EVOLUTIONARY STUDIES

the magazine

ISSUE 1, Spring 2022

Darroch Lab combines paleontology & fluid physics to uncover Ediacaran nurseries

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The evolution of polar bear diets

Tradeoffs between reproduction & aging

Songbird mate choice

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Evolutionary Studies Initiative

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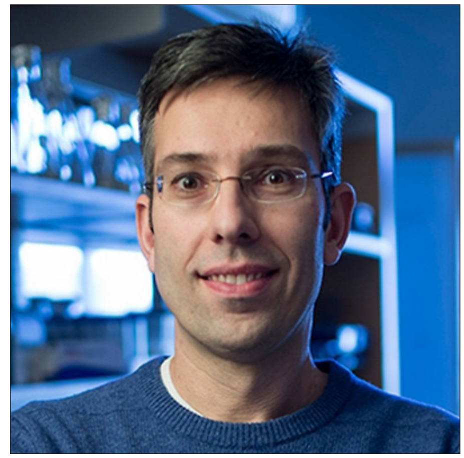
VANDERBILT ESI

Greetings Alumni and Friends,



Dr. Antonis Rokas

Hope you and your family are healthy in these unusual times. It has been a quite productive year for the Vanderbilt University Evolutionary Studies Initiative. We hired a new scientific coordinator, began work toward an NIH training grant application, began a pilot grant program, and welcomed new faculty, graduate students, and postdoctoral fellows to our Initiative. And as I am typing these words, we are interviewing several stellar candidates for the faculty position in evolutionary biochemistry and biological anthropology.

This last October, we hired scientific coordinator, Dr. Andy Flick. Andy did his Ph.D. at Louisiana State University in ecology and evolution under Dr. Bret Elderd. After, he did a postdoc with Dr. Johanne Brunet at the USDA in Madison, WI. He worked on gene flow of roadside alfalfa from genetically modified to conventional plants. Andy has been instrumental in setting up and coordinating our day-to-day activities and operations. In the coming months, Andy will be leading the coordinating and administrating the writing of an NIH training grant application. Specifically, we are developing a cross-disciplinary grant for training graduate students in the evolutionary approaches to infectious and genetic diseases. This project will involve dozens of researchers from our initiative and greatly enhance the graduate experience for our students.

In the meantime, we started two new internal grant programs. The pilot grant program aims to provide seed funding to our scientists for new collaborations and proof-of-concept or preliminary data for larger grant applications. We were really fortunate to fund seven exciting projects this year. We also started a trainee travel grant program and we have already had several applicants.

We are really excited about what the future holds for the Evolutionary Studies Initiative. In the pages of our magazine you will find our list of seminar speakers (you will recognize many, so join us when you can!) and learn about some of the cool science that is taking place in our laboratories. I thank you for your support to our efforts and look forward to sharing our progress with you in the future. If you have questions or ideas, please do not hesitate to reach out.

Sincerely,

Antonis Rokas

Antonis Rokas, Director
Evolutionary Studies Initiative
Cornelius Vanderbilt Chair in Biological Sciences
Vanderbilt University

EVOLUTIONARY STUDIES the magazine

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Evolutionary Studies Magazine is published yearly for members, alumni and friends of the Evolutionary Studies Initiative.

2022 SEMINAR SERIES

1/12 - Cassandra Extavour
Harvard College Professor, Howard Hughes Medical Institute Investigator, Timken Professor of Organismic and Evolutionary Biology and of Molecular and Cellular Biology, Harvard University

2/9 - Beth Shapiro
University of California Santa Cruz Professor, Howard Hughes Medical Institute Investigator, Ecology and Evolutionary Biology Department

2/16 - Corrie Moreau
Cornell University Professor, Martha N. and John C. Moser Professor of Arthropod Biosystematics and Biodiversity, Director and Curator of the Cornell University Insect Collection

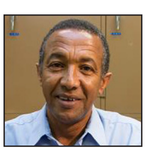
2/23 - J. Arvid Ågren
Evolutionary Biologist at Uppsala University, Author of The Gene's-Eye View of Evolution, Wenner-Gren Fellow

3/2 - Elisabeth Bik
Microbiome and Science Integrity Consultant and Researcher, featured in the New York Times, Wall Street Journal, Le Monde, Nature, STAT News, The Scientist, and RetractionWatch

3/16 - Henry Gee
Paleontologist, Evolutionary Biologist and Senior Editor of Nature, and writer of numerous books, including A (Very) Short History of Life on Earth: 4.6 Billion Years in 12 Pithy Chapters

3/23 - Nicole King
Professor of genetics, genomics, and development at the University of California, Berkeley, Investigator, Howard Hughes Medical Institute

3/30 - Eva Jablonka
Emeritus in History and Philosophy of Science Inst. Tel Aviv University and writer of numerous books including The Evolution of the Sensitive Soul: Learning and the Origins of Consciousness



4/6 - Yohannes Hailes-Selassie
Paleoanthropologist, Curator and head of Physical Anthropology at The Cleveland Museum of Natural History, Discovered numerous fossils and led numerous Ethiopian fossil digs

4/20 - Toby Kiers
University Research Chair and Professor of Evolutionary Biology at VU University Amsterdam, pioneered economic interpretation of mycorrhizal networks of plant, fungi and microbes

Find more information about our virtual seminar series on Vanderbilt.edu/evolution

Creanza Lab

High standards of female songbirds could be driving their mates to evolve

Nicole Creanza (Vanderbilt University)

Hearing longer love songs from songbirds in your backyard? Chalk it up to sexual preference – and high standards. New research on songbirds from Biological Sciences researchers at Vanderbilt suggests that females, who are choosing males with the most elaborate songs as their potential partners, are influencing male songbirds to evolve toward learning (and practicing) songs throughout their lives – an evolutionary occurrence previously believed to be mainly a result of changes in a bird's environment, breeding season, or migration.

