inquiry@ UC SANTA CRUZ RESEARCH MAGAZINE

2021–22

Adaptable academics

BIRDS DO IT | TOMORROW'S FORECAST | CORAL AS CAPITAL

SANTA CRUZ

The spirit of **inquiry**@UC Santa Cruz

Welcome to the 7th edition of *inquiry@UC Santa Cruz*! In this issue you'll find stories featuring the broad range of research being performed across the university's five academic divisions. As in previous issues, the magazine's content was crafted by alumni of our world-renowned Science Communication master's program (see INQUIRING**minds**, p. 51).

Their writing this year invites you to: contemplate an America with true liberty and justice for all, delivered without imprisonment; travel with researchers on ocean voyages to collect and analyze tiny fossils for clues about the coming impacts of climate change; peer over the shoulders of internet sleuths leveraging open-access data in the global fight for human rights; relish the drama of marshlands where coots sneak their unhatched offspring into each other's nests; consider how ancient ruins reflect people's intentional efforts, rather than simply things left behind; and applaud Nobel Prize– winning research on telomeres—a potential key to understanding aging.

In addition, select your next great read from the latest books authored by our faculty in PEN**&**INQ (p. 50) and peruse recently patented faculty inventions, described in **inquiries&**INNOVATIONS (p. 13). All this and more awaits in the pages that follow.

Credit: C. Lagattuta

This year we celebrate in particular the unflinching dedication of the campus's research community, whose members—as revealed in our cover story, "Adaptable academics" (p. 14)—found ways to persevere in their mission to seek answers to difficult questions despite the unprecedented challenges posed by the pandemic. We invite you to join us as we recognize their hard-fought achievements and look forward to a less trying future.

Want to know even more? Access this issue and past issues of *inquiry@UC Santa Cruz* — enhanced with hyperlinks, additional artwork, and references for "**Further Inquiry**"—online at *inquiry.ucsc.edu.*

Finally, we wish to acknowledge previous Vice Chancellor for Research Scott Brandt for his eight years of dedicated service to this office. Scott championed the vision that became *inquiry@ UC Santa Cruz*, and we are thankful for his contributions to the university.

John MacMillan
Interim Vice Chancellor for Research and Professor of Chemistry and Biochemistry

inquiry@ UC SANTA CRUZ RESEARCH MAGAZINE

2021–22

About the cover: These spheres that appear on the landing *page* of the website of *What Makes Us Human: An Art + Genomics Convergence* represent and provide entry points for exploring different projects, each focused on one of a wide-ranging group of topics, including genomics, evolution, beauty, race, and gender. The overall objective of the creation is to spark conversations between scientists, artists, and others who visit the site. See more at whatmakesushuman.org. Credit: Courtesy of Jennifer Parker.

UNIVERSITY OF CALIFORNIA SANTA CRUZ

Chancellor
Cynthia K. Larive

Campus Provost and Executive Vice Chancellor
Lori Kletzer

Vice Chancellor, Research
John MacMillan (interim)

Vice Chancellor, University Relations
Mark Delos Reyes Davis

inquiry@UC Santa Cruz
2021–22

Editor
David Egerter (SciCom '88)

Creative Director
Lisa Nielsen

Art Director
Linda Knudson (Cowell '76)

Associate Editors
Heather Shearer, *principal*
Jeanne Lance

Contributors
Sarah Derouin (SciCom '17)
Amanda Heidt (SciCom '20)
Emma Hiolski (SciCom '17)
Jesse Kathan (SciCom '20)
Alla Katsnelson (SciCom '07)
Jack Lee (SciCom '20)
Jyoti Madhusoodanan (SciCom '14)
Mary-Russell Roberson (SciCom '88)
Priyanka Runwal (SciCom '19)
Helen Santoro (SciCom '19)
Ben Shouse (SciCom '01)
Lisa Strong (SciCom '93)
Cameron Walker (SciCom '02)
K. M. Watson (SciCom '84)
Jennifer Welsh (SciCom '10)
Marcus Woo (SciCom '07)

Produced by UC Santa Cruz Communications & Marketing
1156 High Street
Santa Cruz, CA 95064-1077
Email: inquiry@ucsc.edu
Web: inquiry.ucsc.edu

10/21 (2122-245/2.7M) IM2122

BRIEF **inquiries**

COMPUTATIONAL MEDIA

Board game joy

Playing board of the Japanese board game *Evil Spirit Island* (Bandai, 1983). In his book-in-progress, *Joy Family*, teaching professor of computational media Nathan Altice is chronicling the history of Japanese board games from the end of World War II to 1989; it will be his second book on Japanese games, following *I AM ERROR*, a history of the Nintendo Entertainment System (MIT Press, 2015). Credit: Courtesy of Nathan Altice.

When Teaching Professor **Nathan Altice** first started looking for board game adaptations of video games in 2017, he stumbled down a rabbit hole of possibilities from game-loving Japan. "And then," he said, "I made the mistake of saying, 'Maybe I'll buy one.'" Today, Altice's UCSC office harbors more than 400 Japanese board games, both adaptations and originals, the earliest dating back to 1905. Many can be explored via digital scans and translations on his Analog Joy Club website.

Board games might seem like a trivial pastime, but "games really reflect and embody the culture and values of the societies they come from," Altice said. For example, *Jinsei,* the Japanese version of the Milton-Bradley board game *Life,* introduced as Japan was deep into the economic and social transformation that started after World War II, gained immense popularity from both its aspirational connection to an American lifestyle and its similarity to a centuries-old type of Japanese board games.

In some early versions of these sugoroku, Altice said, players roll dice to follow a pathway resembling a Buddhist scroll, ascending vertically—a metaphor for spiritual enlightenment.

Archiving the games protects these fragile, ephemeral historical records that "connect to the way we express ourselves as human beings," Altice said. "To me, this is an important cultural preservation project."

—Cameron Walker

APPLIED MATHEMATICS

Bandages with brains

Assistant Professor **Marcella Gomez** is teaching artificial intelligence learning models to heal. With electrical and computer engineering professors **Marco Rolandi** and **Mircea Teodorescu**, Gomez co-leads a collaborative project that includes clinical researchers at UC Davis and Tufts University. Funded by a $16 million grant from the Defense Advanced Research Projects Agency, the project aims to develop a "smart bandage" that can speed the healing of difficult wounds, like those suffered by soldiers with battlefield injuries from explosions. "Our task is to identify where in the healing process

we can intervene to accelerate wound closure," Gomez said.

Marcella Gomez, assistant professor of applied mathematics, is creating the artificial intelligence "brain" of a smart bandage, a collaborative project she co-leads with professors of electrical and computer engineering Marco Rolandi and Mircea Teodorescu, and also includes clinical researchers at UC Davis and Tufts University. Credit: Karyn Skemp.

To monitor the wound, the smart bandage will contain optical sensors currently being developed by Teodorescu's team. It will also incorporate a Rolandi team–developed bioelectronic device to deliver ions and biochemicals. What molecules and when to administer them will depend on the bandage's "brain"—the artificial intelligence system being developed by Gomez.

"We'll monitor the wounds in real-time, and my algorithms will process and interpret the images to say, for example, 'Oh, we've started inflammation!'" Gomez said, prompting the bandage to release specific biochemicals. Eventually, she said, the technology could be adapted to help heal chronic sores, like those caused by diabetes, which burden a substantial number of patients and cost the health care system billions annually.

—Jennifer Welsh

ASTRONOMY AND ASTROPHYSICS

Dwarves and dark matter

Starting small can sometimes help tackle a big question, like the nature of dark matter. That's the hope of Assistant Professor **Alexie Leauthaud**, whose research features dwarf galaxies, the most common—but also most elusive—galaxies in the Universe. Cosmologists refer to these relatively tiny collections of stars (e.g., one billion versus our Milky Way's 200–400 billion) as "laboratories for dark matter," Leauthaud said, because they contain copious amounts of the mysterious substance.

With Princeton's Jenny Greene, Leauthaud co-leads the Merian Survey, an international research collaboration that in March 2021 began using the Blanco Telescope in Chile to map and assess 100,000 dwarf galaxies. Captured through custom-made filters, the discovery of so many dwarf galaxies will enable the astronomers to use a technique called gravitational lensing to measure—for the first time—the amount of dark matter they contain. While light normally travels in a straight line, gravitational forces warp its path. Measuring this warp with gravitational lensing infers the mass of a galaxy: the bigger the deviation, the bigger the mass and how much dark matter is present, Leauthaud said.

Given the massive amount of data the survey will collect, Leauthaud anticipates "exciting science," including about the extent, distribution, and nature of dark matter and how it varies between galaxies. "We're pushing into new territory," she said.

—Sarah Derouin

Left: Taken with the Hubble Space Telescope, this image shows a dwarf galaxy, named UGC 685, located about 15 million light-years from Earth. The most common type of galaxy in the Universe, these relatively small collections of stars are a focus of research for assistant professor of astronomy and astrophysics Alexie Leauthaud. Credit: ESA/Hubble & NASA (CC BY 4.0). Right: A sunset photograph shows the Cerro Tololo Inter-American Observatory (CTIO), a program of the National Science Foundation's National Optical-Infrared Astronomy Research Laboratory (NOIRLab) in the mountains of northern Chile. More than 20 telescopes operate at the site; dominating the mountain peak in the foreground is the Víctor M. Blanco 4-m Telescope, now being used for the Merian Survey. Credit: CTIO/NOIRLab/NSF/AURA/B. Tafreshi (CC BY 4.0).

CHEMISTRY AND BIOCHEMISTRY

Watching the clock

A ubiquitous blue-green bacteria found in ponds and lakes worldwide may provide the key to unlocking how life on Earth keeps track of day and night. These cyanobacteria—single-celled, microscopic organisms that create energy from sunlight—provide a simple system that Professor **Carrie Partch** and her collaborators have harnessed to better probe the intricate workings of biological clocks, the molecular machines that keep time in all living organisms.

The cyanobacterial clock, one of the most ancient on Earth, ticks in rhythm with each day, crucially triggering the generation of energy from sunlight during the day and then tripping the switch to use that energy in the dark. The goal of the Partch lab's cyanobacteria research is to reveal, on a molecular level, how this rudimentary clock encodes its timing, how it aligns itself with its environment, and how it communicates time to other parts of the cell.

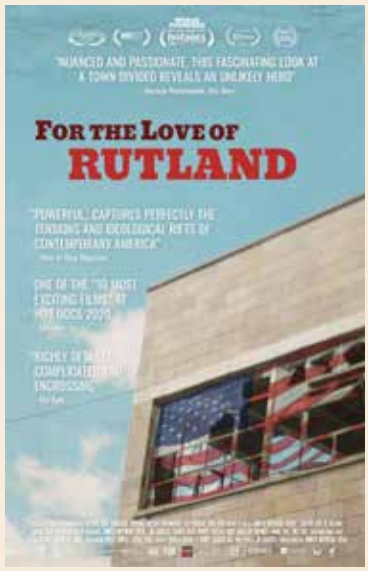
These images show cyanobacteria blooming in a freshwater pond, as commonly encountered (above) and under the microscope (right); each "string" consists of individual cyanobacteria linked together in tangled, single-cell filaments. Professor of chemistry and biochemistry Carrie Partch and

FILM AND DIGITAL MEDIA

Capturing complexity

When Associate Professor **Jennifer Maytorena Taylor** began shooting a new project in early 2016, she didn't realize how much her study of the small town of Rutland, Vermont—where she lived for a time when young—would mirror America's social and political turmoil. Centered around a mayor's decision to settle Syrian refugees in the town and how its 15,000 citizens responded, the resulting film, *For the Love of Rutland*, explores the persistent problems of poverty and addiction and the increasingly divisive issues of cultural identity and nationalism.

Her goal for the documentary, Taylor said, was to avoid portraying Rutland as simply a rural town in decline, to show it as "the complex entity it is, capturing as much nuance and contradiction as possible." The film follows Stacie Griffin, a lifelong Rutland resident whose life has been marked by poverty and substance abuse. Initially wary of the refugees resettling in her low-income neighborhood, Griffin ultimately finds purpose in civic engagement, advocating for change and community building that includes Rutland's newest inhabitants.



