Integrative Biology

2021 IMPACT REPORT

From the Integrative Biology Co-Chairs

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L-R: Eileen Lacey; tyrone hayes

Entering our new positions as Co-Chairs for the Department of Integrative Biology (IB) during a period of multiple challenges for Berkeley, for academia, and for the global communities that we serve, we were quickly impressed by the unwavering commitment and passion that members of our department bring to their work. The need to understand the natural world and our relationships with it has never been more apparent, and the IB community is meeting those challenges head-on.

With the emergence of the COVID-19 pandemic, our department's biomedical scientists and disease ecologists immediately stepped up to lend their expertise and to help guide campus, state, and national level responses. Themes that we have devoted our academic careers to suddenly became critical bodies of knowledge as demand for top-notch organismal and population biologists exploded.

Against the backdrop of the pandemic and the nearly 18-month-long closure of the Berkeley campus, IB has worked steadily to keep our community vibrant and growing and to explore new frontiers in human health, global change, and biodiversity. All of these efforts to share knowledge, resources, and solutions are proceeding with a keen dedication to promoting a diverse, equitable, and inclusive community of discoverers. With these principles in mind, our researchers have established new collaborations through our museums, affiliated centers, and external institutions. In this year's Impact Report, we are excited to share just a few examples of our recent work.

Our first few months as Co-Chairs have been challenging but rewarding. Our new roles have afforded us the chance to learn more about the breadth of research and depth of commitment to service that characterize IB. We are very proud and excited to invite you to share this glimpse into our community as we forge ahead in our mission to explore life.

Inside this report:

Human Connections: Origins, Health and Quality of Life

Health outcomes arise from myriad evolutionary, developmental, societal, and life-history factors. Integrative Biology researchers work towards closing gaps in our knowledge of human origins, aging, physiology, and disease in a highly interdisciplinary setting. Some of our scientists study fossils and genomics to understand human origins and the patterns and processes underlying human biological variation. Others look to nature to reveal how agriculture, environmental toxins, global change, and the microbial world inside and around us affect human health. Many other scientists in the Department of Integrative Biology work to uncover the mechanisms underlying conditions like Alzheimer's disease, aging, cancer, traumatic brain injury, and cardiovascular diseases in comparative, pre-clinical, and translational settings. Collectively, the Department of Integrative Biology works to uncover our origins and improve our quality of life.

Research Highlight: Aging through the lens of evolutionary medicine

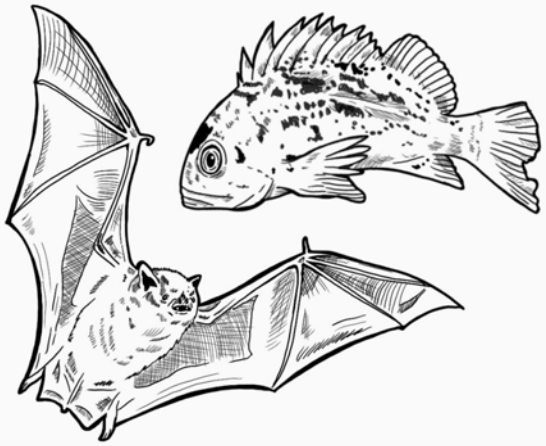

Illustration by Nina Sokolov

As populations age, the burdens they place on the medical system increase due to the emergence of aging-related diseases like muscle weakness, cancer, heart disease, and neurological disorders. Aging is not a uniquely-human phenomenon - all animals age. However, not all animals age equally - many species, such as bats, whales, and rockfish, maintain their youthful vigor and health well into their old age. **The work we do in Integrative Biology helps us understand how these animals thrive in their old age, and by understanding the underlying mechanisms, we can develop treatments and therapies that can be used to extend the human health span and ensure a happy and healthy life throughout our lifespan.** Researchers in the Department of Integrative Biology published a recent paper illustrating the genes explaining variation in lifespan among 88 species of Pacific rockfish, which range in lifespan from just 11 years to over 200 years old! The work is progressing with studies on humans to begin January 2022.

Learn more!

https://news.berkeley.edu/2021/11/11/pacific-rockfish-and-the-trade-offs-of-a-longer-life/
https://www.science.org/doi/10.1126/science.abg5332

Did You Know?