The paper, published this week in the journal eLife by Vanderbilt Biological Sciences professor Nicole Creanza and graduate students Cristina Robinson and Kate Snyder, is the first study to demonstrate that songs, which are sexually selected, coevolve with how long the birds can learn, and may even drive evolutionary changes in birds' brains.

"We were curious as to why some birds learn throughout their lives and why others only learn when they're juveniles," said Creanza. "Researchers have thought about this question for a while, but usually linked their findings back to those other environmental aspects of the birds' lives. We had a hypothesis that sexual preference for songs could also be a factor."

Song, a learned vocal behavior in songbirds that develops in a similar way to how humans learn language, is a relatively rare feature in the animal kingdom. It serves multiple purposes for birds, helping them recognize their own species, defend their territory and attract mates.

While some songbirds continue to learn their songs throughout their entire lives, many species are finished learning by the time they reach sexual maturity – just as we humans learn more easily during our formative years.

The team compiled data on 67 different songbird species as part of their study, and compared various factors for each song including overall length of songs and their "vocabulary size" – or number of different syllables that each species can sing. According to Creanza and her team, the findings demonstrate a link between how songs sound and how birds learn them. This could change the way scientists think about lifelong learning in birds. It could also hold significant implications for how we think about lifelong learning in other species – even humans.

"As we learn more about these time-windows for learning in birds and what causes them to evolve and lengthen, we may be able to apply those findings to how and why human learning windows may have evolved over time. One day, if researchers understand what happens in the brain when a bird maintains its ability to learn, it might shed new light on how to help the brain repair itself in humans."

Tate & Patel Labs

Researchers test evolutionary theories with novel empirical study of 'cheater' mitochondria

Vanderbilt University biologists are testing the theoretical understanding of "cheating" and "cooperative" behavior in mitochondria—the organelles that generate cellular energy—with findings that provide new evolutionary insights into why selfishness and cooperation can coexist among populations.

Maulik Patel and Ann Tate, along with lead author and Ph.D. student Bryan Gitschlag, published their findings in the article "Nutrient status shapes selfish mitochondrial genome dynamics across different levels of selection" in the journal eLife on Sep. 22.

Within a cell, multiple copies of mitochondrial DNA exist in the genome and are constantly being replicated and used. A healthy cell is full of only identical DNA copies, with each working together to produce energy for the cell to fulfill its role. In the case of a mixed population, mutated mitochondria can take advantage of the fitness of their host cell without contributing any energy, selfishly "cheating" the cell of energy. These mutations and associated diminished cellular energy can lead to severe health issues and diseases, including muscle weakness, heart disease and dementia.

"How these mutations in the mitochondrial genome can rise to a high frequency to the point that they become pathogenic is the motivation for our work," explained Patel.

While the concept of cooperating and cheating is widespread in biology, particularly in a social context, it has not been extensively studied because of the challenge of finding a system that affords the ability to control all parameters with scientific precision.

In a release Gitschlag explained, "Cooperation and cheating are widespread evolutionary strategies. While cheating confers an advantage to individual entities within a group, competition between groups favors cooperation."

The researchers found that cheater mitochondria can outcompete those that are cooperative, though only to a point. Once the cheater population reaches the threshold of 60 percent frequency in its host cell, the environment becomes detrimental to survival, as the cheaters lose their advantage over cooperative mitochondria. These results, "suggest that competing selection pressures within an organism and in its environment may shed light on why selfishness and cooperation often exist side-by-side among populations," according to the release.

At the individual level, cheater mitochondria have an advantage over cooperative mitochondria, at the cost of organismal fitness across generations. Nutrient stress decreases the selective advantage of cheater mitochondria within an individual, but this has repercussions at the population level by buffering the detrimental effects across generations.

From there, the researchers investigated how an environmental disturbance—in this case food scarcity—would impact a balanced system. They found that a limited food supply compromises the ability of cheater mitochondria to take advantage of the system. When resources are limited, cheater mitochondria suffer because they benefit more from those resources. Yet, though the cheaters take a greater hit, there is a paradoxical outcome.

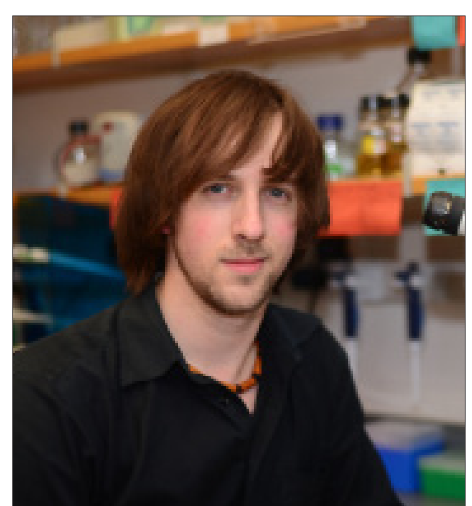
"When we limited food resources, physiological responses were activated to protect the organisms with cheater mitochondria," Tate said. "It increased the threshold of cheater mitochondria that the organism could withstand."

These findings underscore the value of empirical studies in this work, since evolutionary theory does not necessarily predict that limited resources would inadvertently benefit cheaters when a host organism becomes more stress-tolerant. Looking ahead, the researchers intend to continue looking at other mitochondrial cheaters that have different genetic mutations.