Jennifer Maytorena Taylor's *For the Love of Rutland* premiered worldwide at North America's largest documentary film festival, the Hot Docs Canadian International Documentary Festival, held virtually in May 2020. Named one of the 10 most exciting films screened at the festival by *IndieWire* magazine, the documentary continues to screen at film festivals and will have its national broadcast premiere on public television in 2021. Taylor, who grew up in Rutland and Los Angeles, is an associate professor and director of graduate studies in the Social Documentation M.F.A. Program. Credit: Lani Rodriguez, BackTalk Videografica (public domain).

Taylor teaches her students the same ethical practices and principles that have guided her more than two decades of work as an award-winning filmmaker of feature and short documentary films. "Our job is to be honest," she said. "I come in with a 'do no harm' commitment and an assumption that everybody deserves dignity."

—Amanda Heidt

her team work with the cyanobacteria species *Synechococcus elongatus;* its simple biological clock provides an exceptional experimental model for understanding the fundamental principles of how circadian rhythms work on the molecular level. Credits: Christian Fischer; Josef Reischig (both CC BY-SA 3.0).

In a recent report in the prestigious journal *Science*, the researchers detail their success in recreating the cyanobacterial clock protein-by-protein in a test tube. By letting them perform straightforward experiments not previously possible, the model system is allowing them to uncover new steps in the molecular transformations that keep the clock ticking. "The cyanobacterial clock," Partch said, "is helping us understand the general principles that make a biological clock."

—Jennifer Welsh

LATIN AMERICAN AND LATINO/X STUDIES

Border patrol

During the late 18th and early 19th centuries, Portuguese and Spanish mapmakers trekked across South America to create a border 10,000 miles long between the two colonial powers. Many histories assume that, by this time, the region's Indigenous peoples were almost entirely under colonial control. According to Associate Professor **Jeffrey Erbig**, "this narrative is patently false."

WRITING PROGRAM

Assessing access

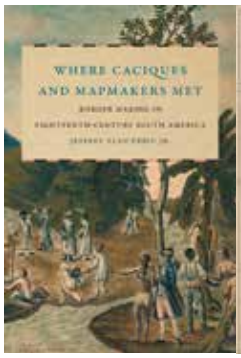
At the 2019 annual meeting of the Rhetoric Society of America, teaching professor and disability scholar-activist **Amy Vidali** led a working group that mapped the accessibility of the meeting site, the campus of the University of Nevada, Reno. "We didn't want it to be just about ramps," said Vidali. Drawing from the field of rhetorical cartography (the use of maps as tools for persuasion), the group attempted to geographically locate the unmet access needs of people with physical disabilities, as well as those with conditions like depression and autism, which are less commonly considered in determining accessibility.

Upon returning to Santa Cruz, Vidali decided to try a similar mapping of her home campus. When one of her students, sophomore **Katie Felberg** (class of '22), expressed interest, the two started the project as an independent study. Felberg's cataloging of the campus's steep slopes revealed the inaccessibility of large areas from the student bus, including the location of the Disability Resource Center. She also found much of the indoor space lit by fluorescent bulbs, making it difficult to use by some people with migraines or other disabilities.

On teaching professor in the Writing Program Amy Vidali's work-in-progress accessibility map of the UCSC campus, the description of this photograph for users with visual impairment reads: "This is a yellow sign on the road to the Hahn Building, where the Disability Resource Center is located. It says: 'No Outlet Buses & Semis Prohibited No Turn Around.' Sunlight streaks the photo, and the sign is on a grassy knoll near cracked asphalt. Redwood trees in the background." Credit: Amy Vidali.

Vidali hopes to continue the project—halted by the pandemic—when students return to campus. In addition to providing a practical resource for people with disabilities, the map will also serve, she said, "as an activist statement about how inaccessible the campus is."

—Jesse Kathan



Left: Associate professor of Latin American and Latino/x studies Jeffrey Erbig examined records from dozens of archives in seven countries while researching *Where Caciques and Mapmakers Met: Border Making in Eighteenth-Century South America* (2020), which details previously overlooked relationships between colonial forces and Indigenous peoples. "Cacique" translates to "king" or "prince" of an Indigenous group. Credit: University of North Carolina Press (public domain). Right: This 1796 map shows how Spain and Portugal had divided South America between themselves with a border some 10,000 miles long. Erbig's research reveals that large areas within this division were in fact controlled by Indigenous peoples and not by the two dominant colonial powers. Credit: Courtesy of the Norman B. Leventhal Map & Education Center at the Boston Public Library (public domain).

Erbig's book *Where Caciques and Mapmakers Met: Border Making in Eighteenth-Century South America* (University of North Carolina Press, 2020) shows that many Indigenous peoples remained autonomous, even as Europeans laid claim to their lands. Since oral histories maintained by Native peoples focus on later national contexts, Erbig's investigation drew on hundreds of archived colonial records from seven

HISTORY OF ART AND VISUAL CULTURE

Deflowering

Flowers as symbols are loaded with meaning. So, what does a flower mean when seen through the lens of Robert Mapplethorpe, the controversial photographer best known for his depictions of radical sexuality?

Mapplethorpe became famous for his celebrity party pictures in the magazine *Interview* and his explicit photography of queer subcultures. But leading up to his death from AIDS in 1989, he focused on portraits of flowers. For **Derek Conrad Murray**, professor of history of art and visual culture, Mapplethorpe's prolific flower artwork—more than 500 published works—trumpets the same themes as his earlier, more highly regarded work, noted for its coupling of classical beauty and risqué nature.

"The prevailing notion is that these were just a way to create something easily saleable," said Murray, who documents his study of Mapplethorpe's flowers in his 2020 book, *Mapplethorpe and the Flower: Radical Sexuality and the Limits of Control.* "I felt this was a critical blind spot."

An image from Robert Mapplethorpe's flower-focused work, *Parrot Tulips*, 1988. Mapplethorpe created many hundreds of flower portraits during his career, until his death from AIDS in 1989. Credit: ©The Robert Mapplethorpe Foundation. Used by permission.

Mapplethorpe is one of few artists who could make flowers look beautiful but also subversive and dangerous, Murray said. "There's something provocative about them. They can make you uncomfortable. When you look at the various meanings associated with flowers, and then at Mapplethorpe's BDSM images, or images of Black men, some of the deeper meanings are the same."

—Jennifer Welsh

countries, many of them maps from the border-making expeditions. His analysis, he said, exposes these maps as "tools of colonial power, which purport to present images of truth, yet conceal many other things."

The mapmakers often omitted the native territories of mobile Indigenous societies, Erbig said, at least partly due to their incompatibility with a sedentary European worldview. But the records show that colonists paid tribute to Indigenous peoples whose lands they crossed, and native leaders ("caciques") leveraged Spanish and Portuguese competition to increase their own power. The historical erasure of the region's Indigenous peoples continues to affect Native people, like those fighting for legal and cultural recognition in Uruguay, Erbig said. He hopes his scholarship will help support their cause.

—Jesse Kathan

HISTORY

Back to the future

Historians typically write about how the past has shaped the present. Professor **Matt O'Hara** contends it's valuable to also consider how the past shaped the future. In his latest book, *The History of the Future in Colonial Mexico* (Yale University Press, 2018), O'Hara explores the world of colonial Mexico by asking questions about how people's perceptions of the future prompted their actions.

"Sometimes we forget that the people we study, most of the time, were thinking about tomorrow or three weeks from then, or slightly more

These woodcut illustrations, with printed labels in Spanish (left) and the Mayan language Huastec (right), prompted colonials—including Native peoples—to remember the Ten Commandments during confession, a practice that doggedly pressed penitents to relate past events to future actions. The church's broad influence strongly affected how all people living in "New Spain" saw their own futures—this present, according to professor of history Matt O'Hara, shaped that future. Credit: Juan de la Cruz, *Doctrina christiana en la lengua Guasteca co[n] la lengua castellana,* 1571, John Carter Brown Library (CC BY-SA 4.0).

PSYCHOLOGY

Baby steps

In her Infant Development Laboratory (the "Baby Lab"), professor of psychology Su-hua Wang and her students study how learning occurs in the first few years of life. While researchers observe, parents and children interact with toys, books, and technology. Credit: Courtesy of Su-hua Wang.

Parents often look to milestones to track their baby's development. Instead of just ticking boxes, Professor **Su-hua Wang** seeks to better understand how babies develop. In her "Baby Lab," Wang and her students use toys, books, and technology to study cognition—the process of learning—in infants and young children.

Babies as young as three months old show signs of cognition, said Wang. While they all actively observe the world around them, how they actually learn is shaped by culture and environment. In recent work studying how babies from different parts of the world learn to use toys, she's found that parenting styles strongly influence the process, with sometimes striking differences that reflect cultural norms. For example, in the U.S., most parents lean towards exploration and hands-off approaches, versus in Taiwan, where most parents stress emulation and practice.

No one style is better than another, Wang said, but such cultural differences can make a one-size-fits-all approach to education problematic. Understanding the learning methods children experience in their early years can help educators adopt more effective teaching strategies. Wang hopes her findings—as applied in UCSC's New Gen Learning, an initiative to support research on strengths-based learning—helps to address "this disconnect between home and school" that can disadvantage many children, especially those from historically underserved populations.

—Sarah Derouin

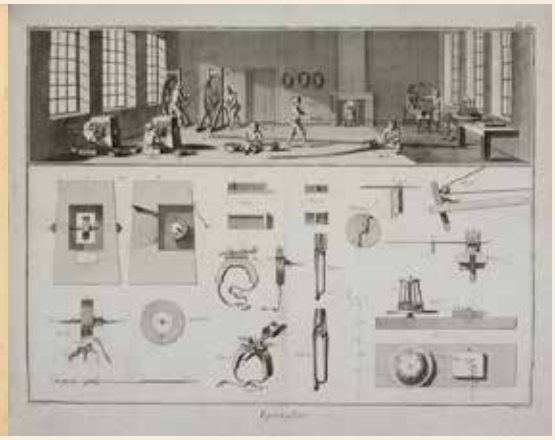
FILM AND DIGITAL MEDIA

The art of computing

Although many artists now use computers to make art, few know that art played a key role in making computers. According to Professor **Warren Sack**, art and craftsmanship laid the foundation on which computing and software design were built. In his book *The Software Arts* (MIT Press, 2019), Sack recounts how early figures in computing—like Charles Babbage, inventor of the first mechanical computer—were inspired by the 28-volume French *Encyclopédie* that cataloged the tools and step-by-step process of 18th-century crafts and trades, such as pin making, glass blowing, and tapestry weaving. "It all came from the workshops of artists and artisans," Sack said.

An artist and software designer, Sack straddles the two disciplines, his work showcasing how computing can influence art as well. In *The Translation Map*, a 2003 installation created with artist Sawad Brooks for the Walker Art Center in Minneapolis, Sack's software routed messages in one language to a series of public discussion forums around the world, resulting in a collaborative process of translation. The artists then traced the pathways of how people worked together, producing translation "maps" that illuminated shared cultural and colonial histories—and enduring divisions. "If you accept the idea that computing is an art," Sack said, "you gain a completely different way of looking at it."

—Cameron Walker



Published between 1751 and 1772 with many contributors and edited primarily by Denis Diderot, the *Encyclopédie,* Ou *Dictionnaire Raisonné Des Sciences, Des Arts et Des Métiers* (English: *Encyclopedia*, or *Classified Dictionary of the Sciences, Arts, and Trades*) inspired the development of computing, according to professor of film and digital media Warren Sack. The engraving on the right from the 28-volume series depicts a factory and detailed drawings of the tools for making pins. Credit: Both, Wikimedia Commons (public domain).

long-term," O'Hara said. "How am I going to get through the year, or leave something to my kids?" O'Hara's analysis of a broad range of archival materials, from legal documents to Inquisition records, shows how people living in 18th- and 19th-century Mexico—regardless of their education or social status—understood complex legal and theological issues. In addition to governing people's daily activities with regard to finances, health, and the natural world, these dogmas also fashioned the future.

It's become clear to O'Hara that critical thinking about what's to come is essential to better understand both the past and present. "This last year proved the importance of thinking about the future," he said, "because we all saw our futures change radically."

