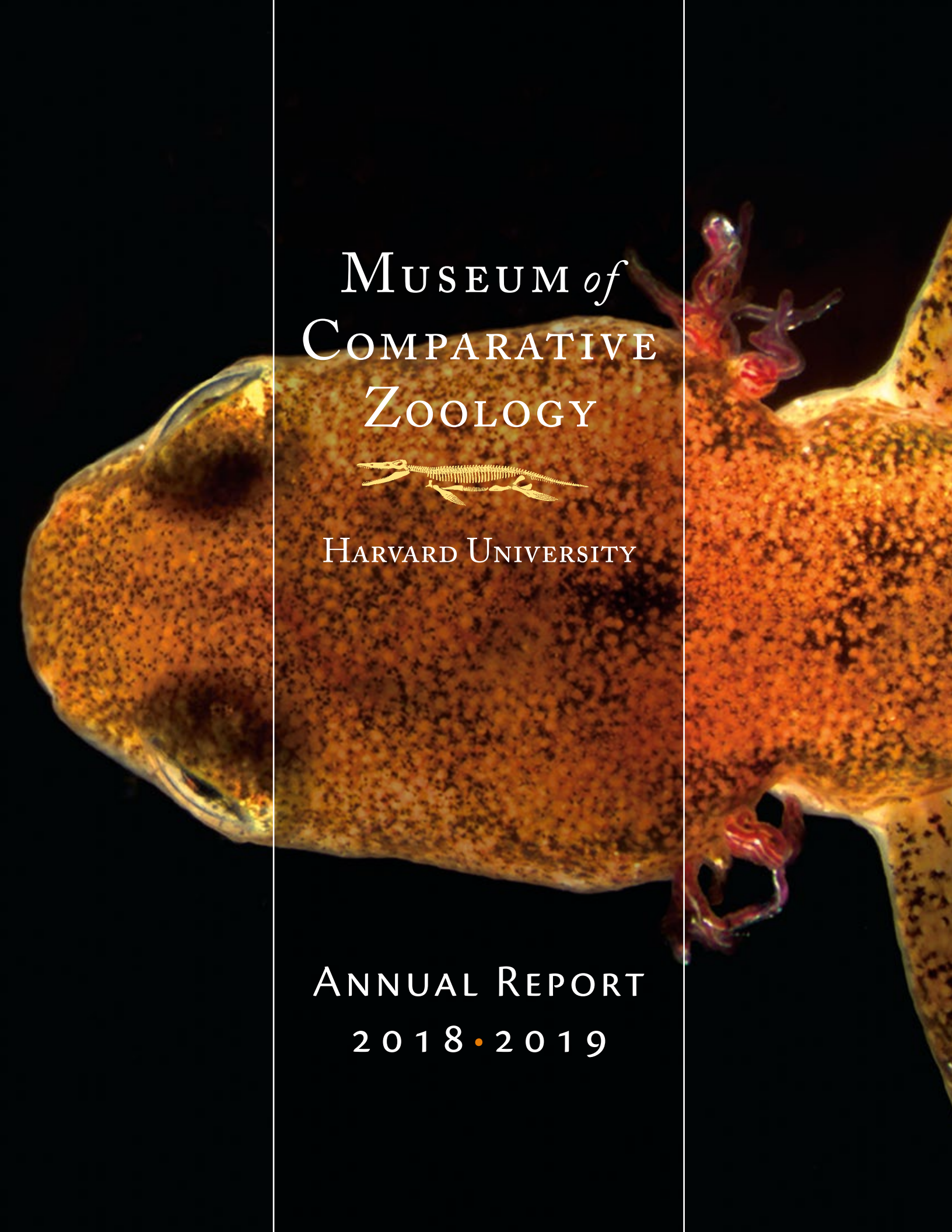


Museum of Comparative Zoology

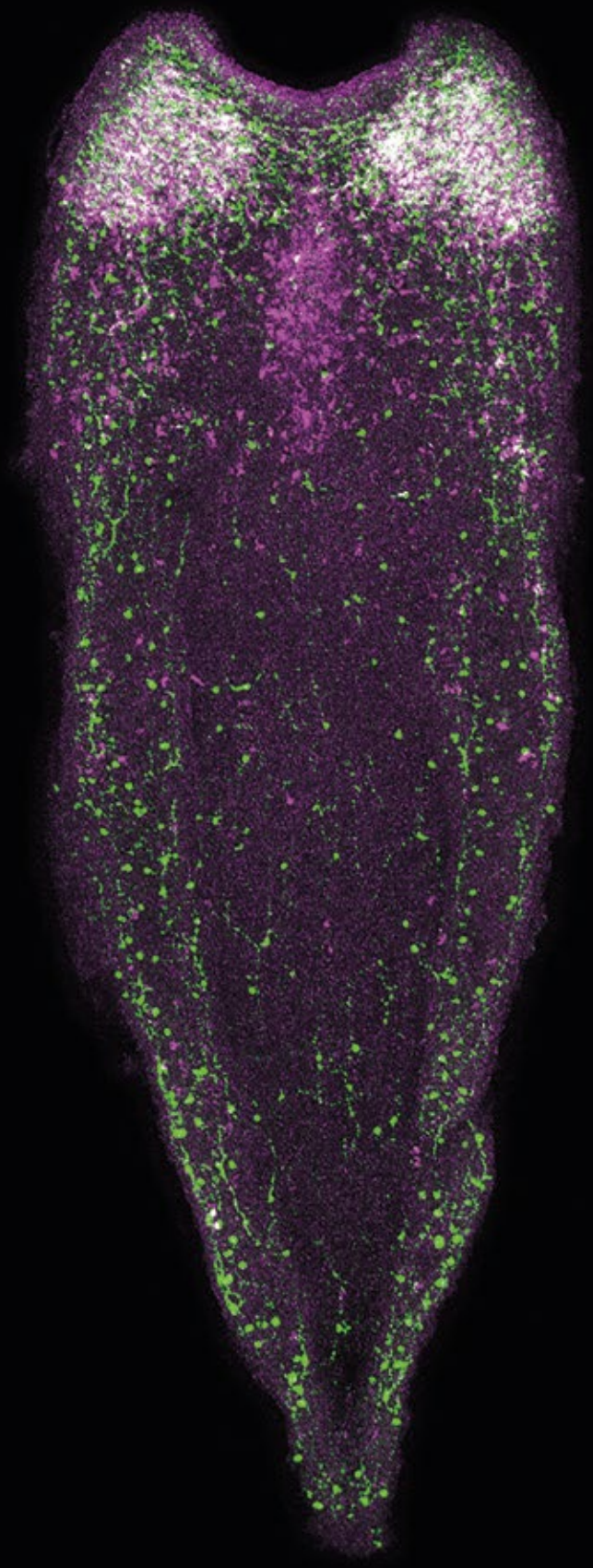
Harvard University

Annual Report
2018 • 2019

About The MCZ

The Museum of Comparative Zoology at Harvard University is a global center for research and education focused on the comparative relationships and evolution of animal life. The MCZ collections comprise approximately 21 million extant and fossil invertebrate and vertebrate specimens, which are a focus of research and teaching for the MCZ, Harvard, and outside students and researchers.

Contents



Director's Message

The past year saw significant accomplishments by the MCZ in our core areas of research, teaching and collections stewardship.

These activities are made all the more urgent by recent authoritative reports that document impending threats to biodiversity worldwide. Perhaps the most chilling is the claim that "around one million species already face extinction, many within decades, unless action is taken to reduce the intensity of drivers of biodiversity loss."[1] MCZ and other natural history institutions can play a unique and essential role in documenting the full extent of life on Earth and in helping to craft strategies to conserve it, and we take this obligation seriously.

MCZ's success is a function of our ability to attract talented and creative people to work and study with us, and we scored big this year on two fronts. First, in January we welcomed Prof. Javier Ortega-Hernández as our new curator of Invertebrate Paleontology, and you can learn more about Javier's background and research plans in the feature story. Second, the inaugural class of **Edward O. Wilson Biodiversity Postdoctoral Fellows** was selected, and they arrived in time for the start of the 2019–2020 academic year. With support from additional donors, we are able to fund four researchers who will discover, formally describe and name new animal species.

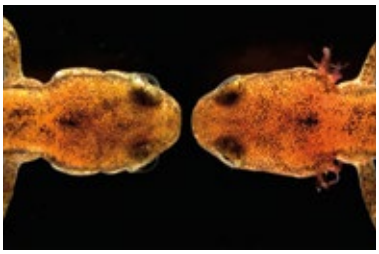
On the curatorial front, we acquired several valuable collections that will enhance our holdings in both vertebrate and invertebrate zoology, and we received another digitization grant from the National Science Foundation that will facilitate free, online access to MCZ specimen data. Looking ahead, negotiations are underway for the acquisition of an important fossil collection as early as next summer.

Following a great multiyear run as executive director of the **Harvard Museums of Science & Culture**, which includes the Harvard Museum of Natural History, Jane Pickering accepted a new appointment at Harvard as director of the Peabody Museum of Archaeology & Ethnology. One of HMSC's many highlights this year is a grant from the Institute of Museum and Library Services to use 3D-scanning technology to develop teaching aids derived from MCZ's specimen collections.

I am saddened to report that a member of the MCZ Faculty passed away this year. George Putnam Jr. was a longtime friend and supporter of the MCZ. In addition to serving on the Museum's governing board, George, together with his wife Nancy, was the founding donor of the Putnam Expeditionary Grants program, which supports field-based research by MCZ graduate students, postdoctoral fellows and faculty-curators. He served with the U.S. Army Air Corps in World War II and was an alumnus of Harvard College and Harvard Business School. George's kindness, wise counsel and advocacy on behalf of the MCZ will be sorely missed.

[1] *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*

James Hanken
Director



About the cover: Two sibling dusky salamanders (*Desmognathus fuscus*) before and after metamorphosis. The molecular basis of cutaneous respiration in these lungless salamanders was the subject of the doctoral dissertation of Zachary Lewis in the Hanken lab. Photo by Zachary Lewis.

Opposite page: Double fluorescent *in situ* hybridization marking mRNA expression of neural transcription factor, *nkx2.4* (magenta) and neural pool (green) within *Hofstenia miamia*. Experiment performed by undergraduate researcher Deirdre Potter of the Srivastava lab.