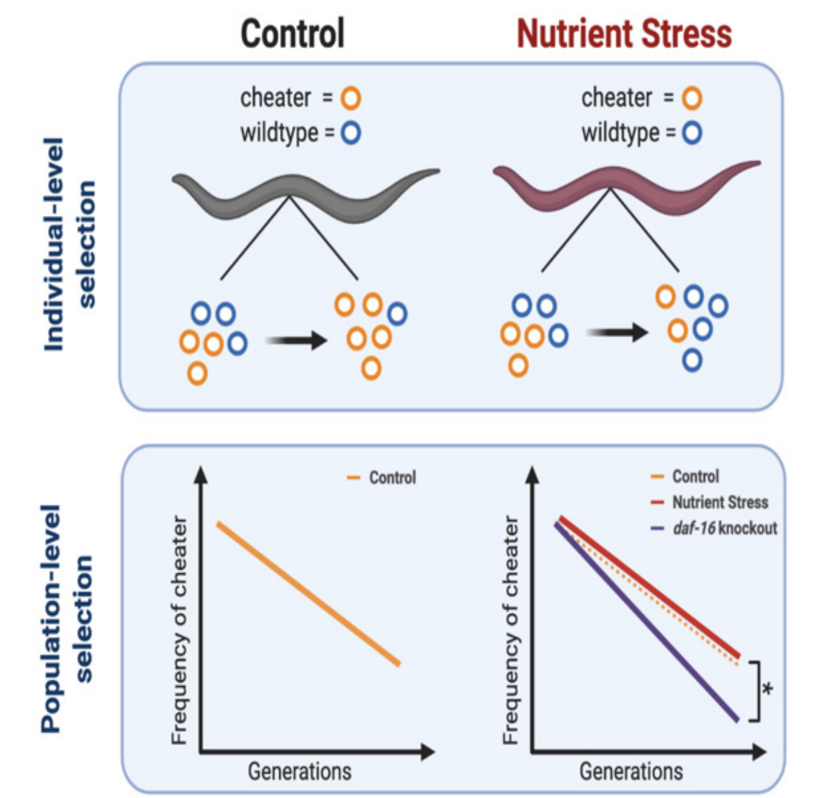
This work was supported by the National Institute of General Medical Sciences grants GM123260 and 1F31GM125344 and the Vanderbilt Diabetes Research and Training Center.

Maulik Patel (Vanderbilt University)

Ann Tate (Vanderbilt University)



Bryan Gitschlag (Vanderbilt University)



At the individual level, cheater mitochondria have an advantage over cooperative mitochondria, at the cost of organismal fitness across generations. Nutrient stress decreases the selective advantage of cheater mitochondria within an individual, but this has repercussions at the population level by buffering the detrimental effects across generations. (eLife)

Evolutionary Studies Seminar Series

Cassandra Extavour (1/12)
Beth Shapiro (2/9)
Corrie Moreau (2/16)
Arvid Ågren (2/23)
Elisabeth Bik (3/2)
Henry Gee (3/16)
Nicole King (3/23)
Eva Jablonka (3/30)
Yohannes Hailes-Selassie (4/6)
Toby Kiers (4/20)

DeSantis Lab

Polar bears maintained highly specialized diets during periods of Arctic warming—until now

Polar bears are often considered the poster-child species for climate change impacts. With global warming and sea-ice declines, it becomes harder for polar bears to hunt their preferred prey—seals.

Increased global temperatures are having the greatest impact on Arctic and Antarctic environments, with arctic polar bears projected to decline by 30 percent by 2050.

Larisa DeSantis, paleontologist and associate professor of biological sciences, with former undergraduate student Ansley Petherick, set out to assess if and how the diet of polar bears differed during periods of rapid warming.

The study, "Dietary ecology of Alaskan polar bears (*Ursus maritimus*) through time and in response to Arctic climate change" published in the journal Global Change Biology, showed that polar bears have maintained highly specialized diets of soft blubber and flesh—even during previous periods of Arctic warming.

"We were really surprised that polar bears consumed soft foods, even during the Medieval Warm Period, a previous period of climate change that occurred approximately 1,000 years ago," DeSantis said.

By using a technique called dental microwear texture analysis, which analyzes microscopic wear on tooth surfaces to infer the textural properties of foods an animal consumed when it was alive, the researchers tracked dietary behavior of polar bears over hundreds to thousands of years. They examined polar bear skulls from museums like the University of Alaska Museum of the North in Fairbanks, Alaska, in collaboration with archaeologists at the University of Alaska and Portland State University.

Larisa DeSantis

"Looking to the diets of polar bears in the past helps us to understand and contextualize any changes that might be occurring in the present," Petherick said.

"Polar bears have historically consumed seals, and our work shows that in the past they have preferentially eaten very soft tissues, like energy-rich blubber."

Polar bears became highly specialized after they diverged from brown bears approximately half a million years ago. Their skulls became elongated, and their molars are actually smaller than is typical for their body size. Eating blubber doesn't cause major damage to the bears' teeth and can be identified from the study of tooth wear surfaces.

"Polar bears are so specialized on hunting seals that they may have a harder time adapting to the warming Arctic," said DeSantis, who specializes in dental microwear among carnivores. "The shift to eating hard foods in a handful of bears in the 21st century is also concerning. Polar bears may be reaching a tipping point and may now be forced to consume less-preferred foods."