—Cameron Walker

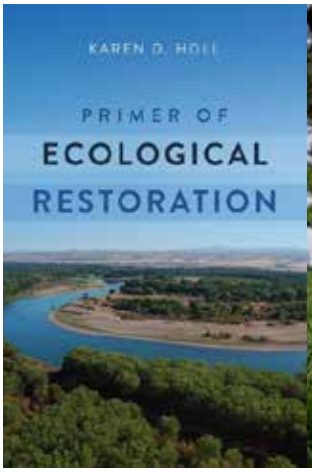
ENVIRONMENTAL STUDIES

Healing the Earth

On June 5, 2021, World Environment Day, the United Nations officially launched its Decade on Ecosystem Restoration, "a rallying call for the protection and revival of ecosystems all around the world, for the benefit of people and nature." The ambitious program aims to prompt and bolster global efforts to halt degradation and restore ecosystems to health, thereby enhancing people's livelihoods, counteracting climate change, and halting the collapse of biodiversity.

In a fortunate convergence of timing, it so happens that Professor **Karen Holl** has written what could serve as the playbook for this grand effort, her *Primer of Ecological Restoration* (Island Press, 2020). Holl said she created the primer for anyone interested in ecosystem restoration, whether students, practitioners, or backyard conservationists—"I was committed to keeping it succinct, and as low-priced as possible."

The primer covers the broad science of restoration, and also the roles played by economic stakeholders, policy makers, and local communities. Each



Left: Professor of environmental studies Karen Holl couldn't find a thorough, inexpensive textbook for her restoration ecology course—so she wrote her own. Along with the book, Holl created downloadable material including case studies, videos, and additional readings, extra resources intended to help tailor lessons to specific classes and locations. Credit: Island Press (public domain). Right: Photographed by former graduate student (Ph.D. '20), now lecturer **Andy Kulikowski**, Holl plants a tree (a species of *Ocotea,* in the avocado family) during a field trip to Costa Rica. Holl's broad-based ecosystem restoration research includes field-based surveys and manipulation studies in both California and Latin America. Credit: Andy Kulikowski, courtesy of Karen Holl.

of these participants has unique but also intertwined needs, and Holl hopes her book provides the guidance needed to avoid failed projects. Ideally, ecosystems should be protected; when needed, though, restoration plans should crucially include forward thinking. "We used to use the past as the template for restoration," Holl said. However, she said, given climate change, restored landscapes will likely need to change too.

—Sarah Derouin

FEMINIST STUDIES

Displacement

Between 1918 and 1942, as part of efforts to assimilate Native peoples, thousands of women worked for white, affluent families in the Bay Area as domestic help during holidays away from their Indian boarding schools. In hindsight, this "outing program" and similar ones throughout the country actually embodied a federal

PHYSICS

Particles from space

In 2018, a high-altitude balloon launched in Sweden ascended 40 kilometers into the atmosphere. While it drifted towards the far north of Canada, its 500-lb. payload of delicate sensors captured more than 130 hours of data intended to help untangle the mysteries of cosmic radiation.

Cosmic rays mostly include subatomic particles like neutrons and protons, which circulate throughout the galaxy at nearly light speed. Many of these particles are thought to be produced by pulsars, the "remnants of ancient stellar explosions," said Professor **Robert Johnson**. But much about these galactic emanations remains unexplained, including the source of low-energy electrons, which make up a fraction of the rays.

To study these elusive electrons, Johnson, then doctoral-candidate **Sarah Mechbal** (Ph.D. '20); now at Deutsches Elektronen-Synchrotron—DESY—in Germany), and John Clem at the University of Delaware collaborated on the NASA-supported mission, for which the UCSC team built AESOP (Anti-Electron Sub Orbital Payload)-Lite, an instrument capable of distinguishing electrons from positrons, their antiparticles.

The Earth's atmosphere absorbs most radiation, making it difficult to measure—hence the high-altitude balloon to ferry AESOP-Lite near the edge of space. With the mission's initial findings now published, the researchers plan to compare their data with measurements from similar sensors on the International Space Station and satellites deep in the solar system. These comparisons, Johnson said, could illuminate how our Sun's radiation affects these particles from space.

—Jesse Kathan

Carried by a high-altitude balloon, shown here shortly after its launch in Sweden, the AESOP-lite mission collected more than 130 hours of data measuring cosmic radiation near the edge of the Earth's atmosphere. The balloon and its equipment payload drifted for six days before landing on Ellesmere Island in the far north of Canada. Credit: Courtesy of Robert Johnson.

They Will Prove Studies in Housework

MRS. B. V. ROYCE, outing matron of the U. S. Indian Service, is here again with a few of the 40 Indian girls of the Carson Indian school who will work in Oakland homes during their vacation period. Left to right: DELPHINE HOLBROOK, BELMA BARBAR, RUBY WILDER, MRS. ROYCE, ROSIE PETE, and RUBY PARADISE.

While searching the archives of the YMCA in Berkeley, assistant professor of feminist studies Caitlin Keliiaa found this clipping from a June 1927 *Oakland Tribune* newspaper. The photograph shows the Bay Area Outing Program's first "outing matron," Bonnie V. Royce (center, in hat), alongside several Native women from the Stewart Indian School in Nevada. Credit: Courtesy of Caitlin Keliiaa.

campaign of labor exploitation, according to Assistant Professor **Caitlin Keliiaa.**

In a government archive housed in San Bruno, Keliiaa unearthed roughly 4,000 letters, photos, and bank statements that trace the lives of the Native women placed in the Bay Area Outing Program. Her study of these documents reveals strict monitoring by the white outing matrons who oversaw them. Women suspected of sexual activity, for example, were "surveilled, managed, sent to detention homes, and sometimes arrested," Keliiaa said. In rare instances, women ran away or even died while on placement.

The legacy of such outing programs, documented in Keliiaa's book-in-progress, *Unsettling Domesticity: Native Women and 20th-Century Federal Indian Policy in the San Francisco Bay Area*, is not entirely negative. Program participants who stayed or returned formed a resilient Native community decades before more extensive migration to the Bay Area from reservations. Social clubs for Native people established by the outing program—to meet under supervision—also persisted, creating what Keliiaa calls "foundational spaces" for displaced Natives to build community and celebrate their tribal cultures.

—Amanda Heidt

EDUCATION

Remote teaching

When the pandemic first shuttered schools, teachers across the country were expected to adapt their courses for remote learning almost overnight. In the Suddenly Distant Research Project, associate professor of education Laura Bartlett and collaborators have interviewed K–12 educators to study how the switch to remote teaching has affected them. Credit: François Philipp (CC BY 2.0).

In March 2020, the pandemic forced Associate Professor **Lora Bartlett** to shift her *Introduction to Educational Issues* class of 300 students to online lessons. Despite having taught the course for years, she found the pivot jarring: "I suddenly felt like a novice."

Knowing that educators nationwide were likely having similar experiences, Bartlett and fellow principal investigators at UC Berkeley and Lewis & Clark College launched the Suddenly Distant Research Project. To better understand how state and local pandemic restrictions challenged teachers and reshaped education, the initiative's collaborators conducted intensive interviews with 75 K–12 educators in nine states, chosen based on COVID-19 death rates and strength of their teacher unions.

The group's first interim report (November 2020) documented teachers' initial reactions to the emergency situation in the spring; the second (January 2021), their experiences in the fall as pandemic restrictions continued. One notable finding was how public treatment of teachers changed over that time. "In the spring, teachers felt celebrated as heroes," Bartlett said. "In the fall, they felt vilified as obstacles to schools reopening."

The results also showed a groundswell in organizing by teachers. In response to this push to consider their voices, which Bartlett said will "no doubt" continue, states with strong teachers' unions, like California, have already negotiated protections to support educators.

—Amanda Heidt

inquiries&INNOVATIONS

By Marcus Woo

Unclogging rock

In hydraulic fracturing ("fracking"), pumping liquid into the ground at high pressure creates cracks in rock that increase its permeability, allowing drillers to extract more oil and gas more easily and quickly.

With former UCSC postdoc **Thibault Candela**, now geomechanics scientist at the Netherlands Organization for Applied Scientific Research, **Emily Brodsky**, professor of Earth and planetary sciences, co-invented what she calls "a somewhat gentler approach."

Like a plunger unclogging pipes, the new pumping technique pulses water already in the rock back and forth at a certain frequency, cleaning out dirt, salts, and other materials that have plugged up naturally occurring fractures. The method would also be useful for tapping hot water or steam for geothermal power, cleaning water wells, or environmental remediation, Brodsky said.

Brodsky E, Candela T. Determination of the optimal fluid pulses for enhancement of reservoir permeability and productivity. U.S. Patent 10513909, filed June 20, 2016, issued December 24, 2019.

Foamy carbon

Supercapacitors, fast-charging energy storage devices that deliver power quickly, could help make recharging electric vehicles as fast as filling the tank, but they require materials with a high surface area-to-volume ratio. The carbon foam co-invented by professor of chemistry **Yat Li** may more than meet this need. Wrapped in a unique structure of interconnecting pores ranging in size from one micron to less than two nanometers, the surface area in just one gram covers nearly six basketball courts.

The inventors have shown the material could serve as an electrode for a potentially better supercapacitor—it is electrically conductive, chemically stable, and can be 3D printed. But it will likely also have other applications, Li said: "It's just a very useful material."

Li Y, Zhang F, Liu T. Three-dimensional porous carbon foams for supercapacitors. U.S. Patent 10526203, filed March 15, 2017, issued January 7, 2020.

Goodbye perchlorate

Perchlorate, a toxic chemical used in producing rocket fuel and ammunition, often becomes a dangerous contaminate of groundwater near industrial sites. Professor of chemistry **Scott Oliver** co-invented a potentially more efficient way to remove the problem perchlorate using a metal organic polymer.

This positively charged material traps only the negatively charged perchlorate ion, unlike the polymers used in conventional methods, which bind all of the various negative ions typically found in water. It therefore clears more perchlorate faster. "It has the highest capacity of any method," Oliver said. The material is also reusable: the reverse chemical reaction removes the perchlorate for disposal and recovers the polymer for indefinite rounds of decontaminating.

Oliver S, Colinas I. Methods for removing perchlorate from water and vessels and systems for practicing the same. U.S. Patent 10597312, filed March 15, 2016, issued March 24, 2020.

Faster chip design

When designing a computer chip, engineers write a program to describe the chip's components. Software then optimizes and translates the code into a map of the chip. To ensure an optimum design, this translation process—which can take hours—must be repeated whenever the code is edited, even if it's just a tweak.

To make the procedure less arduous, professor of computer science and engineering **Jose Renau** co-created a software tool that, after the initial round, translates only what's necessary while maintaining the optimum chip design. "You don't have to redo everything," he said. The new tool means a more efficient incremental approach to chip design, reducing the compute times from hours to seconds.

Renau J, Posignolo RT. Interactive incremental synthesis flow for integrated circuit design. U.S. Patent 10614188, filed June 30, 2017, issued April 7, 2020.

Breaking DC circuits

Circuit breakers prevent electrical fires by opening the circuit when the current is too high due to a fault. When electric current crosses the opening, an arc forms, but is extinguished once the current flips to the opposite direction, as is the case with the alternating current that's standard in the U.S. But with the direct current increasingly common with solar power systems, battery storage, and ship and aircraft power, a different kind of breaker is needed.

In response to high current, a new DC breaker designed by professor of electrical and computer engineering **Keith Corzine** produces a lower current through a transistor, which then shuts off the arc. The new device automatically responds to a fault in microseconds, Corzine said, about ten times faster than conventional DC breakers that rely on current sensors.

Corzine K. Circuit breaker for DC circuits using coupled induction. U.S. Patent 10389104, filed January 6, 2016, issued August 20, 2019.

ADAPTABLE ACADEMICS

Amid pandemic upheaval, flexibility finds opportunity

▶ In March 2020, just after the COVID-19 pandemic abruptly turned the world upside down, Music Department lecturer **Brian Baumbusch** spent a sleepless night alternating between attending to his baby and anxiously pondering how he would manage during lockdown as a musician, composer, and leader of UCSC's two Balinese gamelan ensembles (beginner and advanced). By the morning, he had devised a plan that would allow him to pursue his passion for composing polytempo music while supporting the Wind Ensemble at the same time.

By Mary-Russell Roberson

Spheres float above the UCSC campus, waiting to be explored by visitors' avatars in the virtual hub of *What Makes Us Human: An Art + Genomics Convergence*. Presented by the Sesnon Art Gallery and sponsored by the OpenLab Collaborative Research Center and the Genomics Institute, the exhibit was available online from November 12, 2020, to June 30, 2021. Credit: Courtesy of Jennifer Parker.