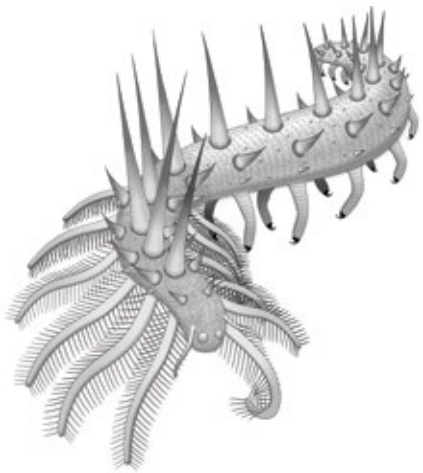
Introducing Our Newest Faculty-Curator

The MCZ is pleased to welcome Dr. Javier Ortega-Hernández as curator of Invertebrate Paleontology and assistant professor in the Department of Organismic and Evolutionary Biology.

Javier Ortega-Hernández

Dr. Ortega-Hernández joined the MCZ in January 2019 after his postdoctoral stint as a Herchel Smith Fellow in Biological Sciences at the University of Cambridge. "Javier brings to Harvard a wealth of expertise regarding a group of animals that are fundamental to our understanding of the evolution of life on Earth," says MCZ Director James Hanken.

As a paleobiologist, Dr. Ortega-Hernández explores the origin and early evolution of invertebrate animals during the "Cambrian Explosion" more than 500 million years ago, when animal fossils first appeared, relatively suddenly, all around the world. He has spent most of his career studying extinct arthropods and their modern descendants, including arachnids, millipedes, centipedes, crustaceans and insects.



Collinsium coliosum reconstruction by Javier Ortega-Hernández based on the fossil at right

"Arthropods and their relatives represent one of the most successful animal groups in the history of life on Earth," says Dr. Ortega-Hernández. As such, arthropods are an excellent group for addressing the origin of animals during the Cambrian Explosion and investigating how evolution has produced one of the most versatile and adaptable body plans known.

"By combining available information on the embryonic development and segmentation of extant species, it has been possible to better understand how the Cambrian organisms—with their often strange body plans—are related to living groups and learn something about their early evolution that would be otherwise impossible to realize if we only study organisms alive today."

Dr. Ortega-Hernández's research utilizes exceptionally preserved fossils that, due to unusual circumstances during the process of fossilization, contain information about the soft tissues such as the legs, eyes and brains. He has helped pioneer the use of X-ray computed tomography to investigate the 3D-preserved morphology in pyritized fossils from the Cambrian in South China, making it possible to study features that are normally concealed within the rock.

The Ortega-Hernández lab will bring together traditional paleontology and fieldwork, developmental biology of extant organisms, state-of-the-art imaging and other analytical techniques to study the evolutionary history

Javier Ortega-Hernández

of arthropods and their close relatives. "We are expanding our access to numerous exceptional fossil discoveries around the world, providing material to better understand the extinct biodiversity of Cambrian and Ordovician ecosystems," he says, "and we are implementing high-end imaging techniques to obtain as much morphological data as possible from the material."

According to Dr. Ortega-Hernández, "The MCZ, brimming with invaluable collections of great scientific significance, has been a powerhouse for invertebrate paleontology. It houses an extremely supportive staff that is as excited about these resources as I am."

Faculty-Curator Profiles

Andrew A. Biewener

Charles P. Lyman Professor of Biology
Director, Concord Field Station

Prof. Biewener's research focuses on understanding the biomechanics, neuromuscular control and energetics of animal movement on land and in the air. His goal is to understand general principles that govern the biomechanical and physiological design of vertebrate animals related to their movement in natural environments.

Tony Rinaldo

Scott V. Edwards

Professor of Biology
Alexander Agassiz Professor of Zoology
Curator of Ornithology

Prof. Edwards' research focuses on the evolutionary biology of birds and related species, combining field, museum and genomics approaches to understand the basis of avian diversity, evolution and behavior. Current projects use genomics technologies to study comparative genomics and the evolution of flightlessness and other traits in birds; phylogeography and speciation in Neotropical and Australasian birds; and the genomics of host–parasite coevolution between house finches and a recently acquired bacterial pathogen, *Mycoplasma*.

Stephanie Mitchell

Brian D. Farrell

Monique & Philip Lehner Professor for the Study of Latin America
Professor of Organismic & Evolutionary Biology
Curator of Entomology
Director, David Rockefeller Center for Latin American Studies
Faculty Dean, Leverett House

Prof. Farrell's research is broadly concerned with the evolution of ecological interactions between host plants and animals and their parasites, such as insects and other tiny consumers.

His current projects include applying next-generation sequencing to speciation and phylogenetic studies of associated species, documenting biodiversity in the Dominican Republic, and repatriating digital information from scientific specimens of insects and fossils in museums to their countries of origin.

Gonzalo Giribet

Alexander Agassiz Professor of Zoology
Professor of Organismic & Evolutionary Biology
Curator of Invertebrate Zoology
Harvard College Professor

© Casey Dunn

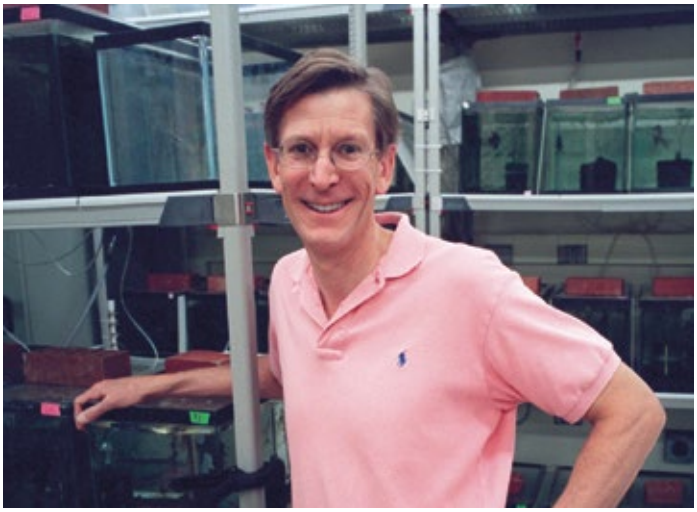
Prof. Giribet's primary research focuses on the evolution, systematics and biogeography of invertebrate animals, including the use of morphology and next-generation sequencing techniques. Current projects in the Giribet lab include a textbook on invertebrates and a comprehensive study of the harvestmen of New Zealand, their systematics and biogeography. The lab also works on other projects on systematics and biogeography of arthropods, mollusks and onychophorans, among other groups. He is also interested in homology-related issues and the use of genomic-level data for inferring phylogenies.

Catherine Weisel

James Hanken

Professor of Biology
Alexander Agassiz Professor of Zoology
Curator of Herpetology
MCZ Director

Prof. Hanken utilizes laboratory-based analyses and field surveys to examine morphological evolution, developmental biology and systematics. Current areas of research include the evolution of craniofacial patterning, the developmental basis of morphological novelty and life-history evolution, biodiversity informatics, and systematics and evolution of neotropical salamanders.



Stephanie Mitchell

George V. Lauder

Professor of Biology
Henry Bryant Bigelow Professor of Ichthyology
Curator of Ichthyology

Prof. Lauder's research focuses on the biomechanics of fishes and the development of robotic models for studying aquatic locomotion.

His current studies focus on the structure and function of shark skin and other fish surface structures and research with various robotic fish models, including a tuna robot. Additional broad interests include biological fluid mechanics and theoretical approaches to the analysis of form and function in organisms.

Kris Snibbe

Hopi E. Hoekstra

Professor of Organismic & Evolutionary Biology
Professor of Molecular & Cellular Biology
Alexander Agassiz Professor of Zoology
Curator of Mammalogy
Howard Hughes Medical Institute Investigator
Harvard College Professor

Prof. Hoekstra combines field and laboratory work to understand the evolution of mammalian diversity. Her research focuses on the genetic basis of morphological and behavioral variation, primarily in rodents, identifying both the evolutionary processes and the molecular mechanisms responsible for traits that help organisms survive and reproduce in the wild. Research in the Hoekstra lab integrates ecological, behavioral, genetic, developmental and neurobiological approaches.

Jon Chase

James J. McCarthy

Professor of Biological Oceanography
Alexander Agassiz Professor of Biological Oceanography
Acting Curator of Malacology

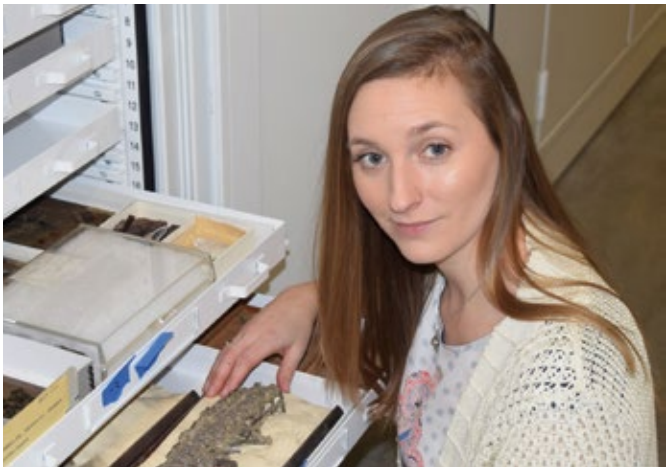
Prof. McCarthy's research focuses on factors that regulate the processes of primary production and nutrient supply in the ocean. Using field studies and modeling, Prof. McCarthy and his group examine the effects of seasonal or interannual climate change on marine life from plankton to whales.

Javier Ortega-Hernández

Assistant Professor of Organismic & Evolutionary Biology

Curator of Invertebrate Paleontology

Prof. Ortega-Hernández's research focuses on the evolution of metazoans that first appeared and rapidly diversified during the Paleozoic Era (ca. 541 to 251 million years ago). His group specializes in the study of exceptionally preserved Cambrian and Ordovician fossil biotas around the world, with a strong interest in the morphology, phylogeny and development of panarthropods and their relatives. The lab combines traditional paleontology with cutting-edge techniques to investigate exceptional fossils, test macroevolutionary hypotheses through deep time, and better understand the origin of the major animal groups that have shaped the biosphere for more than 500 million years.



Paul Whatmough

Stephanie E. Pierce

Thomas D. Cabot Associate Professor of Organismic & Evolutionary Biology

Curator of Vertebrate Paleontology

Prof. Pierce's research is focused on major morphological and ecological transitions in vertebrate evolution through an examination of the fossil record. Her work tends toward 3D modeling and experimentation of the musculoskeletal system, with particular attention to the link between form and function. Current projects include the fin-to-limb transition, the "reptile"-to-mammal transition and the evolution of the horse.