- Alzheimer's disease starts off in deeply evolutionarily conserved brain regions decades before the onset of cognitive decline. Researchers in IB are studying the mechanisms underlying the vulnerability of these regions, identifying routes for earlier detection and intervention for neurodegeneration.
- Bats are among the longest-lived groups of mammals. Not only that, but many species here in California have recently evolved even more exceptional lifespans, including a 34-year old Little Brown Bat! Researchers in IB are developing a clade of Californian bat species as a model system for studying the evolution of longevity and related health traits by combining cutting-edge genetics with cell culture models, lighting the way for extending human health span into old age.
- Elephant seals can dive to astounding depths and tolerate extreme lack of oxygen during dives. Researchers in IB are demonstrating that their cells can survive oxygen-deprivation by up-regulating antioxidant production, which may one day help us better treat human heart attacks and strokes.

Tree of Life: Biodiversity and Global Change

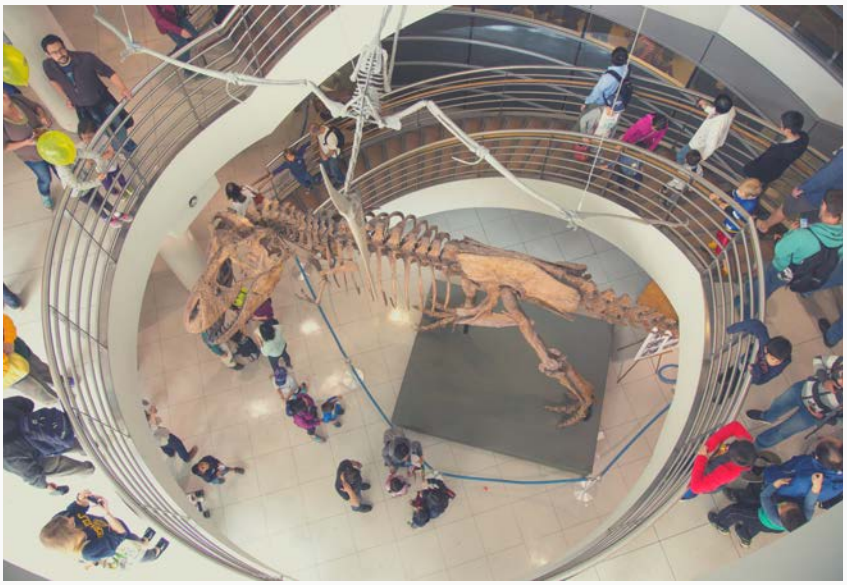

Photo by Hulda Nelson

From coral reefs to tropical forests and deserts, the wonders of the natural world not only inspire and delight us, but also teach us about the evolutionary processes that shape our modern world. Scientists in Integrative Biology study the diversification of life throughout our planet's history, and how that biodiversity has been reconfigured through time in response to global change. Our world-class research museums are a rich archive of biodiversity over vast time scales and geographic breadth. Many of our researchers carry out fieldwork worldwide and at home in California to explore nature's dynamic ecosystems. This work actively guides conservation priorities in the current era of rapid anthropogenic global change.

Research Highlight: Pinning down penguin diversity using genomes

Photo by Keith Barnes

Despite the recognizable, well-known public image of penguins, their evolutionary history has not been resolved until now. Integrative Biology faculty member and Museum of Vertebrate Zoology curator Curator Rauri Bowie and Visiting Professor Juliana Vianna (Pontifical Catholic University, Santiago, Chile) led an international team, including graduate student Cynthia Wang-Claypool and former postdoc Ke Bi, to gather samples of 18 penguin species from museum specimens and live animals around the world to sequence their genomes. **Their analysis reveals that the origins of the modern groups of penguins diversified about 22 million years ago on the coasts of Australia and New Zealand, not in Antarctica as previously thought (Vianna et al 2020).** The study lays the foundation for future penguin work into their unique adaptations, identification of putative new species and improved understanding of their diversification for conservation.

Learn more!

PNAS paper: https://www.pnas.org/content/117/36/22303
NPR story: https://www.npr.org/2020/08/18/903593291/the-evolutionary-history-of-penguins-is-far-from-black-and-white
PNAS podcast on Origin and Diversification of Penguins:
https://podcasts.apple.com/us/podcast/origin-and-diversification-of-penguins/id1367460245?i=1000494470403

Did You Know?