Meanwhile, **Ari Friedlaender**, an associate researcher at the Institute of Marine Sciences and associate adjunct professor of ocean sciences and ecology and evolutionary biology, his research in Antarctica canceled, sat trapped on a cruise ship, desperate to get home to his pregnant wife. When he finally made it back to California, he was struck by the absence of boat traffic on the Monterey Bay. How might this newly quiet environment, he wondered, be affecting the humpback whales?

About the same time, **Jennifer Parker**, professor of digital arts and new media, was scrapping her plans to bring visiting artists to campus to brainstorm potential collaborations with faculty at the Genomics Institute. With everyone stuck at home, she started thinking, "How can we be alone together?" Drawing on her longstanding interests in new media and facilitating community, she decided to create a whole new world.

These faculty and others not only found resourceful ways to continue their scholarship, in many cases they created work and conducted research that the pandemic compelled and made possible. "People have learned a lot about their ability to be resilient," said **John MacMillan**, then associate, now interim vice chancellor for research and professor of chemistry and biochemistry.

Dealing with it

In a year of unprecedented hardships—isolation, sickness, death, the trauma of racism, wildfires, political division—the burdens affected most but were not spread evenly. Pandemic restrictions were more onerous for some than others. While computer scientists apparently prefer to work remotely from home, it's not as straightforward for lab and field scientists, humanities faculty barred from archives, artists without audiences, and anyone needing to travel. Working remotely is also much more difficult for people who had to—as many did—simultaneously take care of children, elderly parents, or other dependents.

"It's a very uneven picture," said **Scott Brandt**, professor of computer science and engineering and now former vice chancellor for research."But many, many people suffered deeply because the work they do requires physical access to people or equipment. At the worst of it, there were profound impacts that were pretty devastating."

Yet despite everything, people in the UCSC community kept working. While the media spotlight shone on the rapid establishment of a COVID testing lab and the SARS-CoV-2 genome browser, faculty across all the campus's five divisions rose to meet the challenges posed by the pandemic. Field researchers formed pandemic bubbles so they could safely stand side-by-side to roll 800-pound elephant seals onto a sling for weighing. Archaeologists caught up on publishing reports from past field seasons and used Google Earth to scope out potential sites for future seasons. The Mary Porter Sesnon Art Gallery mounted online shows complete with a virtual model of the gallery. And the UCSC librarians made more information available digitally than ever before.

In sync in isolation

Brian Baumbusch loves composing polytempo music, which uses different tempos for different players, but his compositions can be challenging for musicians, who naturally tend to synchronize with their neighbors. Pre-pandemic, Baumbusch

solved this problem by giving each musician an ear bud with a pre-recorded click-track, essentially a personalized metronome.

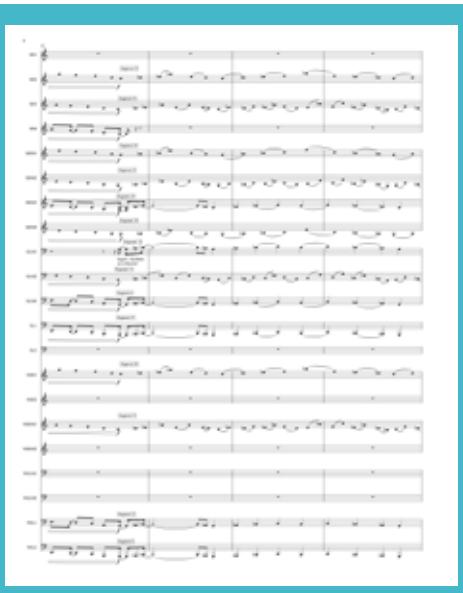
Just before the pandemic, Baumbusch had written a polytempo piece for five players. During his sleepless night, he realized the new conditions were strangely perfect for creating a piece for a much larger ensemble. Everyone could record their parts at home using click-tracks, without having to fight the urge to get in sync with others. "The pandemic opened the door to a really complex musical idea that would have been much harder to do if we were all in the room together," Baumbusch said.

First, he needed to find a large group of musicians. So, he texted his colleague, lecturer **Nat Berman**, director of the Wind Ensemble, on March 15: "Do you know the status of Wind Ensemble for spring?" Berman, who was wondering how he could teach the Wind Ensemble class remotely, immediately texted back, "Why? Do you want to write us a click-track piece we can record?" By March 23, just a week before the first (virtual) meeting of the Wind Ensemble, Baumbusch began composing.

Baumbusch built the score as the spring quarter progressed, writing all the parts in short fragments of a few seconds to a minute in length. Students signed up for fragments each week, downloaded the click-tracks, recorded their parts (usually on their cell phones), and sent them back to Baumbusch, who combined the recordings to create the piece.

If students were puzzled while recording the strange little fragments of music, Baumbusch won them over the first time he played them a finished section of the piece. "It was completely thrilling," Berman said. "The students were really gobsmacked. They were extremely happy to hear themselves together, having been playing alone in bedrooms, especially because some of the fragments felt very abstract to them, as opposed to melodic."

Despite its high-tech creation and production, the finished composition, *Isotropes* (listen here: https://soundcloud.com/brianbaumbusch/isotropes), brings to mind sounds of nature. One of its four movements is called *Murmuration,* a term that refers to flocks of starlings dipping and diving to create beautiful, ever-shifting shapes. "Every bird in a murmuration has its own pattern of getting there, but it still gets there," Baumbusch said. In a similar way, each fragment of music, like each individual bird, moves at a different speed and direction, but they all come together to create mesmerizing, coherent music.



Left: Parts of music lecturer Brian Baumbausch's polytempo composition *Isotropes* were inspired by the mesmerizing movements of flocks of starlings, called murmurations, like this one at Ham Wall nature reserve in Somerset, U.K. Credit: Tony Armstrong-Sly (CC BY-ND 2.0). Right: An excerpt from the score of *Isotropes,* beginning at measure number 22. Each fragment of *Isotropes* can be played by a wide variety of instruments as indicated by the codes at left. SH stands for "sustaining high" and could be played, for example, by a piccolo. SHM stands for "sustaining high mid" and could be played by instruments like clarinets or trumpets. Non-sustaining (NS) parts can be played by instruments such as harp, piano, and percussion. Credit: ©Brian Baumbusch, 2020, with permission.

After the Wind Ensemble's premiere of the piece in June, the Cal State Fullerton Wind Symphony began to record *Isotropes*. The music wouldn't exist if shelter-in-place orders hadn't isolated the musicians. "We took advantage of the unique circumstances," Baumbusch said, "to create something we couldn't have done any other way."

Ari Friedlaender, associate researcher at the Institute of Marine Sciences, shown here (left) on the lookout for whales during a sampling field trip, took advantage of pandemic-quiet waters of Monterey Bay to study how noise affects stress hormones in humpback whales. The research, which is being conducted under the appropriate animal-research permits, involves collecting blubber samples from the whales with the harpoon shown on the right, fired from a crossbow. Credit: Courtesy of Ari Friedlaender.

Boats be gone

Early March found Ari Friedlaender in Antarctica, on that previously mentioned cruise ship. But unlike the other passengers, he wasn't sightseeing—he was conducting whale research. Then, due to the quickly emerging threat of the pandemic, the ship was denied entry at its scheduled port in Chile and forced to find another, becoming the last ship accepted at Port Stanley in the Falkland Islands before it shut down too. The ship's passengers, including Friedlaender, waited in quarantine for 10 long days until the authorities shuttled them straight to the airfield for flights out. During the weeks-long saga, Friedlaender experienced firsthand the physical manifestations of stress, losing 20 pounds and developing painful back spasms.

Back in Santa Cruz at last, Friedlaender's thoughts pivoted from his stress to that of humpback whales. Scientists have hypothesized that noise from boat traffic stresses whales by interfering with their ability to communicate with each other and find food. And now? Many fewer boats. Friedlaender realized he had a once-in-a-lifetime opportunity. He could measure the levels of stress hormones in Monterey Bay humpbacks during this lull, and then compare them to levels in the following year, when the bay returned to its normal noisy condition. He had to hurry, though, before boat traffic picked back up. The Marine Mammal Center in Moss Landing, one of the few organizations not shuttered by the pandemic, agreed to supply a boat and a captain.

Out on the water by mid-April, Friedlaender collected blubber samples from 45 whales. Graduate students—masked, socially distanced, and with staggered work hours—analyzed the samples in his lab. For both quiet 2020 and noisy 2021, the team plans to correlate hormone levels with records of boating activity in the Monterey Bay, as well as the sound recordings of the bay collected continually (really—listen here: https://www.mbari.org/soundscape-listening-room/) by the Monterey Bay Aquarium Research Institute. They're also collaborating with Atlantic coast colleagues conducting a similar study on humpbacks in the Stellwagen Bank National Marine Sanctuary off the coast of Massachusetts.

Pre-pandemic, Friedlaender studied the foraging behavior of humpbacks, not their stress hormones. However, "If we can do something to show the impact of sound on local wildlife, we should," he said. "I want people to think about how human activity affects these animals."

Adaptable academics

Virtual community

The isolation brought on by the pandemic inspired a team assembled and led by Jennifer Parker, founding director of the OpenLab Collaborative Research Center. Their pandemic plan? To create a virtual reality gallery intended to encourage conversations among scientists, artists, and others. "The whole concept is brand new, spearheaded by this moment," said Parker.

Before the pandemic, Parker had been working with **Isabel Bjork** and **David Haussler**, executive director and scientific director, respectively, of the Genomics Institute, on projects aimed at sparking in-person conversations around genomics and art. With in-person no longer possible, Parker reached out to **Colleen Jennings**, technical coordinator for digital arts and new media, and **Shelby Graham**, director/curator of the Sesnon Art Gallery, to explore potential virtual opportunities.

Online visitors to their creation, *What Makes Us Human: An Art + Genomics Convergence,* can explore three-dozen projects, each covering topics as wide-ranging as genomics, evolution, beauty, race, and gender. "Trying to put those things in conversation with each other is challenging,

In the virtual hub of *What Makes Us Human: An Art + Genomics Convergence,* online visitors—as avatars of themselves—could enter the spheres, as shown here, to explore, learn, and converse with other visitors. Credit: Courtesy of Jennifer Parker.

but that's what universities are for," Parker said. While most projects were developed by people at UCSC, others were contributed by people likely to have been visiting artists if not for the pandemic, including Angélica Dass (Humanae), and Gina Czarnecki (the Heirloom Project).

Each project has its own sphere that can be explored on a website or in a "virtual hub." On the website, visitors can click on the spheres to learn more about each project. But much more is possible in the virtual hub. Visitors become avatars, able to move around in virtual space, look inside spheres, and interact with other visitors to share reactions to and discuss the different projects. Why spheres? Parker, a sculptor, prefers three dimensions to two. "The internet is trillions of pages, they are all flat, you have to scroll, and you don't go inside of them," she said.

The team had originally planned to install *What Makes Us Human* in the virtual Sesnon Gallery Jennings had already built, but they soon realized, Parker said, "the sky was the limit." And that's why one of the four galleries in the project's virtual hung in the sky above the Santa Cruz campus. "There's no way we could have done this exhibition in the physical gallery," said Graham.

Back to normal?

What will research at UCSC look like as the pandemic subsides—hopefully—in the face of vaccines and herd immunity? For many faculty members, just returning to campus will do much to bring back their "normal." For archaeologists and others who work in countries where vaccination is proceeding slowly, normal still may be years away.

Some adaptations to pandemic restrictions may stick, such as video conferencing in place of travel and an increased emphasis on digital lending through libraries. University Librarian **Elizabeth Cowell** said, "I always describe the library as having three locations: Science & Engineering, McHenry, and online. It will be interesting to see what that third presence becomes as we reopen to a hybrid environment."

Parker thinks virtual hubs like the one she and her team created for *What Makes Us Human* will continue to grow in popularity because they let people experience a virtual environment in a way that's more satisfying and immersive than posting, clicking, retweeting, and scrolling. She has started teaching hub-building in her classes and is working with Bjork and others on campus to expand opportunities to participate and develop virtual hubs across the arts and sciences. "There is a digital renaissance happening, and the pandemic is pushing it farther and quicker than before," she said. "It's the beginning of what's possible for us."