Isabella Kirkland

Naomi E. Pierce

Sidney A. & John Hessel Professor of Biology

Curator of Lepidoptera

Prof. Pierce's research focuses on the behavioral ecology of species interactions, particularly the coevolution between plants, pathogens and herbivores, and symbioses between ants and other organisms. Her laboratory integrates approaches from phylogenetics, ecology, behavior, genomics and comparative methods to investigate patterns of reciprocal adaptation and diversification exhibited by organisms that live in close association with each other.

Mansi Srivastava

Assistant Professor of Organismic & Evolutionary Biology

Curator of Invertebrate Zoology

Isaac Orderberg

Prof. Srivastava's research focuses on understanding the evolution of animal development and regeneration. Her group utilizes the three-banded panther worm, *Hofstenia miamia*, which she has developed as a new acoel model system. Acoels represent the sister-group to all animals with bilateral symmetry, which allows the study of genetic mechanisms that span 550 million years of animal evolution.

Current projects in the lab range from identifying gene regulatory networks for regeneration to determining the embryonic origins of pluripotent stem cells to understanding the origins of bilateral nervous systems.

Emeritus Profiles

Justin Ide

A. W. "Fuzz" Crompton

Faculty-Curator, Emeritus
Fisher Professor of Natural History, Emeritus

Prof. Crompton, former curator of Mammalogy, was the director of the MCZ from 1970 to 1982, having served as director of both the Peabody Museum of Natural History at Yale University and the South African Museum in Cape Town.

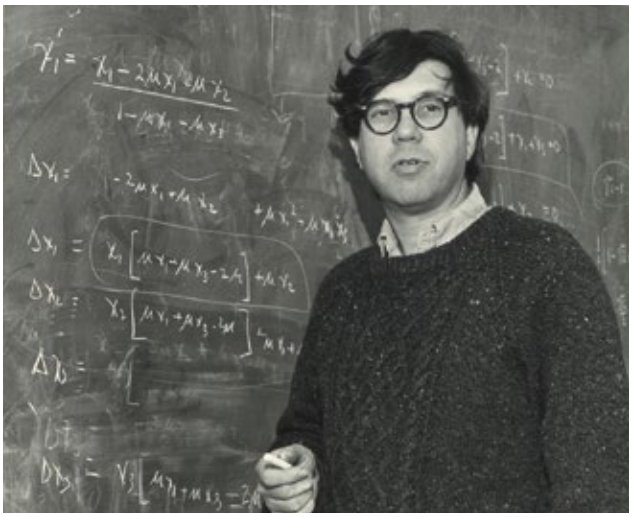
His primary research interests include the origin and evolution of mammals, functional anatomy, and neural control and evolution of feeding in recent and fossil vertebrates. Prof. Crompton received two Guggenheim fellowships for his research on vertebrate paleontology and functional morphology, and in 2011 received the Romer-Simpson Medal from the Society of Vertebrate Paleontology.

Edward O. Wilson

Honorary Curator in Entomology
Pellegrino University Professor, Emeritus

Beth Maynor Finch

Prof. Wilson is considered the founder of sociobiology and has developed the basis of modern biodiversity conservation. He has received many of the world's leading prizes in recognition of his research, creative literature and environmental activism. Prof. Wilson was awarded two Pulitzer Prizes for his books *The Ants* (1990, with Bert Hölldobler) and *On Human Nature* (1978). He received the TED Prize in 2007, where he articulated the concept of the Encyclopedia of Life, and the Hubbard Medal in 2013, the rarely given highest award of the National Geographic Society.



Richard C. Lewontin

Professor of Biology, Emeritus
Alexander Agassiz Professor of Zoology, Emeritus

An evolutionary geneticist, Prof. Lewontin pioneered the field of molecular population genetics by merging molecular biology and evolutionary theory, as well as the philosophical and social implications of genetics and evolutionary theory.

Among his many books are *The Genetic Basis of Evolutionary Change*; *Biology as Ideology: The Doctrine of DNA*; *Human Diversity*; and *The Triple Helix: Gene, Organism and Environment*.

Robert M. Woollacott

Professor of Biology Emeritus

Prof. Woollacott joined the faculty in 1972 and retired in 2018. His teaching and research focus is on the reproduction of marine invertebrates, especially larval biology, as well as human impacts on life in the sea.

Courses Led by Faculty-Curators

Academic Year 2018–2019

Stephanie Pierce

OEB 207: The Fishy Aspects of the Human Body

Organismic and Evolutionary Biology

OEB 11: Introduction to Tropical Biology
Gonzalo Giribet (and David Haig)
Introduction to concepts of tropical biology and tropical biodiversity with a focus on the ecology, physiology and diversity of rainforest and tropical coral reef ecosystems.

OEB 51: Biology and Evolution of Invertebrate Animals
Gonzalo Giribet (and Cassandra Extavour)
Introduction to invertebrate diversity, covering the development, adult anatomy, biology and evolutionary relationships of the main animal phyla, including sponges, mollusks, annelids and arthropods, among others.

OEB 57: Animal Behavior
Naomi E. Pierce (and Bence P. Olveczky)
A review of the behavior of animals under natural conditions, with emphasis on both mechanistic and evolutionary approaches.

OEB 58: How to Build an Animal
Stephanie E. Pierce, Mansi Srivastava
Introduction to animal biology, evolution and development and how these processes combine to shape the diversity of life on Earth.

OEB 115: The Developmental Basis for Evolutionary Change
Mansi Srivastava (and Matthew Harris, Clifford Tabin)
Introduction to evolutionary developmental biology, focusing on the molecular and cellular bases of how embryos generate adult body plans in order to understand how form, physiology and life history strategies are modulated over the course of evolution.

OEB 125: Molecular Ecology and Evolution
Scott V. Edwards
A survey of theory and applications of DNA technologies to the study of evolutionary, ecological and behavioral processes in natural populations.

James Hanken leading tour

Wendy Heywood

OEB 58: How to Build an Animal

OEB 155r: Biology of Insects

Naomi E. Pierce

Introduction to the major groups of insects—life history, morphology, physiology and ecology—through a combination of lecture, lab and field exercises.

OEB 51: Biology and Evolution of Invertebrate Animals

Gonzalo Giribet

OEB 207: The Fishy Aspects of the Human Body

Stephanie E. Pierce

Exploration of how the human body evolved through an analysis of the nonfiction book *Your Inner Fish: A Journey into the 3.5-Billion-Year History of the Human Body* by evolutionary biologist Neil Shubin.

Mind, Brain and Behavior

MBB 980Q: Of Mice and Microbes: How Microbes Shape Animal Behavior

Naomi E. Pierce (and Chris Baker)

Exploration of a variety of animal–microbe symbioses through the lens of animal behavioral ecology.

Freshman Seminar

FRSEMR 21R: The Evolutionary Transition from Dinosaurs to Birds: Fossils, Genomes and Behavior

Scott V. Edwards

Exploration of the dinosaurian origins of modern birds through examination of Harvard's excellent collections of dinosaur fossils, skeletons and specimens of extant birds, and focused readings and discussions.

FRSEMR 50H: The Biology of Movement

Andrew A. Biewener

Explores why and how organisms move, providing an overview of the biological motors animals and microbes use to power movement and the mechanisms plants use for growth and geotaxis and phototaxis, as well as the aesthetics and health benefits of movement.

Life Sciences

LIFESCI 1B: An Integrated Introduction to the Life Sciences: Genetics, Genomics and Evolution
Hopi E. Hoekstra (and Andrew Berry, Pardis Sabeti)

An integrated approach showing how genetics and evolution are intimately related, together explaining the patterns of genetic variation we see in nature, and how genomics can be used to analyze variation.

LIFESCI 2: Evolutionary Human Physiology and Anatomy
Andrew A. Biewener, George V. Lauder (and Daniel E. Lieberman)

Explores human anatomy and physiology from an integrated framework, combining functional, comparative and evolutionary perspectives on how organisms work.

Graduate Courses of Reading and Research

OEB 306: Invertebrate Paleobiology and Evolution
Javier Ortega-Hernández

OEB 307: Biomechanics, Physiology and Musculoskeletal Biology
Andrew A. Biewener

OEB 310: Metazoan Systematics
Gonzalo Giribet

OEB 320: Biomechanics and Evolution of Vertebrates
George V. Lauder

OEB 321: Evolution of Regeneration and Development
Mansi Srivastava

OEB 323: Advanced Vertebrate Anatomy
Stephanie E. Pierce

OEB 334: Behavioral Ecology
Naomi E. Pierce

OEB 341: Coevolution
Brian D. Farrell

OEB 345/E-PSCI 337: Biological Oceanography
James J. McCarthy

OEB 355: Evolutionary Developmental Biology
James Hanken

OEB 362: Research in Molecular Evolution
Scott V. Edwards

OEB 370: Mammalian Evolutionary Genetics
Hopi E. Hoekstra

Bruno de Medeiros

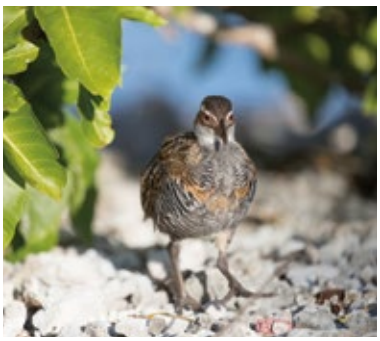
OEB 155r: Biology of Insects

OEB 155r: Biology of Insects

Bruno de Medeiros

Introduction to Tropical Biology in Australia

OEB11: Introduction to Tropical Biology exposes students to concepts of tropical biology and biodiversity. A pre-semester three-week field trip for the course took place in January 2019 in Australia. Students did fieldwork in the rainforest and tropical coral reefs and focused on the ecology, physiology and diversity of these ecosystems. Experts on tropical ecology, including rainforests and marine environments, and taxonomic experts were involved. Taught by **Gonzalo Giribet**, professor of Organismic and Evolutionary Biology and curator of Invertebrate Zoology, and David Haig, George Putnam Professor of Biology in Organismic and Evolutionary Biology at Harvard, along with faculty of the University of Sydney, the ten Harvard students on the trip partnered with ten students from the University of Sydney. The students experienced the local biodiversity and the research related to aspects of diversity, ecology and evolution, while interacting with their Australian counterparts and learning about the local culture. This was the first time the field course was offered and it was a great success.