- Some 2.5 billion Tyrannosaurus rex lived in North America over its ~2.5 million year history. IB faculty and students estimated its body mass, population density, geographic range, generation time and geological longevity, forging new ground on how much can be inferred about evolutionary history from the fossil record.
- The largest flying animal on record, a Cretaceous pterosaur, had a wingspan of 36+ feet. Researchers in IB and colleagues used hundreds of bones to reconstruct how this creature walked on land, took off, and flew.
- There are over 1,600 species of bees in California. IB researchers are studying bee viruses to better understand how these epidemics are affecting honeybee and native bee populations in order to design ecologically minded management strategies for pollinator conservation.

The Tangled Bank: Species Interactions & Biological Communities

To Charles Darwin, ecological interactions between individuals were the main driver of evolutionary change. Integrative Biology researchers illuminate how biotic interactions shape ecological communities and their evolutionary trajectories. From wave-swept shores, to the microbes living within us and the world's tallest trees, we study the nature of biotic interactions across every level of biological organization; from genes, to organisms, to ecosystems. This fundamental understanding of biological communities sheds light on public health, conservation, agriculture, and even genome engineering.

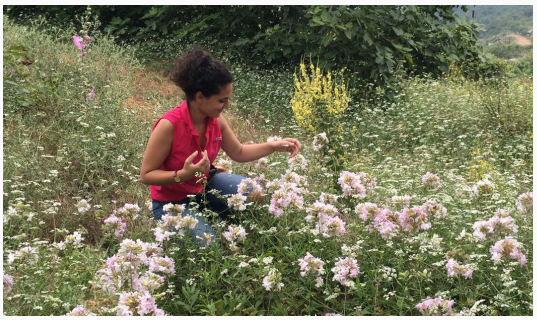

Photo by Maryam Sedaghatpour

Photo by Sina Amini

Photo by Kaitlin Allen; photo taken under NMFS permit #19108

Photo by Erin Voss

Did You Know?

- Almost all frogs and salamanders are toxic, and several snake species can feed on the most toxic frogs in the world. Researchers in IB are studying how amphibians acquire chemical defenses from symbiotic bacteria that live in their skin, and how snakes can fortify their nervous systems against these lethal toxins.
- Animals can exchange genes with one another. IB researchers are showing that gene exchange between species (known as horizontal gene transfer) can confer fitness benefits to animals. They discovered that toxin genes were transferred from protective bacterial species into the genomes of several insects, including flies and aphids.
- California harbors the Earth's tallest and most massive trees – the Redwoods. Researchers in IB have shown that redwood trees can absorb fog water directly into their leaves, and that they harbor unique microorganisms in their roots that can help them obtain nitrogen.
- Some invasive plants depend on nitrogen provided by invasive bacterial symbionts. IB researchers are investigating whether viruses that infect bacteria could help limit co-invasion by these plants and their bacterial symbionts.

Research Highlight: Phyllostart - A New Agricultural Biostimulant

Photo by Elijah Mehlferber

When Integrative Biology graduate student Elijah Mehlferber and Associate Professor of Integrative Biology Britt Koskella first assembled the bacterial community that would come to be known as Phyllostart, they intended to use it as a model system for understanding the basic ecology of the plant leaf microbiome. Like many of the great discoveries in science, their understanding of its role as an agricultural biostimulant started with luck (followed up with a lot of hard work).

They were collaborating with an industry scientist who was performing a fertilizer trial on greenhouse-grown tomato plants, and their goal was to determine how the application of a defined bacterial community would shape the composition of the microbiome over time. **When the trial concluded, they were surprised to see that the plants that were inoculated with the mixture of bacteria produced even more fruit than the control plants.** They spent the next several years following up on this result, testing different dosages, and confirming through multiple greenhouse trials that the bacteria did indeed lead to a significant increase in the number of fruit produced. During that time, they confirmed that the effect was strongest when the bacteria were applied to the plants early, ideally when they were still seedlings, and by comparing them to plants that were grown in the field, determined that the effect was largely due to a lack of bacteria in the greenhouse environment. In essence, the plants grown in the greenhouse were missing out on a key window of exposure to bacterial signals that would shape the rest of their development, much like the human hygiene hypothesis where early exposure to bacteria and viruses is essential for developing a healthy immune system.