By Jack Lee

Digital detectives

Advancing human rights through internet investigations

In the summer of 2020, the killing of George Floyd sparked Black Lives Matter protests across the country, including the one shown here, in Seattle. While most demonstrations were peaceful, photos and videos from some events captured shocking examples of police aggression. Open source investigators have collected this information to document the extent of the violence directed against protesters, journalists, and others. Credit: Kelly Kline (CC BY-NC-ND 2.0).

Demonstrators flooded the streets across the United States and around the world in the summer of 2020, outraged by a ten-minute video—filmed on a cell phone and viewed by millions on social media—documenting the horrific killing of George Floyd by the police. Though most events remained peaceful, some didn't. Videos and photos from Black Lives Matter demonstrations across the country—also posted to social media—captured more than a thousand incidents of police responding with seemingly unwarranted aggression towards protesters, journalists, and medical volunteers.

Two novel organizations collected and analyzed this content: Bellingcat (a Netherlands-based, "independent, international collective of researchers, investigators, and citizen journalists") and Forensic Architecture (a research agency at Goldsmiths, University of London). Together, the teams created an interactive data visualization of where and when violence occurred. The digital compilation highlighted the police's excessive use of kinetic impact projectiles (rubber and plastic bullets) and chemical agents. In a similar way, social media has been instrumental in identifying individuals involved in the January 6, 2021, attack on the U.S. Capitol. According to court filings, federal investigators received more than 210,000 tips, many including video and photos that the insurgents and witnesses had posted to social media.

Such "open-access" evidence is available to anyone with a computer and internet connection—if they know how to find it. Working in the Human Rights Investigations Lab for the Americas, UC Santa Cruz students have become adept at this new type of research, using it to investigate protests in Chile, COVID-19's spread in Latin America, the extent of online disinformation about the Black Lives Matter movement, and other matters that remain confidential. "I have the privilege," said associate professor of Latin American and Latino studies **Sylvanna Falcón**, the lab's founder and director, "to work with amazing students."

New tools

While human rights investigations traditionally relied on interviews and on-the-ground reporting, widely adopted technology now provides another, increasingly important source of information. Cell phone cameras allow anyone to take video and photos, which social media can then rapidly spread around the world. One of the earliest to recognize the potential value of this content was Bellingcat founder Eliot Higgins. Higgins, a former administrator, began his online investigative efforts in 2011 while viewing the surprisingly copious footage he had found online from conflicts in Libya and Syria. "Hardly any of that was making it onto the news," said Giancarlo Fiorella, a Bellingcat investigator and Latin America specialist who has helped train the UCSC students.

Higgins became an expert on weapons used in the Syrian civil war by examining the large number of posted YouTube videos, discovering the army's use of homemade cluster bombs, documenting their use of

chemical weapons, and noting the rebels' reliance on Yugoslav-made guns. In 2014, he founded Bellingcat to perform more such investigations, including the crash of Malaysia Airlines Flight 17 in Ukraine that year.

Human rights organizations have also begun using the open source approach for their investigations, with Amnesty International (AI) an early adopter. In 2016 and 2017, AI investigators confirmed attacks by Myanmar forces against the Rohingya minority by matching features in videos and photos of burning villages with satellite imagery on Google Earth. These findings enabled them to refute the Myanmar government's claims that military operations had ended.

Journalists have also adopted open source investigative methods. Rather than replacing traditional reporting, however, these methods are more appropriately thought of as useful additions to the toolkit, said Christiaan Triebert, a former Bellingcat investigator and now a reporter on the visual investigations team of the *New York Times*. "You can use all of that openly available information to further your story," he said. For example, the team's video feature "How George Floyd was killed in police custody" used security camera footage, police scanner audio, and bystanders' videos, in addition to documents and reporting, to construct a detailed timeline of Floyd's final minutes.

Free for all

"The strength of open source investigation is that everyone with a laptop and an internet connection can do it," Triebert said. AI, for example, has embraced open source methods, crowdsourcing investigations with their Amnesty Decoders platform by recruiting thousands of volunteers to evaluate evidence, like satellite photos and Twitter posts. In addition, their Digital Verification Corps program provides in-depth mentorships for students at partner universities around the globe. "The idea is to train the next generation of human rights researchers who can integrate open source methods into their work," said Mitchell Paquette, coordinator of the Digital Verification Corps.

Top: In the fable titled "Belling the Cat," a group of mice hold a meeting to discuss how to counter a ferocious cat. One mouse suggests hanging a bell around the cat's neck, so they can be warned in advance. The other mice rejoice at the brilliant plan until one mouse stands up and asks, who will volunteer to put the bell on the cat? The fable serves as both the name and mission for Bellingcat, an open source investigation group launched in 2014. Credit: Milo Winter (public domain). Bottom: Three days after the group Bellingcat was founded in 2014, Malaysia Airlines Flight MH17 crashed in Ukraine. Bellingcat investigators used publicly available data, such as a tweet showing the smoke trail of the missile that downed the plane, to assemble a timeline of events related to the disaster. Credit: Bellingcat (public domain).

UC Berkeley, the founding university in the Digital Verification Corps, established its Human Rights Investigations Lab in the Human Rights Center (HRC) in the fall of 2016. Since then, Berkeley students from dozens of majors and minors have worked in the lab to help support the work of advocacy organizations, legal partners, and news organizations.

"It's a new age of student involvement with human rights work," said Andrea Lampros, associate director and co-founder of the HRC Investigations Lab. "The work gives students a rare chance to collaborate with real-world partners while leveraging university resources to promote human rights," she said. Lampros also serves as the lab's "resiliency manager," providing training to the Berkeley and UCSC student investigators on how to think about and mitigate secondary trauma potentially caused by exposure to graphic videos and photographs.

Signing on

Tapping the experience of the Berkeley group, Falcón established the UCSC Human Rights Investigations Lab in the fall of 2019. In the first year, students undertook projects to examine massive protests against social inequality in Chile, motivated by reports from classmates studying there. As with the George Floyd demonstrations, some of these protests turned violent as

police employed tear gas, water cannons, and other repressive tactics against protesters.

The work was very much student-initiated and student-driven, Falcón said. In one report, students from UCSC and Berkeley worked together to explore the discrepancy between violent imagery on social media and the Chilean government's account of events. In a second report, students honored some of those who died during the protests. In a third report, students detailed the days leading up to the death in jail of prominent activist Germán Aburto.

Finding content is just the first step. "Once we find images and videos we think could help us, we have to verify them, to know they're from a reliable source and actually showing us the truth," said **Yoselyne Cerros**, who completed her second year as one of the lab's undergraduate researchers. That means matching up details in a photo or video with what's available on Google Maps or Google Earth. Clues, like a bus with an area code or a store name, can sometimes confirm an image's location, Cerros said.

Verification is crucial given the prevalence of false information, or "disinformation," often intentionally spread by officials as propaganda. This past year, one student group investigated how government officials in Latin America reported on COVID-19 to the public. Scouring Facebook and Twitter posts, they created a timeline of milestone events, like each country's first case and death, to identify trends among Latin American countries. "We've been surprised at how different governments have responded," said **Monica Mikhail**, a Ph.D. candidate in anthropology and one of the lab's graduate student researchers. They found, for example, that Brazil and Venezuela spread a good deal of disinformation about medical treatments.

Above: The UCSC Human Rights Investigations Lab launched in 2019 with an initial group—most seen here—of 17 undergraduate and 3 graduate students. Their diverse backgrounds and wide range of academic disciplines enabled the student researchers to contribute unique perspectives to the team investigations. Credit: Sylvanna Falcón, with permission. Below: Due to the COVID-19 pandemic, the most recent cohort of student researchers met and performed investigations remotely. One group, including both undergraduate and graduate researchers, examined social media posts by Latin American government officials and institutions about the pandemic. They prepared a preliminary research report detailing whether countries spread disinformation as well as an interactive timeline of pandemic milestones, shown here. Credit: Human Rights Investigations Lab (public domain); photograph: Igor Romero (CC BY-SA 2.0).

The skills learned by the students have changed how they now approach information. "When I look at something and go through my Twitter feed, I feel like I have these glasses on that really show me the real world," said Cerros. With the aim of propagating these skills and further professionalizing the field, the Berkeley Human Rights Center and the United Nations High Commissioner for Human Rights co-published in 2020 the *Berkeley Protocol on Digital Open Source Investigations*, the first global guidelines for conducting digital investigations. The *Berkeley Protocol* gives investigators guidance for finding and verifying information and details steps they should take to protect themselves and others, including sources, who become involved.

Especially because of the increasing amount of disinformation being spread via social media, "We're going to be seeing a lot more teaching and training related to open source investigations and digital fact-finding," said Lampros. Efforts to expand the work are already underway: the 2021 UC Multicampus Research Programs and Initiatives competition awarded a $780,000 grant to UC Berkeley, UCSC, and UCLA to establish the UC Network for Human Rights and Digital Fact-Finding, and fund a third investigations lab at the UCLA Promise Institute for Human Rights. The expansion fits with Bellingcat's and the general philosophy of others for open source investigations. "We want everyone to be able to do this," said Fiorella, "The more people the better."

By Ben Shouse

Coral as capital

Showing how coastal conservation pays off

In October 2020, Hurricane Delta smacked the Yucatan coast just south of Cancun. While it largely spared homes and businesses, it "ransacked" the coral reef just offshore, as newspapers reported. For declining coral ecosystems, already weakened around the world by climate change, such storms can be the breaking point.

But this time, the reef carried some unprecedented protection: an insurance policy. The claim paid out $850,000 to help stabilize the reef and reattach fragments of surviving coral.

Key to making this scheme a reality was the work of research professor **Michael Beck** and his team at the UC Santa Cruz Institute of Marine Sciences' Coastal Resilience Lab. Their extensive research has shown how coastal ecosystems—reefs, mangroves, and salt marshes—constitute tangible financial assets, "natural defenses" that dampen storm waves to prevent flooding. They argue that such "natural capital" is a sound investment because it often shields the coast from damage more cost effectively than any artificial barrier.

The heart of the team's work is putting dollar values on the flood protection provided by natural habitats. This accounting underlies the first rigorous estimates of the global flood protection value of coral reefs and mangroves: $4 billion and $65 billion every year, respectively. At a more local scale, their work is helping to steer disaster preparedness and recovery funding toward conservation. "Most of the money currently goes to artificial solutions, which further degrade ecosystems," Beck said, "We need to do some jujitsu on disaster spending, or we're going to lose more habitats."

Top: In Cancun, Mexico, like in other beachfront resort areas around the world, coral reefs help protect high-value property. Thanks in large part to research professor Mike Beck, who holds UCSC's new AXA Chair in Coastal Resilience, and his research group in the Institute of Marine Sciences, a nearby reef carries the world's first insurance policy on a natural structure. Credit: SnappyGoat.com (public domain). Above: Research by Beck and the Coastal Resilience Lab team has shown that the roughness of hard, shallow reefs like this one dampen the energy of incoming storm waves, often protecting people and property onshore better than artificial defenses. Credit: Kydd Pollock (CC BY 2.0).

Building consensus

For decades, ecologists have studied and quantified how people benefit from coastal conservation through, for example, fishing, tourism, and flood protection. But they typically use ecological models that are unfamiliar or novel to engineers and insurers, Beck said. "The most important thing we've done," he said, "is to go to stakeholders and decision-makers and say, 'Let's see if we can figure out how to include nature in your engineering and risk assessment models."

Figuring that out in a way that suits everyone is a difficult task. Insurers need to be convinced that they can treat habitat like built structures in their models. And conservationists need to believe that they can protect biodiversity at the same time as people and property. In the Cancun example, The Nature Conservancy, insurance company Swiss Re, and the state government of Quintana Roo, Mexico, all ultimately agreed on a framework that tied ecosystems and infrastructure together with enough rigor and detail to develop an insurance policy that covers storm damages to the reef. Beck's team was a key partner in the development from the beginning. "Getting these different disciplines to talk to each other and build an integrated model, so that you could actually decide, is a very rare talent," said Glenn-Marie Lange, an economist and chief technical adviser for the World Bank's Natural Capital Accounting program.