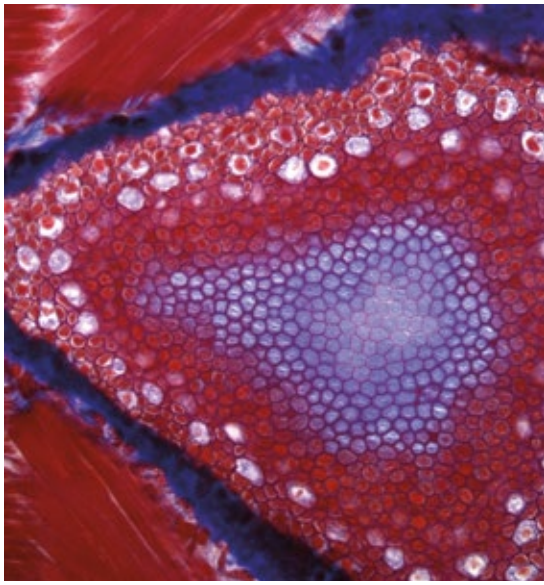
Gonzalo Giribet (4)

Research Making Headlines

Just Breathe

With 478 species, plethodontid salamanders are the largest group of salamanders in the world. They can also survive on land without lungs. Loss of lungs is a major evolutionary change that might be expected to limit body size and thermal tolerance, and therefore location, of a species. However, these lungless salamanders are up to 27 centimeters long and thrive in a variety of environments throughout the Western Hemisphere, South Korea and Italy, so they must have adapted successfully to obtain adequate oxygen.

For decades, scientists have assumed that lungless salamanders "breathe" through their skin and the lining of their mouth, but have not explored exactly how the process works. **James Hanken**, **Zachary Lewis** and **Jorge Dorantes** examined the lungless dusky salamander (*Desmognathus fuscus*) and found that while it has the genes to form lungs—which develop initially but then stop—it instead forms enriched blood vessels to the skin and mouth rather than lungs. They also discovered that a gene which produces a key protein for lung function, surfactant protein C, is expressed in their skin and mouths, possibly helping facilitate absorption of oxygen, and that the dusky salamander has two copies of this gene. Gene duplication is important in evolution because the first gene can continue functioning normally while the second is deployed in some other way to enable the evolution of novel traits. In this case, the second copy turns on in the skin in larvae, but once the salamander comes on land and the skin begins to harden, this expression moves to the mouth. The research was published in *Proceedings of the Royal Society B.*



Zachary Lewis

Lewis ZR, Dorantes JA, Hanken J (2018) Expression of a novel surfactant protein gene is associated with sites of extrapulmonary respiration in a lungless salamander. *Proc R Soc B* 285:20181589

Solving the Segmented Spine

Much of the agility of mammals—climbing, running, flying and digging—is made possible by highly specialized regions of their backbones. To examine how the mammal spine and its distinctive regions evolved, a team led by **Stephanie E. Pierce** and postdoctoral researcher and lead author **Katrina Jones** looked to the fossil record of mammalian ancestors, the nonmammalian synapsids, which diverged from reptiles like lizards and dinosaurs more than 320 million years ago. However, finding extinct animals with all 25-plus vertebrae in place is extremely rare, so the researchers searched museum collections from around the world to CT-scan and measure dozens of fossil spines and more than 1,000 vertebrae from living mammals, reptiles and amphibians. The analysis of the spinal regions showed that, contrary to common assumptions based on living animals, the mammalian spine gained new regions during its deep-time evolution. Around 250 million years ago a new region evolved near the shoulders as the forelimbs lengthened and moved under the body, changing how these animals walked and ran. Later, another region developed near the pelvis forming the ribless lumbar region, an area that is very important for locomotion and adapting to new environments. Formation of the lumbar region is also linked to changes in *Hox* gene expression, the genetic scheme for determining the layout of the spine in early development. Together, these evolutionary changes laid the foundation for a highly adaptable mammalian body plan, enabling mammals to diversify into the myriad forms we see today.

Katrina E. Jones

Jones KE, Angielczyk KD, Polly PD, Head JJ, Fernandez V, Lungmus JK, Tulga S, Pierce SE (2018) Fossils reveal the complex evolutionary history of the mammalian regionalized spine. *Science* 361:1249-1252

A Mouse of a Different Color

In the faraway Sand Hills of Nebraska, steel enclosures and a population of deer mice (*Peromyscus maniculatus*) have been instrumental in an unprecedented, multiyear experiment conducted in the laboratory of **Hopi E. Hoekstra**. Fieldwork led by former postdoctoral researcher **Rowan Barrett** combined with lab experiments led by former postdoctoral researcher **Ricardo Mallarino**, among others, illuminated the full process of evolution by natural selection.

Rowan Barrett (2)

The Sand Hills region contains areas of distinctively dark and light soils, with deer mice of corresponding dark and light fur. It was long hypothesized that the light mice would be better camouflaged from predators on light soil, and dark ones better on dark soil. To test this, researchers built 80-foot-square steel enclosures on both types of soil and placed approximately 100 deer mice with different coat colors into each of six pens open to avian predators. After only three months they already found that coat color strongly predicted the likelihood of survival, with higher survival of mice that matched the soil color, clearly demonstrating how physical attributes can interact with environmental conditions to affect fitness. But that was just the beginning.

In the lab, researchers examined the gene *Agouti* that controls the production of yellow pigment. The darker mice had a functioning copy of the gene, producing dark coats, but the lighter mice were discovered to have a single three-DNA base-pair mutation in the Agouti protein, which affected the protein's binding leading to lighter pigmentation. For the first time in a single study, researchers were able to demonstrate how physical traits impact survival in the wild, determine the gene and mutation that contribute to these physical traits, and establish how that mutation operates.

Barrett RDH, Laurent S, Mallarino R, Pfeifer SP, Xu CCY, Foll M, Wakamatsu K, Duke-Cohan JS, Jensen JD, Hoekstra HE (2019) Linking a mutation to survival in wild mice. *Science* 363:499-504

Flight Delays

Kris Snibbe, Harvard University

It is understandable that early evolutionary biologists assumed that flightless birds descended from a common ancestor. After all, they have similar body types, with small to no forelimbs or wings, an absence of a "keel" in the breastbone for wing muscle attachments, and larger hind limbs. However, recent genomics analysis has shown that since there was no recent common ancestor, flightlessness evolved independently in multiple lineages. But how?

Led by **Scott V. Edwards** and Timothy Sackton, director of informatics for FAS Research Computing, the multi-disciplinary team of ornithologists, developmental biologists, morphologists, statisticians and population geneticists included Harvard members **Phil Grayson**, **Alison Cloutier**, Zhirui Hu, Jun S. Liu, and Michele Clamp, among others. The team assembled and annotated 11 new genomes, including 8 flightless birds like the emu, kiwi and extinct moa, and 3 tinamous, which can fly. These genomes were then analyzed together with the published genomes of 33 bird species, both flightless and flying. The team found that even though the species show wide functional divergences in the protein-coding portions of their genomes, they have very similar regions that regulate these proteins. These shared developmental pathways are employed to alter limb development, stunting or stopping development of the forelimb/wing. Because of their key role in the body- and limb-scaling changes that accompany loss of flight, the study suggests that these developmental pathways have been employed multiple times across the various flightless lineages.

Sackton TB, Grayson P, Cloutier A, Hu Z, Liu JS, Wheeler NE, Gardner PP, Clarke JA, Baker AJ, Clamp M, Edwards SV (2019) Convergent regulatory evolution and loss of flight in paleognathous birds. *Science* 364:74-7

Protecting Pollinators

Bees and insects everywhere are in decline. They help maintain biodiversity and ecosystem function and are critical for the pollination of about a third of the world's agricultural crops. New research has shown that neonicotinoids, the most commonly used class of pesticide around the globe, have profound impacts on a variety of social behaviors to the detriment of the colony's vitality, even in nonlethal doses.

While earlier research showed pesticide exposure decreased foraging activities, new techniques were required to look inside the nest. To observe the bees' interior world, a team of Harvard researchers, including lead author postdoctoral fellow **James Crall**, **Naomi Pierce,** Stacey Combes and Benjamin de Bivort developed a robotic platform to study colonies under field conditions. By placing a QR code on each bumblebee (*Bombus impatiens*), the behavior of individuals in multiple colonies could be monitored with a mobile camera array and computer vision.

Colonies were then exposed to ecologically relevant levels of imidacloprid, a neonicotinoid pesticide. The researchers found exposure impaired queen and worker behaviors within the nest, with even more marked effects at night. The bees were not as efficient at regulating nest temperature and were less likely to build an insulating wax canopy around the brood, an important adaptation to cold.

These results, published in *Science*, illustrate the potential for this high throughput monitoring system to analyze effects of agrochemicals for sublethal impacts on pollinators.

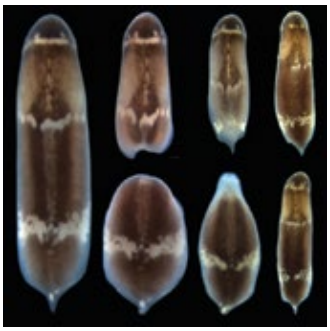
James D. Crall

Crall JD, Switzer CM, Oppenheimer RL, Ford-Versypt A, Dey B, Brown A, Eyster M, Guérin C, Pierce NE, Combes SA, de Bivort BL (2018) Chronic neonicotinoid exposure disrupts bumblebee nest behavior, social networks, and thermoregulation. *Science* 362:683-386

A Model Worm

Like salamanders, some animals are capable of regrowing a missing limb. Others, such as jellyfish, can regenerate their bodies after being cut in half. To study the genetics of regeneration, **Mansi Srivastava** developed the three-banded panther worm (*Hofstenia miamia*) as a model organism for its ability to regenerate its entire body and its phylogenic position as the likely sister group to all other organisms with symmetrical body plans, or bilaterians. Then she developed molecular techniques to study how the worm is able to regenerate.

A team led by Prof. Srivastava is using the three-banded panther worm to uncover the regulatory logic that orchestrates regeneration. Prof. Srivastava and **Andrew Gehrke**, a postdoctoral fellow in the Srivastava lab, and others began by sequencing the genome of *Hofstenia miamia*, the first from this phylum. They used the genome to map functional binding sites and construct a gene regulatory network initiating whole-body regeneration. In the process, they uncovered a regulatory mechanism—the protein encoded by the gene early growth response, or EGR, gets activated right after amputation and binds to noncoding DNA near other regeneration genes to activate them, acting like a master switch. EGR and its target genes together represent a network or circuit of regulatory interactions that launches the process of regeneration in *Hofstenia*.



Mansi Srivastava (2)

EGR and other genes found in the regeneration circuit of three-banded panther worms are also present in other species. The researchers want to determine what the connections are and how they are wired in other animals, including humans and vertebrates that only do limited regeneration.