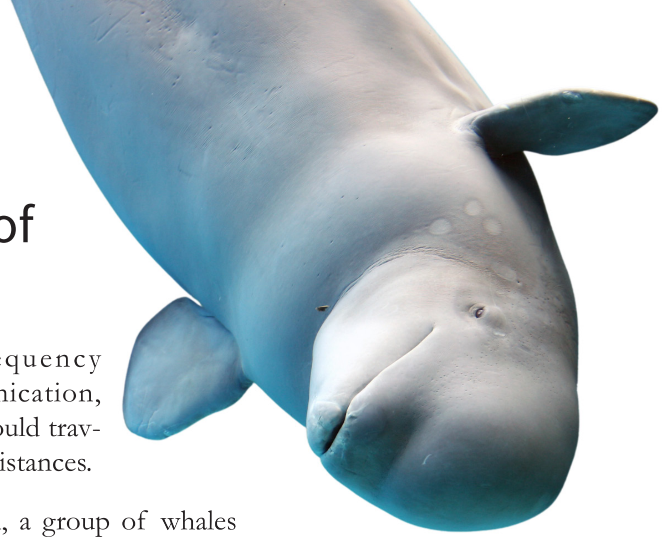
Unlike polar bears, grizzly bears are well adapted to eat hard foods like plant tubers or to scavenge carcasses when resources are limited. The changing terrain brought about by the warming climate also means that grizzly bears can venture farther north and compete with polar bears for whatever food is available.

"That situation does not favor the success of the highly specialized polar bear," Petherick said. "The public has given a great deal of attention to the plight of the polar bear under global climate change, and rightfully so. These apex predators are specialized to a sea-ice hunting lifestyle, melting in the Arctic threatens their whole way of life."

Polar bears, historically, are not the first threatened apex predator in the Western hemisphere.

"Unfortunately, history and pre-history repeats itself," DeSantis said. "Highly specialized sabertooth cats went extinct at the end of the Pleistocene. Only animals that were already generalized or able to adapt survived. Specialists like the polar bear are at greater risk of extinction, especially if their habitat is literally melting away."

This research was made possible by the National Science Foundation, Vanderbilt University and the Littlejohn Family. The authors also wish to acknowledge that the archaeological work was conducted on the traditional lands of the Iñupiat from Utqiaġvik.



Racicot Lab

Imaging technology shows evolution of whale sensory systems

Rachel Racicot (Simon Darroch)

By Dr. Andy Flick
ESI Scientific Coordinator

If you've ever had an ear infection that made you dizzy or unbalanced, the infection likely was affecting your vestibular complex—part of the intricate system of hard and soft tissues that make up the inner ear. Knowledge of this structure has been made possible through computed tomography scans—imaging technology that continues to shape our understanding of evolution across species.

In a review of a century of research on sensory systems of whales, Rachel Racicot, research assistant professor of biological sciences, describes advances in the field and key questions that remain.

The article, "Evolution of whale sensory ecology: Frontiers in nondestructive anatomical investigations" was published in the journal *The Anatomical Record*.

Anatomy and morphology are areas of research where we are making huge discoveries, especially when we can include fossils to help inform our understanding of evolution, function and convergence that we wouldn't otherwise be aware of," said Racicot, also a member of the Evolutionary Studies Initiative. "The evolution of sensory systems in whales (and other groups) can be studied using nondestructive CT scanning and other techniques."

When animals die and become fossils, soft tissues, including those in the ear, break down, and bony areas become scattered with empty pockets where these soft tissues were once housed remain. By recreating these areas digitally, researchers can determine the frequencies animals could hear. One of the questions this technique addresses is whether echolocation evolved independently in different whale groups.

According to Racicot's review, it is thought that the first completely marine whales used low-frequency communication, which could travel long distances.

Later on, a group of whales evolved higher frequency communication and developed echolocation. In 2019, she discovered that echolocation may have evolved twice and in separate groups of whales.

Whales aren't the only animals whose ears are being examined with imaging techniques; researchers are also looking at dinosaurs, birds and other mammals.

"Another cool study found that cochlear coiling has independently evolved at least twice: once in monotremes (platypus) and another time in therians (live-bearing mammals)—something that we wouldn't have been able to detect without including fossils in the analysis," she explained.

Racicot's review also acknowledges the open questions about how the whale sensory system has evolved, which are critical to our understanding of the overarching evolutionary trends in ocean-dwelling mammals that have proven difficult to access and study.

This work is already informing and directing the research of Racicot and her trainees. Several undergraduates in her lab are reviewing a data intensive sample of ziphiid (beaked whale) inner ears to understand their hearing sensitivities.

"We can't directly measure their hearing ranges easily because they are deep sea diving animals, but there's a lot of interest because they tend to strand when naval sonar is used," Racicot said.

"Many of the big questions we've answered using nondestructive imaging like CT scans in studying sensory evolution in whales have led to more questions—which means there are so many more discoveries to be made!"

> "Cochlear coiling has independently evolved at least twice..."
>
> Dr. Rachel Racicot
> Research Assistant Professor

Darroch Lab

Researchers combine paleontology and fluid physics to uncover Ediacaran nurseries

By Dr. Andy Flick
ESI Scientific Coordinator

Knowing how life worked on Earth 550 million years ago can give perspective on how life could evolve on other planets. And geobiologist and assistant professor of Earth and environmental sciences Simon Darroch and postdoctoral researcher Brandt Gibson are working to figure that out.

"At the broadest scale, understanding how, when, and why complex life evolved on this planet gives us a sense for how likely it is that we'll find complex life elsewhere in the solar system, and what it may look like," Darroch said. "I honestly can't think of anything cooler to be working on."