Elsewhere in the world, Beck has led research aimed at supporting other local conservation efforts. One such study showed that restoration of salt marshes and oyster reefs on the U.S. Gulf Coast could produce $7 in flood protection benefits for every dollar spent in habitat restoration. In the Caribbean nation of Grenada, Beck worked with associate research professor **Borja Reguero** to help design a coral restoration project for flood protection and to slow further damage to the coastline from erosion.

Climbing onboard

According to his many collaborators, Beck's success stems from his ability to straddle multiple disciplines—and his collegiality. "He's really good at understanding things outside his expertise," said **Curt Storlazzi** (Ph.D. '00), a frequent Beck collaborator and research geologist at the U.S. Geological Survey. "There's a lot of great scientists, but there's very few great scientists you actually want to work with."

Along with insurance companies, other deep-pocketed institutions have climbed onboard Beck's conservation train. The World Bank has used his team's work to support its funding of mangrove restoration in the Philippines. The Federal Emergency Management Agency is making it easier to fund habitat restoration for flood protection instead of just dikes and seawalls. In late 2020, the Department of Defense announced a funding initiative—"Reefense"—to spur research on "self-healing, hybrid biological and engineered reef-mimicking structures" to protect military installations and personnel. And capping the year 2020, the global insurance company AXA funded a €1 million ($1.19 million), five-year grant to UCSC, naming Beck to the AXA Chair in Coastal Resilience.

Mike Beck counts Olympia oysters on Vancouver Island. Studying these healthy populations has helped his team set reasonable goals for oyster restoration in Puget Sound. Credit: Brian Kingzett, with permission.

One limitation of the work, Beck said, may be its emphasis to date on conservation near high-value property. Something like the Cancun reef insurance arrangement is "not even an option" in less-developed southern Belize, said **Lisa Carne** (B.A. '93), founder and executive director of Fragments of Hope, a Belizean nonprofit focused on reef restoration.

To address this concern, Beck is broadening his approach. One research proposal, for example, would engage community stakeholders in Florida, the Virgin Islands, and Belize in finding ways to reduce the vulnerability of low-income people to storms. Still, finance needs to stay in the picture, said Maya Trotz, a collaborator on the proposal and associate professor of civil and environmental engineering at the University of South Florida. "Until we get out of a system where so much focus is placed on economic value," Trotz said, "I do think we have to play the game."

By K. M. Watson

Prison break

Challenging what is, imagining what could be

▶ The wide-ranging art project *Barring Freedom* delves into unsettling aspects of prisoners' lives, with prison factory American flags, troubling sounds from Chicago's Cook County Jail, letter descriptions of an imagined garden. In one piece included in the UC Santa Cruz project's recent exhibition co-organized with the San José Museum of Art (SJMA), artist Titus Kaphar suspends words excerpted from court documents by poet Reginald Dwayne Betts across a large portrait. The words tell the story of a Black father of three jailed for 23 days and forced to clean feces and blood from the floors, all because he couldn't pay court fines. His detention also cost him his job.

Top: Conceptual artist Hank Willis Thomas used a photograph of prisoners grasping a Nazi concentration camp barbed wire fence to create his bronze sculpture, *If the Leader Only Knew,* 2014, included in the *Barring Freedom* exhibition. Part of a series, the piece casts "the current state apparatuses of prisons, jails, and detention within a wider history of racism and dehumanization." Credit: ©Hank Willis Thomas, courtesy of Hank Willis Thomas and the Jack Shainman Gallery, New York.

Focused on historical and structural racism in the criminal justice system, the collaborative *Barring Freedom* exhibition at the San José Museum of Art featured the works of more than 20 contemporary artists. Displayed here are Sharon Daniel's *Undoing Time/Amends/Excessive Force,* 2016, with a prison factory flag; Levester Williams' *Tar Ball,* 2014, made using unwashed bed sheets taken from a Virginia penitentiary; and Dread Scott's *Stop*, 2012, a video installation of Black men from both sides of the Atlantic recounting their experiences of being stopped by police. Credit: Impart Photography, courtesy of San José Museum of Art and UCSC Institute of the Arts and Sciences.

By highlighting one man's experience, Kaphar and Betts seek to draw attention to the criminal justice and prison system's devastating and long-lasting impacts on the lives of those it ensnares, even for the most minor offenses, and the pervasive social and economic destruction and upheaval it causes. According to a 2020 report from the Prison Policy Initiative, the United States has the highest incarceration rate in the world, with 2.3 million people behind bars in more than 7,000 correctional facilities. Of those imprisoned, the majority are not accused of serious crimes but are charged with misdemeanors or noncriminal violations. And most are Black or brown.

Activists, including many UCSC scholars and artists, have long sounded the alarm over structural racism and mass incarceration. In May 2020, however, the killing of George Floyd beneath the knee of a police officer raised the calls to action to a much higher pitch. Thousands marched around the world with demands to end racist institutions and practices. Shouts and signs of "defund the police" scared many who thought it meant no constraints

Prison break

To create this portrait, artist Titus Kaphar and poet Reginald Dwayne Betts tapped material from lawsuits filed by the Civil Rights Corps on behalf of people imprisoned because of their inability to pay court fees. Words float over the portrait, telling the story of a man jailed for 23 days because of unpaid traffic tickets. *Redaction (In Alabama 6),* 2019, etching and silkscreen on paper, 30" x 22". Credit: ©Titus Kaphar, courtesy of Gagosian.

on crime. But those envisioning radical change in the criminal justice system say it would mean less crime because the new practices and institutions they call for would help ameliorate the conditions that cause crime in the first place.

"The abolitionist imagination allows us to imagine other ways of addressing issues of safety and security," distinguished professor emerita of feminist studies **Angela Davis** told the *New York Times* last October, following the massive summer protests for policing reforms. "Most of us assume that when it comes to public safety, the police are in charge. When it comes to issues of harm in the community, prisons are the answer. But what if we imagined different modes of addressing harm, different modes of addressing security and safety?"

The multifaceted *Barring Freedom,* together with its offshoots, *Visualizing Abolition* and *Music for Abolition,* provides fodder for this imagining. Over the course of a year the project has drawn together 22 artists and more than 35 speakers and 15 musicians. More than 4,000 students nationwide have participated through the study guide and other resources provided by the project's website. "A growing number of exhibitions and art projects are taking up the challenge of revealing the deep social harms enacted by prisons and policing," said *Barring Freedom* co-curator **Rachel Nelson**, director of the UCSC Institute of the Arts and Sciences. "Multiple studies have shown the arts and education can play important roles in addressing systemic inequalities and promoting a culture that prioritizes empathy and understanding."

Long time coming

Barring Freedom grew out of a conversation more than four years ago between Nelson and professor emeritus of sociology **Herman Gray**, an expert in Black cultural politics. At the time, there was growing unrest and anger following abusive and deadly police actions against Black and brown people captured on cell-phone videos. The Black Lives Matter movement had emerged and, together with the power of social media, was driving a new wave of activism aimed at changing the criminal justice system. Long-time activist artists such as Keith Calhoun and Chandra McCormick, known for photographing the Louisiana State Penitentiary for decades, and others, including professor of film and digital media **Sharon Daniel** and jackie sumell, found themselves joined by an emerging new group of artists.

In *Who's that man on that horse, I don't know his name but they call him boss*, 1980, an archival pigment print, a guard stands watch over prisoners working farmland in Louisiana that was once cotton and sugarcane plantations tended by enslaved people. The stark image is part of the series *Slavery: The Prison Industrial Complex* by longtime documentary photographers and New Orleans natives Keith Calhoun and Chandra McCormick. Credit: Courtesy of Keith Calhoun and Chandra McCormick.

Gardening from death row

Tim Young makes quite intentional choices for his garden on the UCSC campus, 90 miles from his solitary prison cell in San Quentin State Prison. Each plant has special meaning, explained in letters to his proxy gardeners. About the daisies fronting the door of the garden's prison cell sculpture, he wrote: "Prison cells are often referred to as 'coffins' or 'concrete tombs.' When people enter the cell, they should know it was specifically designed to punish, oppress, and bring about one's demise. Hence, 'pushing up daisies.'"

The *Solitary Garden, UCSC*, part of the *Barring Freedom* project, invites visitors to contemplate Young's severely confined world. Perched on a hillside overlooking Monterey Bay, the sculpture replicates the size of the 6-by-9-foot cell where Young has spent nearly every hour of every day for 15 years following his homicide conviction and death sentence. He proclaims his innocence and has been actively appealing his case, vicariously treasuring in the meantime the garden he envisioned that borders the sculpture.

Most U.S. prisons have places where incarcerated men and women like Young are kept in extreme isolation, sometimes for decades. According to the best estimates of the nonprofit Solitary Watch, at least 80,000 prisoners exist under this condition on any given day. Isolation makes people depressed and puts them at greater risk for physical illness and dying young, said UCSC psychologist **Craig Haney**, a leading expert on the effects of solitary confinement and ardent advocate for its elimination.

The publicly created *Solitary Garden, UCSC*, is one of 17 such gardens around the country orchestrated by artist jackie sumell. Her artwork intentionally involves the community in "planting" hope for prison abolition and the end of solitary confinement. "A *Solitary Garden* is a collaborative social practice that 'seeds' important conversations around alternatives to incarceration," she said. "It asks us to imagine a landscape without prisons."

Jocelyn Lopez-Anleu, a '20 graduate now working as a curatorial assistant at Los Angeles Contemporary Exhibitions, tended *Solitary Garden* as an undergraduate intern with other students and volunteers. Right before the pandemic closed everything down, she and project co-curator Rachel Nelson met Young at San Quentin, an experience Lopez-Anleu described as "one of her most powerful" while working on *Barring Freedom*. For visitors to *Solitary Garden*, "The horrific truth that a person presently exists in those confines becomes apparent," said Lopez-Anleu. "But just next to it are all these plants and flowers that act as an extension of that person's body, mind, and soul."

Volunteers and students serve as proxy gardeners for San Quentin death-row prisoner Tim Young, using his ideas and direction to create and tend *Solitary Garden, UCSC*, 2019. Located on campus at the Elena Baskin Visual Arts Studios, the sculpture and garden installation is one of 17 around the country intentionally built with public participation by artist jackie sumell. Credit: R. R. Jones, courtesy of UCSC Institute of the Arts and Sciences.

Prison break

Adding scholarship and other arts to the mix made sense for *Barring Freedom*, Nelson said, since UCSC is a place where art, research, and activism around prisons have flourished. The focus also perfectly fit one of the campus's three academic priority areas: "Justice in a Changing World." Among those joining up were Davis and project collaborator **Gina Dent**, associate professor of feminist studies, both among the faculty and student founders in 1997 of Critical Resistance, a group formed to challenge the idea that imprisonment and policing can solve social, political, and economic problems. Another was distinguished professor of psychology Craig Haney, who has spent four decades studying the damaging psychological effects of imprisonment and solitary confinement.

Also: anthropology assistant professor **Savannah Shange**, whose research focus includes racism and the Black diaspora; Daniel, whose multimedia artworks explore prison labor politics; and associate professor of art **Dee Hibbert-Jones**, an Emmy-winning filmmaker whose documentaries address racism and crisis in the criminal justice system.

The initial vision evolved over time with the emergence of the coronavirus pandemic and the resulting social constraints. To replace a summit gathering of experts, the collaborators created *Visualizing Abolition*, a series of virtual events held over several months. Streamed live and then archived, each event featured a mix

Giving them a voice

The state of emergency at the pandemic's start prompted Professor Sharon Daniel to create *EXPOSED*. Daniel, a digital media artist with a long history of activism around prison abolition, knew the outbreak would hit incarcerated people hard. She felt a pressing urgency to give them a voice, she said, a way for the public to hear the growing alarm within prison walls.

So, Daniel set aside a long-term project in Alaska and switched to a new one. With no time to apply for grants, she paid a research assistant out-of-pocket, harnessed a team of undergraduate research interns, and had designer/programmer Erik Loyer, a frequent collaborator, modify a web program created for the Alaska project. The hastily assembled team combed through hundreds of text and audio sources as the pandemic unfolded, documenting the pandemic's impact on the imprisoned in an interactive timeline of words, statistics, and sounds.

The catastrophe Daniel had foreseen then exploded. The tight quarters, lack of personal protective equipment, and limited resources for health care provided "perfect conditions for superspreading events," said Thomas Inglesby, M.D., director of the Johns Hopkins Center for Health Security, in a National Public Radio interview. According to The Marshall Project, as of early April 2021, more than 392,500 COVID-19 cases had been reported in prisoners, resulting in at least 2,515 deaths.