Gehrke AR, Neverett E, Luo Y-J, Brandt A, Ricci L, Hulett RE, Gompers A, Ruby JG, Rokhsar DS, Reddien PW, Srivastava M (2019) Acoel genome reveals the regulatory landscape of whole-body regeneration. *Science* 363:eaau6173

Highlights from the Collections

Ornithological Expedition to Mongolia

With support from a **Putnam Expeditionary Grant**, members of the Edwards lab and the MCZ Ornithology Department collected specimens in southern Mongolia from June 23 to July 27, 2018. The first goal was to collect high-quality tissues from common species distributed along a north-south gradient of aridity and temperature for eventual gene expression studies. The second goal was to increase the global genomic resources for Mongolian birds through general collecting. MCZ participants included **Scott V. Edwards**, curator of Ornithology, **Jeremiah Trimble**, curatorial associate in Ornithology, and graduate student **Jonathan Schmitt**. The expedition was led by Sundev Gombobaatar, professor of biology at the National University of Mongolia.

"Expedition highlights came not through acquisition of impressively plumaged birds, although that occasionally happened, but through collecting in series, which means obtaining a number of members of single species that can document geographic variation," says Prof. Edwards. Specimens collected in series included willow tits (*Parus montanus*), great tits (*Parus major*), wrynecks (*Jynx torquatus*)—the most basal lineage of woodpeckers—Daurian redstarts (*Phoenicurus auroreus*), black redstarts (*Phoenicurus ochruros*), lesser whitethroats (*Sylvia curruca*), Godlewski's buntings (*Emberiza godlewskii*) and common rosefinches (*Carpodacus erythrinus*). Several birds were new to the MCZ Ornithology collection, either as species or tissues. Two Saxaul sparrows (*Passer ammodendri*) collected are among only around 100 specimens of this species worldwide and the best represented in terms of high-quality tissues.

"An expedition innovation was the pre-labeling of cryotubes in the MCZ," says Trimble, "which expedited the accession of the Mongolia specimens into the Ornithology collection and made them quickly available on MCZbase." Another innovation was the rapid freezing and high diversity of most of the tissues, since multifaceted tissue preservation is still unique for ornithology.

Scott Edwards (4)

New Histological Collections at MCZ

Andrew Williston

Northcutt Collection
The R. Glenn Northcutt Collection of Comparative Vertebrate Neuroanatomy and Embryology consists of an estimated 40,000 histology slides showing the minute structure of animal tissues discernible by microscope.

The collection was amassed over Dr. Northcutt's career from 1963 to 2014 and generously gifted to the MCZ by him and his friend and colleague, Cornell University professor Dr. William E. Bemis.

Almost 250 unique genera from all living vertebrate groups are represented, including species that are rarely found as histological preparations in museum collections, such as the South American hoatzin, or stinkbird. Most specimens are serially sectioned whole or partial brains. Entire heads and hundreds of serially sectioned embryos are also included. The collection, with incredibly fine histological preparation, is well suited for slide digitization and has provided anatomical voucher material for more than 240 publications in neuroanatomy and development.

Since the collection represents taxa from multiple curatorial departments, it is being cataloged in MCZ's Special Collections. According to **Linda S. Ford**, director of collections operations, "The collection has remarkable representation among the vertebrates and is a wonderful complement to the Minot Harvard Embryological Collection, which is also cataloged and housed in Special Collections."

Wilder Collection
The Wilder Collection was built by anatomist and zoologist Harris Hawthorne Wilder (1864–1928). "The collection contains around 2,600 slides of various vertebrate skulls and developmental series, and numerous salamander histological sections," says **José Rosado**, curatorial associate in Herpetology.

A member of the Smith College faculty, Wilder lived with his wife in Northampton in a house situated on the campus. When she passed, the contents were stored away and the house used for offices. At some later time, the contents were reviewed by Smith College, which gave the slides to Dr. Stephen Tilley, a herpetologist in the Department of Biology. He, in turn, donated the collection to the MCZ.

Melissa Aja

Caribbean Millipedes

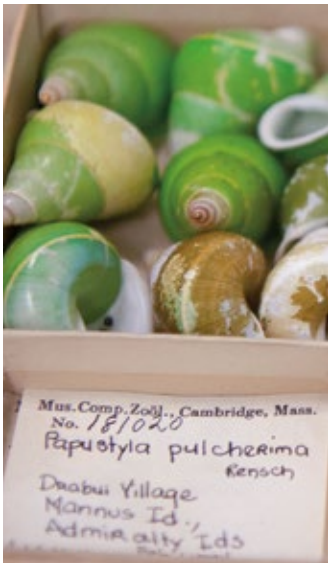
The Department of Invertebrate Zoology recently acquired a large and valuable collection of Caribbean millipedes from well-known Cuban zoologist Antonio Pérez-Asso. The Pérez-Asso Collection was amassed during a lifetime of dedication to myriapodology and includes his major taxonomic interest, juliform millipedes of Hispaniola.

Gonzalo Giribet (2)

"Juliform millipedes are often poorly preserved in collections due to their tendency to curl during initial fixation, and many specimens are fragile and can break when in contact with other specimens or container walls," says **Gonzalo Giribet**, curator of Invertebrate Zoology. To prevent this damage, Pérez-Asso carefully placed each specimen in a straight plastic tube—often a piece of straw—and stored them in these tubes in jars, so all specimens are beautifully preserved.

The collection includes about 5,650 specimens collected between 1993 and 2008 in the Dominican Republic and Haiti; 24 are holotypes—specimens used to formally describe a species—and 595 are paratypes, additional specimens of a type series. This extensive collection also comprises numerous topotypes—specimens collected at the same location as the original holotype—of most of the species from the Dominican Republic, plus a few from Haiti, that were described by Loomis and Chamberlin between the 1910s and 1940s.

Malacology Receives NSF Digitization Grant



Melissa Aja (2)

Land snails are a major component of terrestrial ecosystems. There are more than 25,000 species of land snails worldwide with more than 6,000 species occurring on the Pacific Islands. Unfortunately, Pacific Island land snails account for 40% of all documented recent animal extinctions (IUCN 2016).

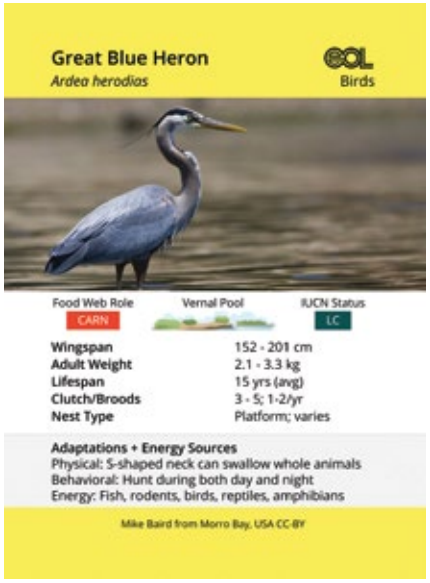
MCZ is a member of a consortium of five of the largest natural history collections in the U.S. that has been awarded a National Science Foundation grant to establish the Pacific Island Land Snail Biodiversity Repository (PILSBRY). "When complete, this resource will document the biodiversity of land snails that occur now, or once lived, on many of the Pacific Islands," says Principal Investigator **James J. McCarthy**, acting curator of Malacology. "It will allow researchers to assess species distributions, population variation, morphological variation, species invasions, and other ecological and evolutionary relevant questions."

"From various Pacific Islands, MCZ has over 11,407 lots—around 104,000 specimens—representing 2,840 different species of land snails, and more than half of them are from Hawaii," says **Adam J. Baldinger**, curatorial associate in Malacology. MCZ's primary role will be to ensure the accuracy of these records and enrich them with habitat data, collectors' observational notes, genetic data and georeferences. MCZ staff will digitally capture data for uncatalogued specimens as well as create digital images of all primary types—516 specimens in all—from the Pacific Islands.

Projects & Initiatives

Encyclopedia of Life Learning + Education Group

The Encyclopedia of Life (eol.org) is an open-science project that aggregates biodiversity content and data from partners such as MCZbase, the Smithsonian Institution, the Global Biodiversity Information Facility and iNaturalist. EOL is also used in formal and informal education settings and for citizen-science activities. All resources, data, tools and applications are freely available.



Due to EOL's shift to ecological modelers and scientists as its primary audiences, the EOL Learning + Education Group, hosted at the MCZ, disbanded in June 2019.

Educational Resources

The EOL Learning + Education website (education.eol.org) continues to offer podcasts, lesson plans and biodiversity cards, all aligned with the U.S. Next Generation Science Standards. The EOL Biodiversity Card Maker allows anyone to access, download and make biodiversity cards for classroom learning and to support biodiversity-related citizen science projects.

City Nature Challenge

In 2019, the City Nature Challenge took place April 26 to April 30 in 159 cities and 29 countries, engaging 35,126 observers and logging 963,773 observations. All 351,671 research-grade images flowed from the iNaturalist biodiversity observation platform to EOL, including observations of 1,100 rare, endangered and threatened species globally. EOL led the effort to create the CNC Education Toolkit and helped organize the Boston event.

Teaching with Specimens and Digital Images

Through a 2018 grant from the Institute of Museum and Library Services, the Harvard Museums of Science & Culture will improve the ability of middle school teachers to teach with museum collections-based digital resources. With teachers as advisors, the museum will create four classroom activities and associated teacher professional development programs. The project, which will run through 2021, will provide schools with classroom-ready resources that support student learning.

Melissa Aja

The activity *The Natural History of Frogs* uses 3D-printed frogs created from the MCZ Herpetology collection. The museum worked with graduate student **Mara Laslo** in the Hanken lab to identify a dozen frog species that show a variety of strategies for survival, and students will use these lifelike replicas to observe physical traits that allow survival in a particular habitat.

For *Is it a snake? Not all legless reptiles are snakes!*, students will investigate morphological traits of limbless specimens through digital images from the Herpetology collection to determine which ones are snakes and which ones are not, and to explore convergent evolution that led many disparate lineages to adopt similar morphologies.

Teeth, Toes and Temperature: Climate Change and Horse Evolution utilizes 3D-printed fossil horse teeth to illustrate the changing food source, and hence changing environments, of horse ancestors during the Cenozoic. Graduate student **Brianna McHorse** of Stephanie Pierce's lab and **Jessica Cundiff**, curatorial associate in Vertebrate Paleontology, assisted in selecting fossil horse teeth.