Their research features strange, vase-like organisms (in the genus *Ernietta*) that lived in the Ediacaran Period—approximately 635 million to 541 million years ago. These organisms lived in marine environments, where fluid dynamics drive the evolution of the organisms that inhabit them.

This work brought two distinct areas of science together—paleontology and fluid dynamics, which describes the flow of liquids and gases.

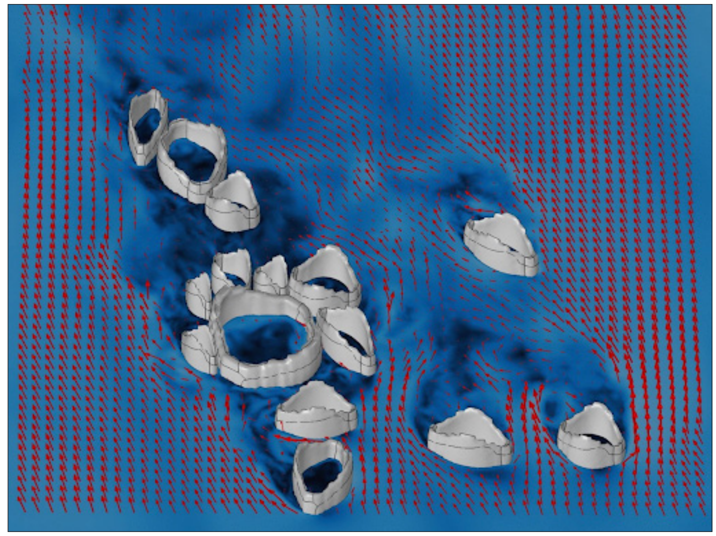
"Paleontology is at its most exciting—and arguably most successful—when it works at the interface with other disciplines. In this case, it's fluid physics," Darroch said.

Computer models of fluid dynamics that affect communities of organisms suggest that when isolated, larger individuals have better nutrient circulation in their body cavities than smaller individuals. However, when different sizes of individuals live together, larger ones can create beneficial conditions for smaller ones that are downstream. Gibson led this research, conducted within the Evolutionary Studies Initiative, which resulted in an article published by Frontiers in Earth Science on Oct. 18.

Throughout Gibson's graduate studies in Darroch's lab, the two participated in the Blended and Online Learning Design Fellows Program which enables graduate student and faculty teams to develop online instructional materials grounded in solid course design principles and an understanding of how people learn.

"I'm sure some of our discussions in generating those materials helped spark ideas presented in this research," Gibson said.

"The same ecological tricks that allow organisms to feed, move and reproduce have evolved again and again through time, likely because life in moving fluids exerts such strong selective pressure. *Ernietta* in particular seem to behave a lot like some gregarious mussel groups, especially beds of mussels and oysters," Darroch explained.



A digitally reconstructed *Ernietta* population placed in simulated flow. (Gibson)

"Perhaps the greatest benefit is that smaller *Ernietta* would be protected from adverse flow when downstream of larger ones, but they also consistently receive stronger cavity recirculation (probably aids in suspension feeding)," Gibson said. "Our simulations suggest that these sorts of ecological dynamics, which are well-known in living animals, also helped to structure Ediacaran communities composed of organisms that are entirely mysterious to us."

Darroch praised the lab's efforts in spearheading this research: "It took talented students like Gibson to actually get this effort going, and he's been expanding the lab's horizons ever since."

These new horizons are already approaching in the capable hands of Andrei Olaru and Hale Masaki, undergraduate students in biological sciences and EES, respectively. "Andrei and Hale are using similar techniques to help understand some other mysterious

Ediacaran taxa," Darroch said. The students recently earned trainee travel grants through the ESI to present their work at the annual meeting of the Paleontological Society in Oxford, England. This research was supported by joint funding from NSF (NSF-NERC EAR-2007928) and NERC (NE/V010859/1) to Darroch and his collaborators.

"We're working with a very talented team at Oxford, and together we've reconstructed whole surfaces from Mistaken Point in Newfoundland, Canada. Looking at how these broader-scale flow regimes evolve through the Ediacaran-Cambrian boundary will give us vital clues as to how facets of biology and ecology were changing throughout that time period," Darroch said.

ESI kicks off pilot grant program

Seven awards support evolution research across disciplines

By Dr. Andy Flick
ESI Scientific Coordinator

The Evolutionary Studies Initiative (ESI) has awarded seven grants to researchers in the initiative. These grants will seed new projects and collaborations. We highlight a quick snapshot of the variable and exciting projects below – with full stories on three individual projects below.

ESI director, Cornelius Vanderbilt Chair in the Department of Biological Sciences Antonis Rokas, is especially excited to get these projects off the ground. “The ESI is delighted to offer these pilot grants and sees this investment as a great opportunity to help members of our initiative form strong and lasting interdisciplinary collaborations across campus or explore new areas of research. We look forward to the awesome outcomes of these seven funded projects,” said Rokas.

The labs of assistant professors Megan Behringer and Benjamin Bratton will study the response of experimentally evolved *Escherichia coli* to starvation. The pair use a technique called single-cell phenotyping, which allows for a greater understanding of evolution caused by microhabitats. For instance, E. coli cells in environments with slightly different pH concentrations can show a range of responses (phenotype) – even though they started genetically identical (genotype). Read more on page 15.