EXPOSED joins two other Daniel installation pieces, *Undoing Time|Pledge* and *Amends|Excessive Force*, in *Barring Freedom*, with contingency grants from UCSC's Arts Research Institute and Institute of the Arts and Sciences funding the designer/programmer as well as the hands-free, autoplay version of *EXPOSED* launched online to coincide with the opening of the SJMA exhibition. Daniel hopes to find funding to support her team's ongoing updates of *EXPOSED*. "People inside are trying to take care of each other," she said, "even while the state strips them of any agency or ability to protect themselves, virtually abandoning them to let the virus run its course."

As the COVID-19 pandemic began to unfold, digital media artist Sharon Daniel envisioned an interactive piece that would document its impacts on prisoners and the prison community. This screenshot is from her resulting online documentary and installation, *EXPOSED*, 2020, available on the *Barring Freedom* website. Viewers experience an audio/visual timeline starting with the first infections and then tracking the pandemic's unsettling sweep across the particularly vulnerable prison population. Credit: Courtesy of Sharon Daniel.

More than 35 artists, activists, academics, lawyers, and people formerly or currently incarcerated participated in *Visualizing Abolition*, a series of livestreamed virtual conversations, now archived as videos on the *Barring Freedom* website. During the event *Images, Memory, and Justice*, 2020, human rights activist Bryan Stevenson, founder and executive director of the Equal Justice Initiative, MacArthur Foundation Fellow, and author of the *New York Times* bestselling book *Just Mercy* (Speigel & Grau, 2014), discussed his work with Gina Dent, associate professor of feminist studies and *Barring Freedom* collaborator. Credits: Stevenson, Nick Frontiero; Dent, courtesy of UCSC Institute of the Arts and Sciences.

of artists, activists, scholars, and lawyers. They also added *Music for Abolition*, directed and curated by Grammy Award–winning drummer and composer Terri Lyne Carrington, with the aim of bringing together "musicians across a variety of genres to create a soundtrack—and provide a heartbeat—to our shared struggle for abolition."

Nelson and graduate student **Alexandra Moore**—supported by funding sources including the Nion McEvoy Family Trust, Ford Foundation, and Future Justice Fund—co-curated the exhibition at the SJMA. "The art in this exhibition," said Moore, "is particularly committed to challenging and shifting societal narratives and structures." To this end, she and Nelson chose a diverse group of contributors from across the country to reflect different perspectives and a broad range of policing and prison systems. In shaping the project's in-person—limited, unfortunately, by COVID-19—display, the pair worked with SJMA senior curator Lauren Schell Dickens. Describing the experience, Dickens said, "I'm drawn to projects I can learn a lot from—*Barring Freedom* and *Visualizing Abolition* have been profoundly eye-opening." The exhibition travels to the John Jay College of Criminal Justice in New York this fall.

Imagining the future

The project's website (https://barringfreedom.org) contains everything connected to the project, including the art in the exhibition, music, and archives of the discussions. Crafted by Moore and fellow graduate students **Abram Stern** and **Aaron Mulenga**, the site also offers extensive study guides for exploring each of *Barring Freedom*'s four themes: "the histories that structure our current system of incarceration and policing; the ways the carceral state shapes our vision of the world; bridging the distance between inside and outside the prison; and imagining possible abolitionist futures." The project's creators and collaborators hope that the inspiration, education, and fruitful discussions it offers will help eliminate racism and shape dramatic changes in the criminal justice system. The reach so far, Nelson said, has gone beyond anything they imagined, with tens of thousands of people across the U.S. and around the world attending the online discussion events and other virtual programming.

Grammy musical artist and jazz drummer Terri Lyne Carrington brought together more than 15 musicians for the *Barring Freedom* spin-off *Music for Abolition*. Among those featured in the online collection of original works is Grammy Award–winning trumpet player and multi-instrumentalist Nicholas Payton, shown here. He created *Freedom is No Fear*, 2020, inspired by the American singer and songwriter Nina Simone. Credit: Courtesy of Nicholas Payton.

The project challenges its viewers and participants to think about justice in a new way. In a video created for the website, formerly incarcerated Emile DeWeaver, a co-founder of Prison Renaissance, an art and community-building program that aims to create "transformation to end cycles of incarceration," puts it this way: "Do you believe in universal health care, housing for everyone, and a universal income? Would you want those things in this world? Would you trade prisons and police for that? That's what abolition is."

By Priyanka Runwal

Birds do it

Putting your eggs in more than one basket

Professor of ecology and evolutionary biology Bruce Lyon studies reproductive and social behavior in animals. His research on alternative strategies that female birds use to gain reproductive success seeks to understand how and why some species like American coots avoid parental care by cheating and laying eggs in the nests of other coots. Credit: Elena Zhukova.

▶ Slogging through Canada's Riske Creek wetlands as a graduate student in 1987, **Bruce Lyon** noticed something odd in the nests of American coots. Early in the breeding season, some nests held extra eggs not quite resembling most of the rest. Furthermore, many parent birds had pushed those slightly different eggs aside.

It turns out that, in addition to—or instead of—laying eggs in their own nests, female coots sneak into their neighbors' territories to lay eggs in their nests. Like the infamous cuckoos and cowbirds that evade parenting duties by laying their eggs in nests of other bird species, these ducklike fowl use a similar reproductive strategy, only they commit the offense against their own kind.

"I was so intrigued by this behavior," said Lyon, now a UC Santa Cruz professor of ecology and evolutionary biology. "I thought it was bizarre that they were laying eggs in each other's nests."

For the next three decades, Lyon has worked to understand how and why coots lay some of their eggs in the nests of their fellow coots, a behavior formally called "conspecific brood parasitism." Using coots as his primary model, Lyon aims to determine how this curious cheating by females—also seen in many other animals—might boost their reproductive success. In the bigger picture, the research is helping to explain the ecological and evolutionary basis for the development and persistence of such reproductive behaviors in the natural world.

Biologists have mostly focused on the peculiar strategies used by males within the same species to increase their reproductive success, like guarding mates and sneaky mating, i.e., dodging more dominant males to access females. The use of similarly complex tactics by females has received far less attention. "Males are more conspicuous and easier to study, while females usually play a bigger role at the nest and are more careful and secretive," said Malte Andersson, an emeritus professor of animal ecology at the University of Gothenburg in Sweden. "There's been a general underappreciation of the sophistication of female reproductive behaviors."

In the coots he first observed as a graduate student, Lyon found a career-making opportunity to provide a better appreciation of one such sophisticated female reproductive behavior—the seemingly anomalous strategy of putting your eggs in more than one basket.

Hidden in plain sight

Observations of egg-dumping in same-species nests were not new. They go back to the start of the 20th century, with hunters and specimen collectors writing about occasional encounters with "misfit" eggs in waterfowl nests. On a hunting trip in 1900, for instance, Walter Sampson found two kinds of eggs—nine somewhat darker and slightly larger than the remaining 12—in a wood duck's nest

In addition to laying eggs in their own nests, a variety of birds, insects, and fish lay eggs in, or "parasitize," the nests of other adults belonging to the same species. American coots are among the nearly 250 bird species that engage in this reproductive behavior, provided they can make the extra eggs, find neighbors nesting around the same time, and manage to access their nests. Some coots completely forego nest-building, instead relying only on brood parasitism some years. Credit: Betty Wills (public domain).

in California. In 1922, Donald Dickey and Adriaan van Rossem counted additional new eggs on several days in a fulvous whistling duck nest in California, unusual because of the typical one-egg-a-day laying sequence in most birds.

While these reports were treated as freak cases at the time, we now know better. Lyon and other biologists have to date documented conspecific brood parasitism in 245 bird species—nearly two percent of all known birds. And several experts believe even more birds do it. The challenge to learning more about the behavior, however, comes from the difficulty of detecting it in the field. "It's really hard to pick up," said John Eadie, a Lyon collaborator and the Dennis G. Raveling professor in waterfowl biology at UC Davis. "The eggs of the same species can almost look the same. You have to do detailed, in-depth studies to really spot it."

The eggs of different cliff swallows, for instance, are visually hard to distinguish. To confirm their nest parasitism behavior, researchers marked and tracked more than 200 eggs from 50 nests built by the colony-nesting birds. They also watched a few sneaky swallows laying eggs in their neighbors' nests and even ferrying eggs in their beaks from their own nests to another's when the neighbors

were away. In American coots, moorhens, and several duck species, biologists have observed thousands of eggs each year to spot parasitism-linked extra eggs in nests that would otherwise house only a single new one every 24 hours. In some cases, differences in egg features are a giveaway. In others, researchers have needed genetic analysis to validate that a nest's eggs belong to different females.

As the evidence has mounted, it's become apparent that brood parasitism is most rampant among waterfowl—particularly ducks. Waterfowl have precocial chicks, meaning that the chicks are mobile and can quickly feed themselves, hatching at an advanced enough stage that parental care isn't much needed. The increased prevalence in waterfowl makes sense, Eadie said, as "the cost of being parasitized is probably not very high when the kids are raising themselves."

Recognize and reject

Although not waterfowl, American coots have semi-precocial chicks, which the parent birds feed for the first week or so. These dark-bodied, white-billed bird species live in the shallow waters of lakes, ponds, and marshes, nesting amid reeds in the spring and early summer.

With his survey of 417 nests between 1987 and 1990 in the wetlands of central British Columbia, Lyon was the first to document brood parasitism in coots. His monitoring of each nest at mostly daily intervals spotted the cheating when there were two or more new eggs within a 24-hour period, when egg color differed from that of the host's eggs, and by finding extra eggs in the nest after the host had completed laying her clutch.

Even though coot pairs defend their territory aggressively during the breeding season, Lyon recorded three parasitic eggs, on average, in more than 40 percent of the nests—a substantial addition to a clutch otherwise including, on average, nine eggs. While a quarter of the parasitic eggs came from females with no nests at all, the majority came courtesy of neighboring coots—sometimes multiple females—with thriving nests.

Lyon also noticed that a third of the nearly 600 parasitic eggs he observed were buried under nesting materials the coots had stacked over them, raising the question of whether the birds were recognizing and rejecting them. Indeed, same as him, female coots could tell which of the eggs in their nests belonged to someone else. He confirmed this in a 2003 study, which showed the birds rejecting eggs with coloring different enough from that of their own. When they were uncertain, they banished potentially parasitic eggs to the periphery of their clutch—an inferior incubation position associated with delayed hatching; eggs hatching later pose less of a competitive threat to the bird's true chicks.

In the wetlands of central British Columbia, finding eggs colored differently from the majority in an American coot nest is not unusual. Between 1987 and 1990, Lyon found that 13 percent of the more than 4,500 coot eggs he surveyed were laid by parasitic females. If their color was different enough, host coots rejected the parasitic eggs by burying them into the nest (as seen in the left image). Credit: Bruce Lyon, with permission.

Counting losses

Lyon found that coots also exhibit a remarkable ability to count their own eggs. Like many birds, American coots are indeterminate layers, meaning they use external cues such as number of eggs or their surface area to decide when to stop laying. If they couldn't distinguish between parasitic eggs and their own, the final clutch would contain fewer host eggs. Instead, the coots who recognized parasitic eggs, and later rejected them, didn't alter their egg laying. In contrast, the coots that couldn't tell the eggs apart laid one less egg for every parasitic one in the nest.

Knowing that many parasitic eggs pass the rejection test, Lyon's graduate student **Daizaburo**

Shizuka (Ph.D. '09), now an associate professor of biological sciences at the University of Nebraska–Lincoln, wondered if the coots could further mitigate the costs of nest parasitism by discerning their own chicks.

In the nest, parasitic eggs—although deposited early by sneaky coots—typically hatch later amongst a brood that emerges over several days. In the field, Shizuka and Lyon documented more deaths of parasitic chicks than the hosts' true chicks. This finding led them to suspect that the birds imprint on their own young that arrive early, using them as a template for recognizing the chicks that hatch later.

Former UCSC graduate student Daizaburo Shizuka, now an associate professor at the University of Nebraska, tags coot chicks hatched in incubators from eggs collected in the field before returning them to nests as part of a cross-fostering experiment which showed that parent coots imprinted on the first chicks they were exposed to. Credit: Bruce Lyon, with permission.