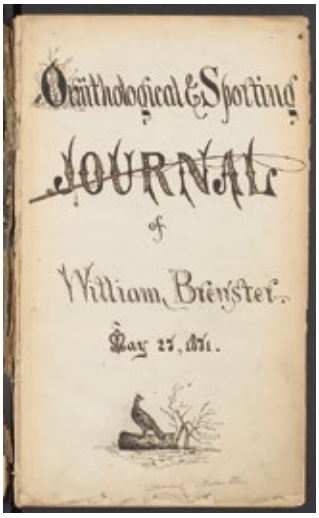
Ernst Mayr Library

Biodiversity Heritage Library

EML staff has enriched BHL's online content while focusing on MCZ's unique collections, such as adding digital versions of more than 500 books held by MCZ in just the last year. EML content in BHL is viewed by an average of 7,191 users per month, with 22,296 total views per month.

William Brewster Collections Digitized

This year volunteers transcribed more than 900 pages of William Brewster's journals and diaries. To date, 41 volumes have been transcribed and validated for a total of 8,009 pages. Since the November 2018 soft launch of BHL's transcription functionality, EML has added eight transcribed volumes—1,547 pages—of his journal entries, which are full-text searchable in BHL.



MCZ, Ernst Mayr Library (2)

Jacques Burkhardt Fish Illustrations Published

The 2019 book *Brazilian Fishes: Watercolors by Jacques Burkhardt (1865–1866)* features nearly 1,000 paintings made during the Louis Agassiz–led *Thayer Expedition to Brazil*. A grant in 2000 enabled digitization of these paintings and associated *Thayer Expedition* materials. The Jacques Burkhardt Scientific Drawings collection is available on Harvard Library's CURIOSity Spotlight digital collections platform.

Digitizing MCZ Collection Documents

More than 1,000 pages of field notes, ledgers and ancillary materials from several MCZ departments have been scanned, including 196 sponge photographs and cards from Invertebrate Zoology, 314 ledger sheets from Malacology (*Thaanum Catalogue of Hawaiian Land Shells*) and 515 data cards from Mammalogy (*Asiatic Primate Expedition 1937*). They are archived in the Harvard Digital Repository Service and will be linked to MCZbase specimen records.

MCZ History

Swiss-born Jacques Burkhardt was among the finest natural history illustrators of the 19th century, and for most of his life he worked for the MCZ's founding director, Louis Agassiz. His greatest artistic legacy may be a collection of more than 400 watercolor and pencil drawings of Amazonian fishes from the *Thayer Expedition to Brazil*, 1865–1866. Each haul of the ship's nets would deposit piles of fishes on deck, with Agassiz quickly identifying new species while Burkhardt furiously sketched outlines of select specimens and made color notes to complete the drawings later.

Watercolor featured in *Brazilian Fishes: Watercolors by Jacques Burkhardt (1865–1866)* by Heraldo Britski and José Lima de Figueirado (2019)

Widespread appreciation of Burkhardt's watercolors has come only recently. In 2004, the Ernst Mayr Library began offering digital scans of the drawings, which have been viewed thousands of times, and in 2019 many were reproduced in a lavish volume by Heraldo Britski and José Lima de Figueirado of the University of São Paulo Museum of Zoology. But not everyone recognized their value. In 1940, MCZ Director Thomas Barbour shipped the drawings to Stanford, telling ichthyologist George Myers: "They are a gift, pure and simple, and I hope that you may . . . perhaps find some use for them. If not, I suppose even in California you occasionally have a fire in the grate." Thankfully, Myers didn't take Barbour's advice, and the paintings were eventually returned to the MCZ.

Harvard Museums of Science & Culture

In July 2019, Jane Pickering became the director of Harvard's Peabody Museum of Archaeology & Ethnology. Pickering will oversee the curation, care and conservation, and programming of one of the oldest and largest collections of cultural objects in the Western Hemisphere. Founded in 1866, the Peabody Museum houses more than 1.2 million objects.

Pickering had been executive director of the Harvard Museums of Science & Culture since 2013, directing public programming for a consortium of six partner museums: the Museum of Comparative Zoology, the Harvard University Herbaria, and the Mineralogical & Geological Museum, which contribute to the Harvard Museum of Natural History; the Semitic Museum; the Peabody Museum of Archaeology & Ethnology; and the Collection of Historical Scientific Instruments.

During the consortium's first five years, museum attendance increased by 34 percent to almost 300,000 annual visitors. Pickering worked to expand the reach of HSMC programming in collaboration with other Harvard communities, and in 2017, more than 150 Harvard faculty members participated in HMSC curation, presentations and program advising.

Stephanie Mitchell, Harvard University

Jane Pickering

HMSC Highlights

During the academic year, HMSC opened several new exhibitions. The multimedia *Climate Change* at the Harvard Museum of Natural History is a complete gallery renovation that features Harvard research about the warming climate, its global and local consequences, and how to reduce fossil fuel emissions and prepare for its effects. *The Rockefeller Beetles*, an exhibition of hundreds of specimens from David Rockefeller's recently donated collection, debuted in October. Two new photographic exhibitions were shown at the Peabody Museum—*Caspian: Chloe Dewe Mathews* and *Kalahari Perspectives: Anthropology, Photography and the Marshall Family.*

In celebration of the 10th anniversary of the *Evolution Matters* lecture series, a special event was held with authors David Quammen and Carl Zimmer. Later in the semester, *Frontiers in Evolution* featured lightning talks by four Harvard graduate students, an experimental format that was very successful.

More than 6,000 people enjoyed HMSC's evening programs, with the live streams watched by viewers around the world. Special evening programs were hosted for Harvard students at both ends of their college experience. A new program at the Peabody, *Native American Poetry Playlist: Poems in the Gallery*, enabled visitors to listen to contemporary poems by Native American authors while exploring the first-floor galleries.

Awards & Recognition

George V. Lauder

Faculty-Curators

Scott V. Edwards was awarded the 2019 Molecular Ecology Prize. Along with several other colleagues, he was awarded a National Science Foundation grant in *Dimensions of Biodiversity*, a new program that supports projects that yield a better understanding of Earth's biodiversity.

Gonzalo Giribet

Two new species of invertebrates were named after **Gonzalo Giribet**: the sponge *Leucetta giribeti* and the annelid worm *Pterocirrus giribeti*.

George V. Lauder received the Joseph S. Nelson Lifetime Achievement Award in Ichthyology from the American Society of Ichthyologists and Herpetologists.

Javier Ortega-Hernández was granted the distinction of National Researcher Level 1 by the National System of Researchers of the Government of Mexico.

Mansi Srivastava received a National Institutes of Health Maximizing Investigators' Research Award for Early Stage Investigators for the project *Using a new regenerative model system to elucidate mechanisms for stem cell regulation.*

Staff

Jason Fleming, senior research administrator, and **Nikki Hughes**, faculty assistant, each received a Dean's Distinction Award from the Faculty of Arts and Sciences.

Karsten E. Hartel, former curatorial associate of Ichthyology, was honored by the American Society of Ichthyologists and Herpetologists with the Spiritus Award for his excellence in service and support of natural history collections.

Breda Zimkus, cryogenics collections manager for genetic resources, received a Certificate of Teaching Excellence for Lecturers from the Derek Bok Center.

Breda Zimkus

Postdoctoral Researchers

Ligia Benavides Silva received a Certificate of Distinction in Teaching from the Derek Bok Center.

Valentina Di Santo received the She Made a Difference award from the European Women's Management Development International Network.

Graduate Students

Caitlin Baker received first place for best student talk in Evolution, Systematics and Biogeography at the 21st International Congress of Arachnology.

Nicole Bedford, **Blake Dickson**, **Nathan Edelman**, **Kadeem Gilbert**, **Philip Grayson**, **Alyssa Hernandez**, **Nicholas Herrmann**, **Ryan Hulett**, **Sang Il Kim**, **Julian Kimura**, **Vanessa Knutson**, **Mara Laslo**, **Inbar Maayan**, **Dave Matthews**, **Sofia Prado-Irwin**, **Jonathan Schmitt**, **Kari Taylor-Burt**, **Kira Treibergs**, **Brock Wooldridge** and **Zane Wolf** each received a Certificate of Distinction in Teaching from the Derek Bok Center.

Jasmin Camacho was awarded an American Association of University Women 2018 American Fellowship for her project *Developmental, cellular and genetic mechanisms underlying striking cranio-facial variation in New World leaf-nosed bats.*

Anole by Sofia Prado-Irwin

Kadeem Gilbert was awarded a National Institute of Food and Agriculture Postdoctoral Fellowship from the United States Department of Agriculture.

Phil Grayson won Best Student Talk in the Division of Evolutionary Developmental Biology at the Society for Integrative and Comparative Biology annual meeting.

Richard Knecht was awarded a National Science Foundation Graduate Research Fellowship and a Crustacean Society Fellowship in Graduate Studies.

Jeremiah Trimble

Scott V. Edwards

Olivia Meyerson received the Lewontin Research Award from the Society for the Study of Evolution and a National Science Foundation Graduate Research Fellowship.

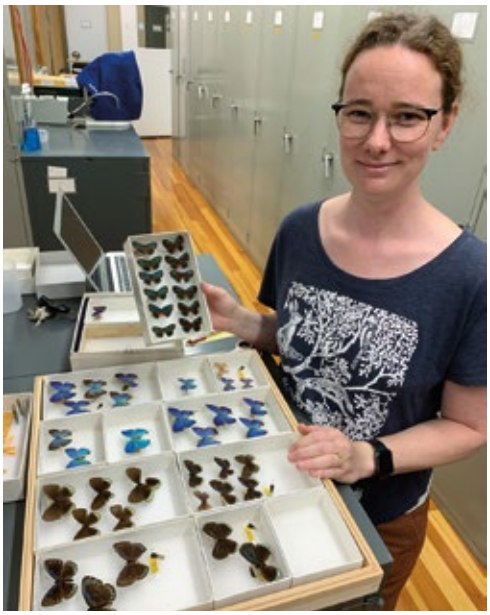
Sofia Prado-Irwin was awarded a Society of Systematic Biologists Graduate Student Research Award.

Shayla Salzman and **Dylan Wainwright** were each awarded a National Science Foundation Postdoctoral Research Fellowship in Biology.

Undergraduate Students

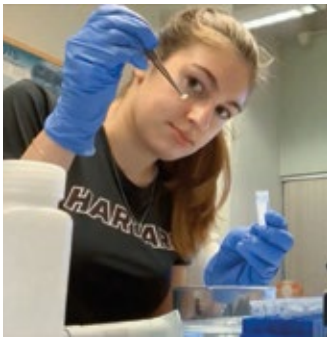
Sophie Westbrook received the Freund Prize for the highest academic standing in Harvard College.