Assistant professor Nicole Creanza will work with associate professor Jada Benn Torres to study creole word lists along with unique pronunciations and how they relate to African ancestry of populations in the Caribbean. Much of the data have already been collected, so analyzing those data and publishing the results are top priorities. Check out Creanza’s work on sexual selection of song birds on page 5.

Assistant professor Maulik Patel will use *Caenorhabditis elegans* to study the tradeoff between maintenance and reproduction. Patel’s lab will investigate which environmental conditions and life-history traits activate the molecule that determines whether *C. elegans* uses energy for maintenance or reproduction. Continue reading on Page 14.

Assistant professor Larissa DeSantis will lead a team of students up to the Smithsonian Institute to partake in collections-based research on crabeater and leopard seals. Her research focuses on the diets of animals long extinct. Check out her story about the diets of polar bears over thousands of years on Page 8.

Research assistant professor Rachel Racicot will use advanced software to study the biosonar apparatus of toothed whales. This software will allow Racicot’s lab to digitally extract the space containing the bony labyrinth, which informs on the cochlear structure. Check out a recent story covering her work review of the evolution of whale ears on Page 10.

Assistant professor Ann Tate’s lab will use the funds to study optimal immune responses in flour beetles (*Tribolium castaneum*). They will study how the immune system responds when regulatory molecules that control immunity are switched off. Check out a story with Tate, Patel, and graduate student Bryan Gitschlag studying mitochondria on Page 6.

The sole graduate student awardee, Audrey Arner, will spearhead a group studying evolutionary mismatch, specifically looking at how the Semang – an indigenous people of Malaysia – may be experiencing a mismatch in the environment they recently emigrated from (rural areas) to the new environment some currently occupy (urban areas). This work will be in conjunction with anthropologists, physicians, and research technicians. Check out her full story on the following page.

Lea Lab

Graduate student studies lifestyle-associated diseases as evolutionary mismatch

By Dr. Andy Flick
ESI Scientific Coordinator

Audrey Arner, a first-year Ph.D. student in Dr. Amanda Lea's lab, recently earned a pilot research grant from the Evolutionary Studies Initiative (ESI) to study the evolutionary mismatch hypothesis. Arner described evolutionary mismatch as, "the same allele that was beneficial in the ancestral environment could be detrimental in the novel environment, which could lead to negative health impacts."

Looking at the big picture, Arner said, "these results will help us better understand how lifestyle-associated diseases emerge due to evolutionary mismatch."

Arner is trained in biological anthropology and human genetics.

"I wanted to make sure that I use my anthropological skills to make connections with communities and make sure that my research was a mutually beneficial partnership while also doing functional genomics research to understand how the interaction of adaptation and lifestyle change impacts health," she explained. "Dr. Lea's lab was perfect for that. Vanderbilt also seemed to have a lot of resources available, especially the Evolutionary Studies group"

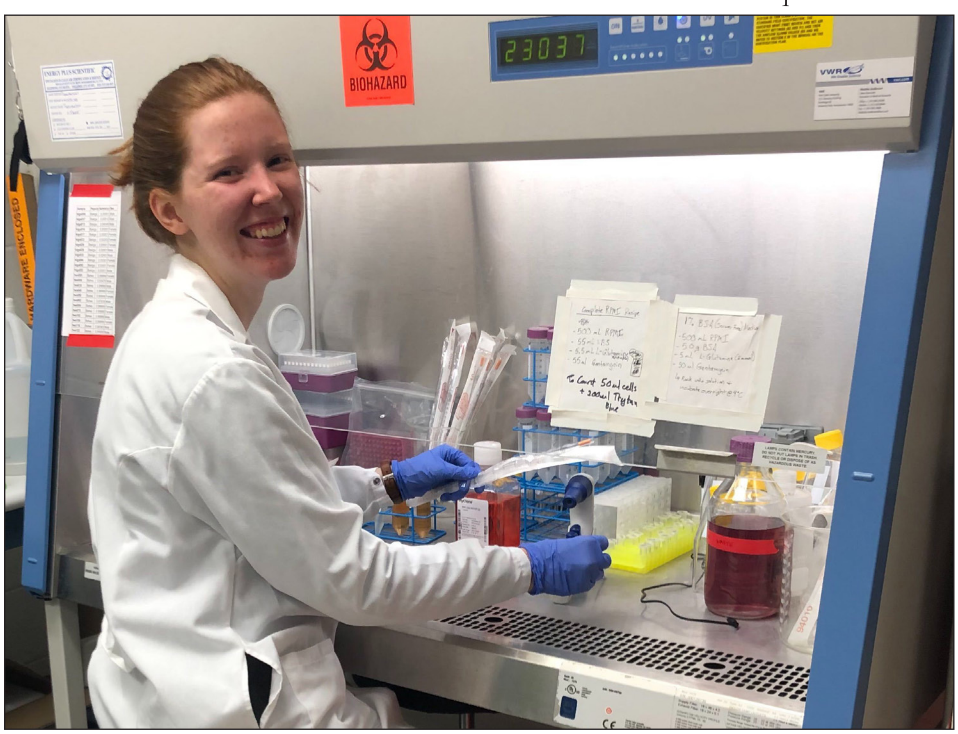
Evolutionary mismatches could be driven by changing environments due to climate change or migration from rural, traditional environments to urban environments. Traits that used to be beneficial – imagine a propensity to store fat in an environment where food sources are unpredictable – might now be detrimental and lead to cardiovascular disease or obesity.

