomical basis for singing behavior?

Cara Hall, Jo Gogola, Dan Margoliash
University of Chicago

The discovery that female syringeal innervation patterns are distinctive in the zebra finch (*Taeniopygia guttata*) has sparked interest in whether peripheral neuroanatomical patterns can substantially influence behavior as females of this species do not sing. Preliminary results from the expansion of the sample size to additional species suggest that interspecific differences in innervation patterns are dominant over intersexual differences, despite conserved muscle networks and irrespective of syringeal dimensions across songbird species. Conceptually, the relationship between the spatial positions of neuromuscular junctions and muscle performance can be modelled using a system of equations to represent responses to synaptic firing at all levels of muscle organization. This poster presents the preliminary empirical data as well as a proposal for the phenomenological model.

P10. How birds find their way: investigating navigation cue use during active migration

Ethan Minikes
University of Illinois Urbana-Champaign

Nocturnally migrating birds, which make up 80% of North American avian migrants, use information from the Earth's geomagnetic field and stars to navigate. These cues are regularly degraded by natural fluctuations in magnetic and atmospheric conditions and space weather anomalies. When these cues are disrupted, birds struggle to orient in their migratory direction. In my poster I present methods for investigating species-specific responses to degraded navigation cues in free flight. I propose three projects to evaluate migratory behavior in the presence of uncertain

navigation cues. First, I will determine if birds vocally communicate cue disturbances through nocturnal flight calls. Then, I will use full migration route tracking to gain new insights into how birds respond to cue instability while in free flight. Lastly, I will investigate how birds resolve sensory conflicting information during migration and how they calibrate the magnetic compass. I will evaluate how responses differ across avian lineages and what they reveal about how migratory behavior is shaped by evolutionary and ecological contexts.

P11. Spatial relationships between the fetal nasal capsule and the maxillary incisors in the aye-aye

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The aye-aye (*Daubentonia madagascariensis*) is a lemur that has evolved ever-growing incisors, a trait otherwise absent among primates. Previously, we compared the shape and curvature of adult *Daubentonia* maxillary incisors with the range of variation observed in rodents and lagomorphs. We found that *Daubentonia* incisor morphology differs dramatically from that of all other taxa examined: its incisors are dorsoventrally flattened and mediolaterally expanded. Here, we propose that the unusual curvature of these teeth may reflect ontogenetic changes in the fetal nasal capsule, potentially related to the broader evolutionary reorganization of the primate sensory system. As primates became increasingly reliant on vision, the need to accommodate larger and more forward-facing eyes was associated with the reduction of the midfacial skeleton and decreased emphasis on olfactory structures. We combine microCT and diceCT (diffusible iodine-based contrast-enhanced computed tomography) segmentations to visualize the developing teeth and nasal cartilages of a perinatal aye-aye and compare their spatial relationships with those of the corresponding structures in adults.

P012. Planned Research: Using IEGs in *Galleria mellonella* to identify neural populations active during ALAN exposed flight

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Artificial Light at Night (ALAN) disrupts natural light-dark cycles, impacting the biological processes and behavior of many organisms. ALAN causes flight disruptions and spatial disorientation in moths due to a dorsal light response, where they orient their dorsal axes towards light sources. However, the neural mechanisms underlying such behavior are not well understood. It is unclear which neural populations are associated with the behavior. One method for identifying neural populations active during a behavior is through the use of Immediate Early Genes (IEGs). Shortly following a behavior, neurons that were active express certain IEGs. The objective of this study is to identify which neural populations are active in *Galleria mellonella* (wax moths) when flying in response to acute exposure to ALAN. We will address this question using behavioral analysis and molecular techniques. We plan to acutely expose naive *G. mellonella* to ALAN during subjective night, filming and observing their behavior 5 minutes pre-ALAN exposure and 30 minutes post-exposure. We will then analyze the videos to characterize behavior using an

ethogram and flight trajectories. To identify neural populations active when moths are flying in the presence of ALAN, we will compare IEG expression between ALAN-exposed flight and unexposed flight. After observing the behavior of interest in each treatment group, moth brains will be dissected and flash frozen for RNA extraction. Quantitative polymerase chain reaction (qPCR) will be used to validate reference genes and IEGs in *G. mellonella*. We will select two reference genes with stable expression across treatment groups. Then, we will confirm the suitability of two different IEGs used in insects, *Hr-38* and *Egr-1*, based on quick and transient expression following the behavior of interest. We will also use this method to determine the appropriate time course for this experiment. After validation, *in-situ* hybridization chain reaction (HCR) will be used to locate areas where the IEG was expressed across the treatment groups, thus identifying neurons that were recently active. Understanding the neural populations associated with ALAN-induced behavioral changes in *G. mellonella* will provide insight into the connections between anthropogenic change, neural mechanisms, and behavior.

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