Brendan Dean Zhi Min received a Hoopes Prize for his thesis project *Burning questions: Responses to fire by partners in a complex ant–plant symbiosis.*

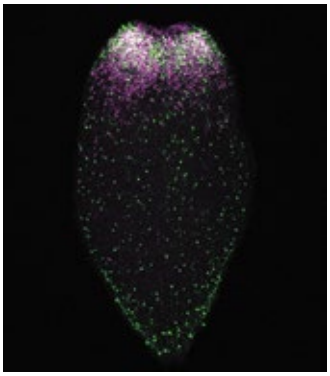


Shayla Salzman

Sonja Eliason



Elena Moncada



Deirdre Potter

Julissa Melissa Churata Salcedo

Grant Recipients

Tauana Cunha

Grants-in-Aid of Undergraduate Research

These grants support research by Harvard College undergraduates under faculty supervision. Priority is given to projects that utilize MCZ, Harvard University Herbaria (HUH) and Arnold Arboretum (AA) research collections, laboratories and facilities. Support for these grants comes from the MCZ's Myvanwy M. and George M. Dick Scholarship for Students, HUH and AA.

Recipient	Academic Dept./ Faculty Sponsor	Project Title	Amount
Chloé-Rose Colombero	OEB/George Lauder	Dermal denticle replacement in sharks: A comparative analysis across species	$5,000
Emmanuel D'Agostino	OEB/James Hanken	Estimating behavioral, morphological and genomic divergence in precopulatory isolation of *Anolis sagrei*	$500
Camille DeSisto	HUH/Charles Davis	The spread and consequences of the invasive strawberry guava in Madagascar	$4,797
Elizabeth D'haiti	OEB/Mansi Srivastava	Determining the timeline of development of adult pluripotent stem cells in *Hofstenia miamia*	$4,000
Sonja K. Eliason	HEB/Bridget Alex	Investigating the genetic coevolution of humans and *Yersinia pestis*	$500
Skye Fenton	OEB/Paul Moorcroft	Senior thesis research: Mechanistic modeling of reintroduced roe deer movement and resource use	$4,000
Laura Jenny	OEB/Naomi Pierce	Analyzing changes to the microbiota of cucurbit plants during infection with *Erwinia tracheiphila*	$2,311
Anne Kennedy-Yoon	OEB/Naomi Pierce	The effect of ant species on tree growth and morphology in African whistling thorn acacias	$2,750
Eli Martin	OEB/Gonzalo Giribet	Investigation of pteropod diversity and distribution in Panama using numerical and genetic methods	$3,100
Elena Moncada	OEB/Gonzalo Giribet	Phylogenetic analysis of the family Donacidae (coquina or bean clams)	$1,750
Deirdre Potter	OEB/Mansi Srivastava	Neural regeneration in *Hofstenia miamia*: Investigating expression of genes in adult neurogenesis	$4,000
Jaelithe Virgin-Downey	Kennedy School of Government/Sheila Jasanoff	The science and politics of Florida's red tide (harmful algal blooms)	$2,600
Brendan Dean Zhi Min	OEB/Naomi Pierce	A song of time and fire: Symbiosis maintenance in a complex Kenyan ant–acacia system	$2,500
Brendan Dean Zhi Min	OEB/Naomi Pierce	Burning questions: Responses to fire by partners in a complex ant–plant symbiosis	$3,740
		Total Awards	**$41,548**

Putnam Expedition Grants

Putnam Expedition Grants are intended to support MCZ faculty-curators, postdoctoral fellows and graduate students in collecting specimens and data relating to the study of comparative zoology. Priority is given to projects that collect living specimens in regions where habitats are threatened or fossil specimens in regions most likely to hold important clues for unraveling evolutionary strategies. These grants are made possible by a gift from Mr. George Putnam Jr., AB 1949 and MBA 1951, and Mrs. Nancy Putnam.

Recipient	MCZ Department/ Faculty Sponsor	Project Title	Amount
Richard Childers	Entomology/Naomi Pierce	Ants and associated myrmecophiles of East African acacias	$8,699
Shahan Derkarabetian	Invertebrate Zoology/ Gonzalo Giribet	Genomics of phenotypic convergence: Evolution of limb loss in squamates	$7,030
Scott Edwards	Ornithology	Chromosomal evolution in Australian honeyeaters (Aves: Meliphagidae)	$6,105
Sang Il Kim	Entomology/Brian Farrell	Systematics of *Anoplophora* longhorn beetles (Coleoptera: Cerambycidae) and their genomic basis of adaptation to the temperate zone	$9,000
Juan Moles	Invertebrate Zoology/ Gonzalo Giribet	Exploring Maldives sea slug diversity	$9,240
Javier Ortega-Hernández	Invertebrate Paleontology	A new early Cambrian Burgess Shale–type fossil biota from shallow marine waters	$10,860
Flavia Termignoni Garcia	Ornithology/Scott Edwards	Genomics and neurobiology of cooperative breeding in birds	$5,508
Zhengyang Wang	Entomology/Naomi Pierce	Co-diversification of entomophagous fungi and their lepidopteran hosts: Surveying "mummified caterpillars" of the Himalayan and Hengduan mountains	$9,570
		Total Awards	**$66,012**

Flavia Termignoni Garcia

Tauana Cunha

Shahan Derkarabetian

Luca Saponari

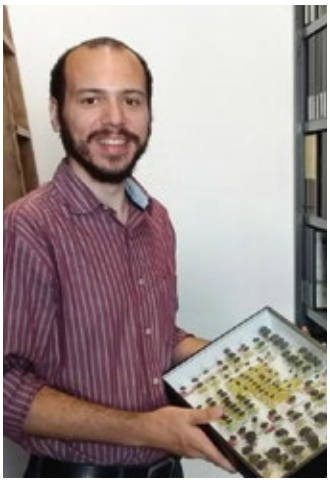
Juan Moles and Tauana Cunha

Luca Saponari

Tauana Cunha

Carlos Aguilera Calderón

Omar Valencia Méndez



Olivier Montreuil

Mario Cupello

Dagmara Żyła

Sangeet Lamichhaney

Ernst Mayr Travel Grants in Animal Systematics

Ernst Mayr Grants support travel for research in animal systematics and are open to the scientific community worldwide. The principal objective of these grants is to stimulate taxonomic work on neglected taxa and/or poorly described species. Ernst Mayr Grants typically facilitate visits to institutional collections, with preference given to research that uses MCZ's collections. These grants are made possible by a gift from professor and former MCZ Director Ernst Mayr.

Recipient	Institutional Affiliation	Project Title	Amount
Federico Alejandro Agrain	CCT-CONICET, Argentina	Study of type specimens of Cryptocephalinae: Aiding current systematics and phylogenetic works (Coleoptera: Chrysomelidae)	$1,380
Jeffry A. Ardila-Camacho	Universidad Nacional Autónoma de México	Systematics of the mantidfly subfamily Symphrasinae (Neuroptera: Mantispidae)	$1,500
Nelson Buainain Neto	Instituto Nacional de Pesquisas da Amazônia	Phylogenomics and species limits in two Oscine (Aves: Passeri) genera	$1,500
Alexandre Casadei Ferreira	Universidade Federal do Paraná, Brazil	Taxonomy of the hyperdiverse ant genus *Pheidole* (Hymenoptera: Formicidae: Myrmicinae) in the Brazilian Atlantic Forest	$1,500
Julissa Melissa Churata Salcedo	Universidade Federal do Paraná, Brazil	Phylogeny of Chnoodini Mulsant, 1850 (Coleoptera, Coccinellidae, Coccinellinae)	$1,500
Victor Manuel Conde Vela	El Colegio de la Frontera Sur, Unidad Chetumal	Revision of type and non-type materials of the polychaete family Nereididae (Annelida: Polychaeta)	$1,500
Mario J. Cupello	Universidade Federal do Paraná, Brazil	Unrevealing the megadiversity of an adaptive radiation: Systematics of the New World dung beetle genus *Ateuchus* Weber, 1801 (Coleoptera: Scarabaeidae: Scarabaeinae: Ateuchini)	$1,500
Hayden R. Davis	Villanova University	Uncovering the hidden diversity of Borneo in the gecko genus *Cyrtodactylus*	$1,385
Valeria Gabbanelli	Instituto de Investigaciones Marinas y Costeras, CONICET	Taxonomy of Southwest Atlantic longnose skates	$1,000
Nayeli Gutierrez Trejo	American Museum of Natural History	Revision of the genus *Tetraopes* Dalman in Schoenherr (Coleoptera, Cerambycidae)	$1,000
Nicolas A. Hazzi	The George Washington University	Taxonomic revision and distribution of wandering spiders (Araneae: Ctenidae) in Costa Rica	$1,400
Richard A. B. Leschen	Landcare Research	Australasian Elmidae	$1,500
Thiago Mahlmann	National Institute of Amazonian Research	Systematics of *Ceratina* (Calloceratina) Cockerell, 1924, and its phylogenetic position within *Ceratina* in the New World (Hymenoptera: Apidae: Xylocopinae)	$1,500
Carlos Alberto Martínez Muñoz	University of Turku, Finland	Revision of Hispaniolan Scolopendromorpha	$1,200
David B. Muniz	Universidade Federal do Paraná, Brazil	Review of *Trypoxylon* (*Trypargilum*) species occurring in Brazil (Hymenoptera, Crabronidae, Crabroninae)	$1,500
Jill T. Oberski	University of California, Davis	New World ants of the genus *Dorymyrmex*: A systematic revision	$1,250

Recipient	Institutional Affiliation	Project Title	Amount
Janakiraman Poorani	ICAR–National Research Centre for Banana	Examination and imaging of Coccinellidae types	$1,500
Tania Pineda Enriquez	University of Florida	Diversity and evolution of brittle stars across the world ocean: Revisionary systematics of ophiolepidids	$1,500
Tiago R. Simões	MCZ	Taxonomy, ontogeny and phylogeny of early rhynchocephalians	$1,500
Alexandra Tokareva	Saint Petersburg University	Taxonomy of the neglected mycophagous rove beetle subfamily Oxyporinae Erichson, 1839 (Coleoptera: Staphylinidae)	$1,500
Omar Valencia-Méndez	Universidad Autónoma Metropolitana, Mexico City	Marine and coastal gobies (Teleostei: Gobiidae) from Eastern Tropical Pacific: A systematic revision	$1,500
Dagmara Żyła	Iowa State University and University of Gdańsk	Generic revision of Lathrobiini (Paederinae) and Xantholinini (Staphylininae) rove beetles	$1,500
		Total Awards	**$31,115**

Francisco Felipe Xavier-Filho

Thiago Mahlmann

Samantha Royle

Robert G. Goelet Research Awards

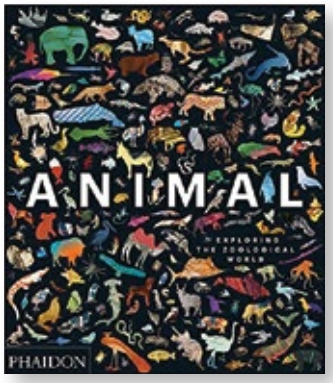
Goelet Awards support MCZ graduate student research projects. These grants are made possible through a gift from Mr. Robert G. Goelet.