Arner will be working with other anthropologists and physicians through the Orang Asli Health and Lifeways Project (OAHeLP). The OAHeLP has a working relationship with a subset of the indigenous Malaysian people known as the Semang. According to Arner, "the Semang are a hunter-gatherer population that is transitioning to a more urbanized lifestyle such that individuals of the same genetic background live in both traditional and urban settings."

The research will take her to Malaysia where she will work with local scientists and medical doctors to collect blood samples. These samples will be used to generate whole genome sequencing data where she can identify areas of the genome under selection. Arner will then identify whether selected loci have different phenotypic effects in traditional versus urban settings.

She will also use data generated with this grant to train undergraduate students in methods of biological anthropology and evolutionary genomics. These students will be well prepared for lab-based or bioinformatic careers in industry or academia. Arner also hopes to have undergraduate trainees pursue their own questions and really get excited about work in the lab.

Results from this work would serve as a proof of concept and preliminary data allowing Arner to apply for larger research grants – such as the National Science Foundation's Biological Anthropology Doctoral Dissertation Improvement Grant and the Leakey Foundation's Graduate Student Research Grant. It is also a high priority to get the results she finds back to the communities from which the data come. To this end, Arner will also help train Semang field assistants in molecular techniques.



Graduate student Audrey Arner

Patel Lab

Lab studies evolutionary trade-offs between reproduction and aging

By Dr. Andy Flick
ESI Scientific Coordinator

Sometimes serendipity can open the doors to scientific discovery.

That's the case for the new project in Dr. Maulik Patel's lab funded by a Pilot Research Grant from the Vanderbilt Evolutionary Studies Initiative (ESI), an organization supporting cross-disciplinary evolutionary studies.

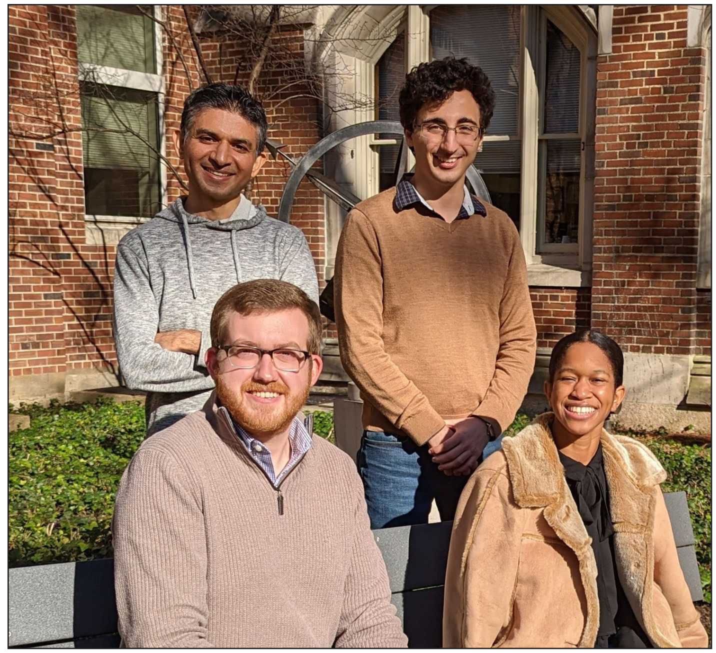
Why do we age? According to one theory in evolution, aging is the price animals pay for reproduction. Research in the Patel lab explores this trade-off between somatic – or body – maintenance and reproduction. They use the tiny but experimentally mighty roundworm model organism *Caenorhabditis elegans* for their work. The researchers employ CRISPR genome engineering technology to knock out specific genes to determine if they affect certain processes or correct cellular glitches.

The diverse team of researchers in the Patel lab are from various career stages, including Ph.D. candidate James Held. Speaking of the lab's new work, Held said, "we decided to study the soma-reproductive trade-off because the associated phenotype that we serendipitously came across was just too remarkable not to follow-up on."

The researchers use a fluorescent reporter that illuminates cells when their mitochondria, or power center, stop working. The reporter signals that the cell has employed a process to help the impaired mitochondria, the mitochondrial unfolded protein response, or UPRmt for short.

"The fluorescent reporter was one of the most striking things we saw," said Patel. "This reporter is indicative of mitochondrial stress and gives us a quantifiable way to measure distress. Historically, studies use lifespan as a measure of maintenance. However, lifespan is a complex phenotype, measurements are notoriously variable, and the biological significance of small differences is not always clear." By using mitochondrial distress, the lab has a quantifiable and practical way to measure changes in somatic maintenance.

Held described the process he used that led to questions about the trade-off. "I created a mutant in which a protein called HOE-1 cannot leave the nucleus because it's nuclear export signal—NES for short—is compromised. I found that the NES mutant robustly induces UPRmt, seen most obviously by activation of the UPRmt reporter. The mutants grow normally but are sterile." More work in the