Photo by Elijah Mehlferber

With many crops grown in a greenhouse setting (for example, up to 30% of domestic grown tomatoes spend their lives indoors), they realized that these bacteria might have an important role in agricultural food production, and Phyllostart was born. **With the anticipated increase in demand for food in the coming years and a goal of reducing reliance on traditional fertilizers (due to their increasing scarcity and negative impact on the environment), this is a critical time to invest in and develop new methods for increasing crop yield.** They are currently working to commercialize this product, developing methods for growing and distributing it on a commercial scale, and finding industry partners to help connect them with farmers. They hope that, as Phyllostart makes it to market, it can help pave the way for a future with more natural, and sustainable, plant stimulants and fertilizers.

Learn more! Phyllostart journey: https://i-cultiver.com/phyllostart/

IB IN THE PUBLIC

Public outreach and engagement are a critical part of the job for researchers in IB. Read below for just some of the ways we communicate the discoveries occurring in our department to the public.

Writing for the public

IB researchers wrote articles for *Scientific American*. A grad student received the Mangum student journalist award and internship from the Society of Integrative Biology, writing two popular science articles highlighting research on the effect of lockdowns on singing behavior in White-crowned sparrows, and the effects of light pollution on ecosystem health.

Health

IB researchers assisted with campus COVID-19 response and public communication regarding SARS-CoV-2 evolution. We contributed to policy, education, and public outreach with the Joint Medical Program with UCSF.

Outreach with K-12

Students participated in the *Skype a Scientist* and *Be a Scientist* programs. Designed and taught lessons for Bay Area Scientists in Schools (BASIS) and Science Ambassadors program. Distinguished Lecturer for the California State Summer School for Mathematics & Science (COSMOS), a program for students grades 8-12 to prepare the next generation of STEM leaders.

Policy

Assisted with local, state, and federal policy around regulation and legislation for regulating chemicals. Collaborated on a paper focusing on conservation prioritization of Californian lands, which has been considered in recent land protection actions. Participated in *California Biodiversity Network Stewardship Roundtable* to write an appendix for *California State 30 x 30 initiative,* which aims to protect 30% of California's land by 2030.

Workshops

Bay Area Science Festival workshop on native bees. *Expanding Your Horizons* conference leaders for middle school girls interested in STEM. *The Jepson Herbarium* hosted online public workshops for an inclusive audience, on California native plant identification and evolutionary understanding.

Public Exhibits & Resources

Served on the *Scientific Advisory Committee* for a *National Science Foundation* program, "Exploring the Intersection of Mathematics, Science and Art." *The University of California Museum of Paleontology* developed resources for teaching "Understanding Evolution (evolution.berkeley.edu) and "Understanding Global Change" (https://ugc.berkeley.edu/). This website enables exploration of the causes and solutions to climate and environmental change, and construction of models that explain what drives global changes.

Grad Student Voices

Much of my early experience running science communication workshops came from collaborative opportunities within IB. I launched a new initiative, the Berkeley SciComm Fellows, which trains graduate students to run science communication workshops for the Berkeley community and the public.

- Sara ElShafie

I decided to study biology because I wanted to understand the shapes, smells and colors I was experiencing. **Attending a public university opened my eyes to the socio-political reality of my country. I am convinced that biological knowledge and society can work closely together.** Currently, I organize seminars to think about how we can improve that interaction.

- Valeria Ramirez Castaneda

In Memoriam: David Wake

Our beloved colleague and friend, David Wake, passed away on April 29, 2021, surrounded by his family. A native of South Dakota, Dave earned his PhD at the University of Southern California where he met his wife, Marvalee. He began his career at the University of Chicago, and then joined the faculty of UC Berkeley in 1968. He was the Director of the Museum of Vertebrate Zoology for 27 years (1971–1998). He served as President of the Society for the Study of Evolution, the American Society of Naturalists, and the American Society of Zoologists. Dave was a towering figure in evolutionary biology and herpetology and trained generations of students, including many leaders in the field today. Hewas a member of the US National Academy of Sciences and was recognized by many awards. His deep wisdom, gentle demeanor, and friendship were an inspiration to all. Read more about his life and professional contributions online: https://news.berkeley.edu/2021/05/04/david-wake-a-prominent-herpetologist-who-warned-of-amphibian-declines-is-dead-at-84/