Recipient	Department/ Faculty Sponsor	Project Title	Amount
Jennifer Austiff	Herpetology/James Hanken	Embryology: Concepts and techniques in modern developmental biology	$3,000
Gustavo Bravo	Ornithology/Scott Edwards	Gordon Research seminar on ecological and evolutionary genomics	$240
Daren Card	Ornithology/Scott Edwards	Gordon Research seminar on ecological and evolutionary genomics	$240
Nathaniel Edelman	OEB/James Mallet	Gordon Research seminar on ecological and evolutionary genomics	$240
Sangeet Lamichhaney	Ornithology/Scott Edwards	Gordon Research seminar on ecological and evolutionary genomics	$240
Sofia Prado-Irwin	Ornithology/Scott Edwards	Gordon Research seminar on ecological and evolutionary genomics	$240
Samantha Royle	Herpetology/James Hanken	Cell and developmental biology of *Xenopus*: Gene discovery and disease	$2,460
Tianzhu Xiong	OEB/James Mallet	Deciphering the divergence-with-gene-flow pattern in several swallowtail butterflies from the Hengduan Mountains (SW China)	$1,825
Guillem Ylla Nou	OEB/Cassandra Extavour	Gordon Research seminar on ecological and evolutionary genomics	$240
		Total Awards	**$8,725**

Nayeli Gutierrez

Nayeli Gutierrez

Publications in 2018



James Hanken was consulting editor for *Animal: Exploring the Zoological World.*

Research by **Tiago R. Simões** and colleagues on the origin of squamates was featured on the cover of *Nature*.

The cover story highlighted research on early limb patterning in the direct-developing salamander *Plethodon cinereus* by **James Hanken** and colleagues.

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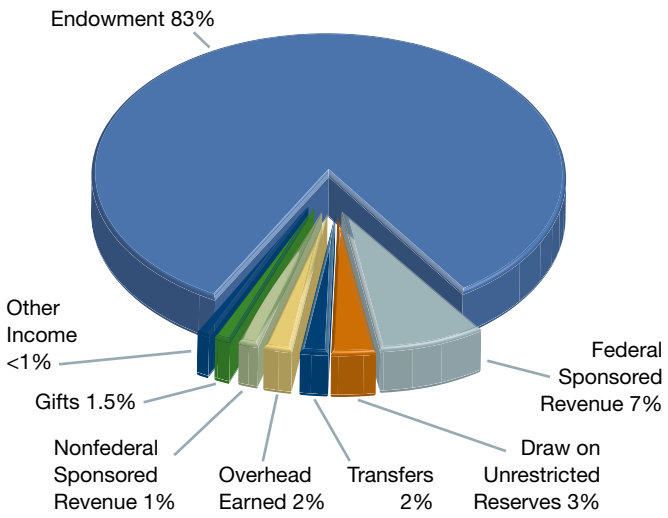
Financial Data

These charts describe the income and expenses of the Museum of Comparative Zoology in fiscal year 2019.

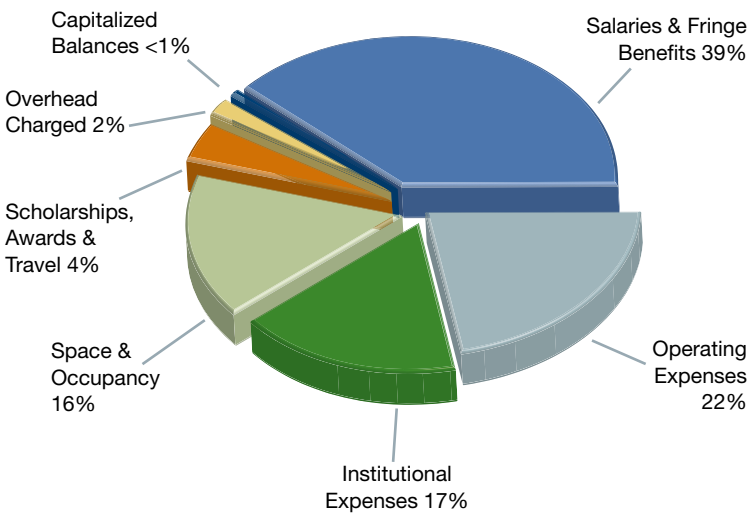
Endowment income funds much of the Museum's activities, such as acquisition and maintenance of collections, faculty and staff salaries, capital projects, facilities renovation and maintenance. It includes the annual distribution (payout) and endowed funds decapitalized per donor request. **Transfers** include financial support for the Ernst Mayr Library and other Harvard-funded projects. **Other Income** comprises miscellaneous income from publication subscriptions, royalties, sales and fees, and cost recovery from other MCZ-sponsored activities. **Overhead** is funds paid from sponsored projects to cover associated facilities and administrative costs. It is shown as both income (**Overhead Earned**) and expenses (**Overhead Charged**). **Draw on Unrestricted Reserves** indicates unrestricted fund balances utilized to fund operations.

Accumulation of Restricted Reserves indicates net growth of balances in highly restricted gifts and endowments. Building expenses such as maintenance, facility improvements and utilities are captured in the **Space & Occupancy** category. **Operating Expenses** consist of equipment purchases, supplies, and consultant and conference fees, as well as annual subventions to the Department of Organismic and Evolutionary Biology (OEB) for administrative services and MCZ support for faculty-curator research. Support for MCZ-affiliated graduate students in OEB is included in **Scholarships, Awards & Travel**. **Institutional Expenses** are support for other University activities outside the MCZ, including FAS and University initiatives and general operating support to the Harvard Museums of Science & Culture.

INCOME



EXPENSES & NON-OPERATING FUNDS



Income

Endowment	$16,565,294
Federal Sponsored Revenue	$1,314,674
Draw on Unrestricted Reserves	$679,739
Overhead Earned	$456,280
Transfers	$383,183
Gifts	$294,699
Nonfederal Sponsored Revenue	$171,292
Other Income	$168,732
Accumulation of Restricted Reserves	($606,938)
Total	**$19,426,955**

Expenses

Salaries & Fringe Benefits	$7,658,953
Operating Expenses	$4,207,614
Institutional Expenses	$3,245,348
Space & Occupancy	$3,088,728
Scholarships, Awards & Travel	$744,760
Overhead Charged	$456,280
Capitalized Balances	$25,272
Capital Projects	—
Total	**$19,426,955**

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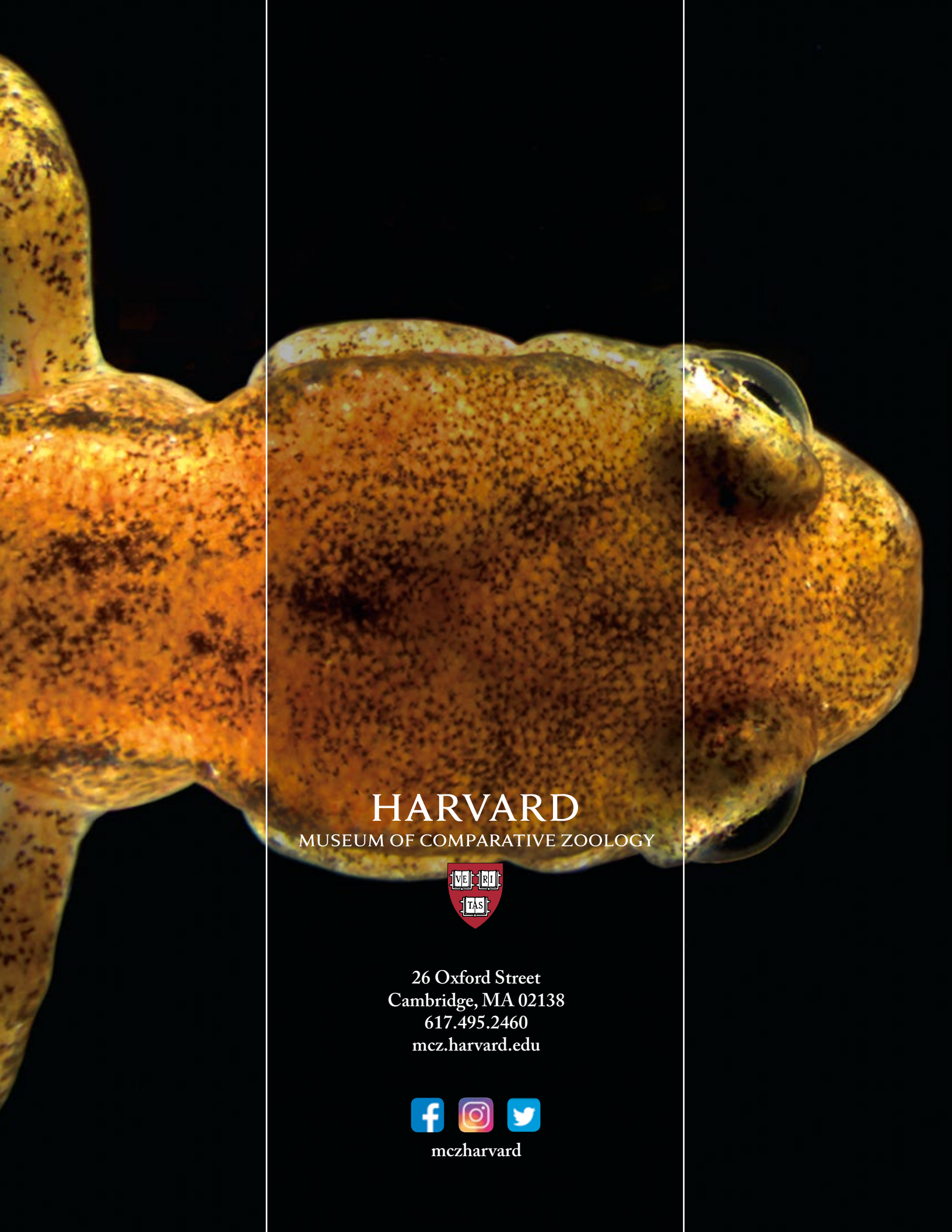

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