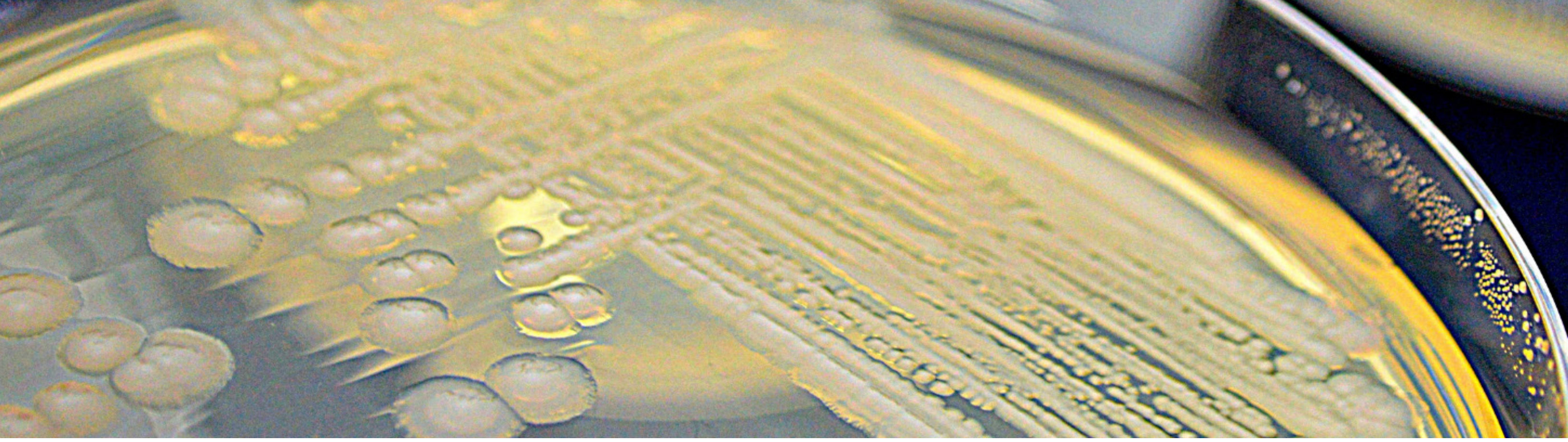
Patel lab members pictured are front row, from left: James Held, Cassidy Johnson, back row, from left: Maulik Patel, Nadir Dbouk

Patel lab focuses on clarifying the role of protein HOE-1 in UPRmt activation. "At this time, it seemed that simply elevating HOE-1 levels in the nucleus should be sufficient to activate UPRmt. Thus, to complement the NES mutant, I made a strain in which nuclear HOE-1 is over-expressed. Surprisingly, UPRmt is not activated in these animals." Held noticed that the main difference between the NES mutant and complementary mutant was the presence of sterility – which led to the link in a trade-off between maintenance and reproduction.

According to Patel, "given the importance of the topic and the exciting findings, this new project will be a major focus of the lab. We want to look at multiple factors like environmental cues or communication between the germline and the soma. Currently, we use genetic mutations to artificially knock down key pathways in reproduction. I'm really excited to see where James and the other trainees can help take this project."

The ESI grant has the potential to fundamentally expand the work conducted in Patel's lab and will provide preliminary data necessary to seed a larger National Institutes of Health (NIH) grant this coming summer. Patel hopes a future grant from the NIH will also offer the opportunity to alleviate resource limitations.

"The challenge has always been to identify the molecular basis for the evolutionary trade-off between body maintenance and reproduction," he said. "Using *C. elegans* and a fluorescent reporter provides an elegant framework to think about this trade-off—and more generally—how we age."



Behringer and Bratton Labs

Microbiologists collaborate on new interdisciplinary research program studying *E. coli* evolution

By Dr. Andy Flick
ESI Scientific Coordinator

Big surprises can come from the smallest packages, for example, microbes. Assistant professors Drs. Megan Behringer and Benjamin Bratton have formed a collaboration to study the evolution of *E. coli* - funded by a pilot grant from the Evolutionary Studies Initiative (ESI).

The pair use a technique called single-cell phenotyping, which allows for a greater understanding of micro-habitats. For instance, *E. coli* cells in environments with slightly different pH concentrations can show a range of responses (phenotype) – even though they are genetically identical (genotype).

Behringer noted, "I was trying to measure intercellular pH; I've found papers that said I can. However, when I started measuring intercellular pH, it became apparent that I was actually measuring extracellular pH. It turned out the dye was leaking at relatively high pH concentrations."

Behringer then reached out to Bratton, who had experience studying these kinds of dyes. Bratton studies single cell responses and measuring fitness and physiology of single bacterial cells, instead of whole populations.

One benefit of studying evolution in bacteria is the speed at which it happens. According to Bratton, "bacteria grow so fast they are a great place to look at evolution because you have clonal populations that can vary on a reasonable timescale."

Behringer continued, "People think of *Drosophila* (fruit flies) as evolving quickly, but you're not going to leave the lab and come back in three hours and see any real changes. In bacteria, the entire population can change greatly in that amount of time."

This collaboration comes at an important time for the two new faculty members. One extra hurdle in the time of a pandemic is getting to know a department primarily working from home and so finding a sense of community is more important than ever.

"As I started out, the junior faculty have been lifelines because they had to be on campus and they have to be engaged," said Behringer. She continued, "as we're seeing the next set of faculty starting now, we don't want them to feel as alone as we felt when we first started."

The project also includes earlier career researchers like new postdoctoral scientist Dr. Sarah Worthan and undergraduate scientist Aaron Yeh.

Worthan, in the Behringer lab, will bring a physiology background along with CRISPR skills to this collaboration. "She will be able to create designer mutants and think about where in the physiology space this sits and what type of phenotypes we should be thinking about," said Behringer.

TOP *E. coli* on an agar plate; BOTTOM (from left) Prof. Megan Behringer and Prof. Ben Bratton

Yeh is excited to get research lab experience working with Bratton. According to Bratton, "this will be a great way for him to see what he likes about lab work. He's undecided about his future career between being an infectious disease pediatrician and a basic science researcher. I loved getting lab experience early on and that's something that's been difficult for undergraduates during the pandemic."

The two researchers are eager to see how microbes evolve beyond persistence to eventually thrive in resource-limited environments.

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