To test this hypothesis, Shizuka and Lyon conducted three cross-fostering experiments in wetlands of British Columbia between 2005 and 2008. They controlled the order in which the parents met their young after hatching by presenting them with either their own chick, a parasitic one, or both on the first day, followed by equal numbers of parasitic and true chicks over five subsequent days. Sure enough, the parents used the identity of the first provided chick, host or parasite, to discriminate against the other, which sometimes meant unleashing brutal aggression in the form of pecking and drowning to eliminate the unwelcome guests. "It was really non-random," Shizuka said.

It gets more complicated. Parasitic chicks, although hatching later, usually come from the first few eggs laid by females before they begin laying in their own nests. These early eggs produce duller chicks—a consequence of laying order: chicks from eggs laid later sport ostentatious orange feathering. This means that the duller chicks must compete for food with the host's younger, but showier, chicks born around the same time. At first, parents feed all their chicks on a first-come-first-served basis, but then the more ornamented orange offspring become their priority, and Shizuka and Lyon found that the flashiest chicks receive more food. In an earlier experiment, Lyon and colleagues compared orange chicks with dull ones whose colorful feathers had been experimentally trimmed, showing that the orange ones grew faster and had an increased chance of survival. Additionally, when older, duller offspring tried to steal food from their younger siblings, parent coots aggressively discouraged them. These findings all suggest that survival may be an uphill battle for parasitic chicks.

Why bother?

Despite the multiple lines of defense and extremely limited success in overcoming them, why do birds like American coots continue to make extra eggs and lay them in the nests of others of their own kind? It truly appears related to the old adage advising one to not put all one's eggs in one basket. "Eggs are really cheap for coots," Lyon said, and "babies are expensive." In their own nests, females lay more eggs than they can raise because food availability is often unpredictable and limited. Starvation is a common cause of death among chicks. Given these capricious circumstances, "parasitism gives females a more flexible set of options to customize their reproductive effort," Lyon said.

In nesting females, reproductive enhancement seems to be the likely motivation for parasitism. The total eggs produced by parasitic coots in British Columbia, for example, was greater than the clutch size of nonparasitic nesting coots. By laying eggs in someone else's nest, the former might manage to have more successful offspring as compared to laying all eggs in their own nest. Some experts also think that if nests are preyed upon or destroyed, mothers may find another nest to lay their eggs in.

In the case of non-nesting females, on the other hand, lack of nesting sites or inability to defend territories could push them to make the best of a bad situation. Eadie, for instance, demonstrated

Birds do it

Unlike most bird chicks, which are camouflaged, coot chicks are colorful. Mama coots increase the color-lending carotenoid pigment content in the yolk as egg-laying progresses, thus producing an array of older, relatively less showy to younger, gaudy chicks. Feather manipulation experiments revealed a parental preference for feeding orange chicks. The more orange baby coots become their parent's favorites and get fed more after hatching, disadvantaging duller parasitic chicks born from early-laid eggs. Credit: Bruce Lyon, with permission.

elevated brood parasitism among cavity-nesting goldeneye ducks when he experimentally reduced the number of nest boxes available to them. In American coots, Lyon suspected that the female parasites without nests were younger or in poorer body condition compared to nesting birds, probably lacking the experience and fitness to secure a nest. "Their option is to sulk and lay no eggs or to lay some eggs elsewhere," he said. Some have also wondered if non-nesting females might be professional, lifelong parasites, never making their own nests. But studies following such birds over multiple breeding seasons have shown that they resort to nesting at some point.

Long-term benefit

Unfortunately, female coots don't return to the same nesting grounds year after year, so Lyon and his collaborators have been unable to track individuals to assess how often they parasitize others' nests through their lifetimes, and thereby determine the behavior's potential long-term reproductive benefit.

Female wood ducks are, however, loyal to their nesting spots. With Eadie, Lyon is studying nest-parasitising wood ducks tagged with trackers since 2014 that live in nest boxes in California. Among the questions they're seeking to answer is when and why these fowl switch between laying eggs only in their own nests and additionally in their neighbor's.

While he's partial to birds, Lyon's interest in reproductive parasitism extends to other creatures. Along with UCSC colleagues, Lyon recently reported an unusual case of potential brood parasitism in the nests of two damselfish species that spawn in the coral reefs of Philippine's Calamian Archipelago. These fish appear to foster the young of other adults of their own kind as well as those of another species, all while taking care of their own.

The work is difficult, typically requiring years of painstaking field observation and, increasingly, the use of sophisticated methods such as genetic analyses. But for Lyon, the reward comes from helping to illuminate a previously poorly explored part of nature. "We're taking this behavior that was neglected, seen as unimportant and kind-of flaky, and connecting it to species' life histories," he said. "There are books about alternative mating strategies where it's all about males, with almost zero focus on females. My research shows the value of taking another look."

In California's Sacramento region, wood ducks typically nest in the same wooden boxes year after year. A single nest may contain eggs laid by multiple females. Transponders implanted in the fowl have allowed John Eadie, UC Davis professor in waterfowl biology, and colleagues, including Lyon, to track nearly 700 adult females and more than 5,000 chicks since 2014. In addition to understanding why some mothers foist their parental care duties on others, Eadie and Lyon are collaborating to assess if certain wood duck females pass on the parenting buck every year or mix it up, avoiding nest parasitism only during certain years. Credit: Bruce Lyon, with permission.

By Jennifer Welsh

A short story

By strong example and action, advocating for diversity in science

Above right: Telomeres (pink dots) at the end of chromosomes help protect genetic material from being degraded when cells divide and multiply. The research of Carol Greider has illuminated the cellular mechanisms that keep these caps from becoming too short and promises to provide insights about the biology of age-related diseases and cancer. Credit: National Cancer Institute (public domain). Above: Greider's career-defining discovery of the enzyme telomerase came while studying—as a Berkeley grad student in the 1980s—the molecular biology of this ubiquitous pond dweller, a single-celled, ciliated protozoan in the genus *Tetrahymena*. Credit: Robinson R (CC BY 2.5).

Carol Greider, UCSC's first Nobel laureate, joined the faculty in October 2020. A California native and product of the UC system, Greider has used her prestige as a laureate to fight for diversity in academia. Credit: Wikimedia Commons (CC BY-SA 3.0).

▶ The Nobel Prize weighs about six ounces, but it feels much heavier if you're female. Only 23 women—about 3 percent of the total—have won a Nobel Prize in the sciences. One of these select few is distinguished professor of molecular, cell and developmental biology **Carol Greider**, UC Santa Cruz's first Nobel laureate.

Feeling the weight, Greider has wielded her influence as a laureate to advocate for increased diversity in the research community, working to help ensure women and other scientists from historically disadvantaged groups are free from discrimination and harassment. To this end, throughout her long career, she has spoken out, signed letters, authored op-eds, and joined working groups, in addition to serving as a committed mentor to many students.

"Carol takes this as a duty," said Gisela Storz, a graduate student with Greider in the 1980s, now associate scientific director of the Division of Molecular and Cellular Biology at the National Institute of Child Health and Human Development. "I've always admired her resilience and persistence—she has a voice that people pay attention to."

Greider's resilience and persistence manifested early. In her hometown of Davis, Greider struggled in school with undiagnosed dyslexia. At UC Santa Barbara, where she earned her undergraduate degree, the late Beatrice Sweeney guided her into biological research. She next joined Elizabeth Blackburn's lab at UC Berkeley as a graduate student studying a ubiquitous pond dweller, a single-celled, ciliated protozoan in the genus *Tetrahymena*.

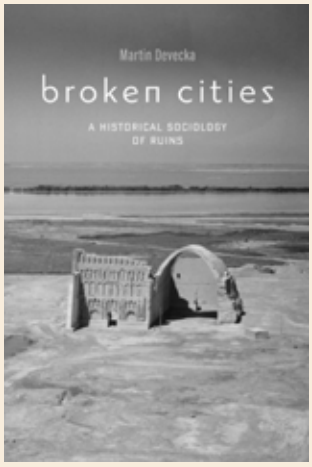
In this model organism for basic research, Greider helped find the answer to the long-standing question of how cells shield the genetic material in their chromosomes from growth-related degradation. During cell division and copying, chromosomes are protected by telomeres, repetitive DNA sequences that cap their ends. But with each division, telomeres get shorter. Greider—as a 25-year-old in 1984—discovered and characterized telomerase, the enzyme that makes sure telomeres don't get too short. The work led to her sharing the 2009 Nobel Prize in Physiology or Medicine with her graduate mentor Blackburn and Harvard University professor Jack Szostak.

Greider's research at UCSC continues to focus on telomeres and the fundamental mechanisms that maintain their length, work that has important implications for human health. Telomeres play a key role in cancer because "to continue dividing indefinitely, all cancer cells have to solve the problem of maintaining their telomeres," Greider said. Knowing how this happens could yield new ways of fighting cancers. Our telomeres also get shorter as we age, and a better understanding of how this happens could help prevent or treat age-related diseases. "We're not going to go from having general lifespans of 120 years to 200," said Greider. "But the number of people who achieve 120 could be higher if we didn't suffer from lethal age-related diseases."

Many mysteries—like why some degenerative diseases are associated with shortened telomeres—still linger at the end of chromosomes for Greider and her new UCSC colleagues and students to solve. "We know very little about the actual regulation of telomere length," she said. "We know how to make telomeres longer with telomerase, but we don't understand how cells maintain this length day-to-day."

By Jyoti Madhusoodanan

Human remains



Devecka's book *Broken Cities* explores how different civilizations created and considered ruins in their own lifetimes. Credit: Johns Hopkins University Press (public domain).

People's choices shape the ruins they leave behind

▶ Top tourist attractions like Tenochtitlan's pyramids and the Coliseum's columns provide fascinating glimpses of faded civilizations, inspiring awe in those who experience them. But how did such crumbled magnificence come to be? According to assistant professor and director of classical studies **Martin Devecka,** the people in the past who left those ruins shaped what we see today, just as we are shaping our cities now.

Modern visitors explore the Pyramid of the Moon at Tenochtitlan on the outskirts of Mexico City. According to Assistant Professor Martin Devecka, Spanish troops led by Hernán Cortés burned temple structures and left stone ruins as symbols to cement their conquest of the Aztec capital city. Credit: MollySVH (CC BY 2.0).

In his book *Broken Cities, A Historical Sociology of Ruins* (Johns Hopkins Press, 2020), Devecka travels through historical writings from four civilizations of the past to arrive at a more nuanced understanding of ruination as a complex social process. The texts he examined range from legal documents and letters, to ancient literature, inscriptions on monuments, and other writings that reveal how people in the past perceived and engaged with their cities. The ruins they left behind reflect deliberate decisions, Devecka argues—they're not just the result of decay after people moved on.

In case studies of classical Athens, late antique Rome, medieval Baghdad, and 16th-century Mexico City, Devecka shows how human choices—apparent in the texts and other materials they produced describing life at the time—shaped what remains of these cities of the past. Political forces, religious beliefs, and cultural symbolism all contributed to decisions to repopulate or abandon a city after a conquest, or repurpose toppled pillars to build a new temple after an earthquake. Yes, military conflict or natural disasters often forced people to choose, but their choices determined what became a ruin, and how.

Ruins have long been viewed through the lens of European romantic tradition, said Brown University associate professor of archaeology Felipe Rojas Silva, an architect by training whose own research focuses on the material remains of ruined cities. Typically, researchers compare and contrast how people from different cultures recorded ruins and engaged with them. "Martin's work is unusual and bold and exciting," Rojas said, "because he's shown connections and continuity within civilizations over time."

We spoke with Devecka about how ruins represent more than mere decay, and how his study of ancient cities suggests we should think about the ruins we're creating in our own time.

What do ancient writings reveal that's not obvious in the ruins themselves? There's a question that archaeologists always ask about a ruin site: what was this used for? I think more about why people stopped using it. It's not a question that you can answer by looking at the site itself. You can say, for example, whether it was burned. But when you look deeper at the site, you see other burn layers where the city had been sacked before, and people just rebuilt it. Why did this particular disaster, this particular sacking of the city cause it to be abandoned afterward? Catastrophe is just the pretext for ruination, not the cause.

How did people in the past think about ruins and their formation? Ways of thinking about ruins are idiosyncratic. In other words, ruins belong to particular times and places—there's not some kind of narrative that starts in one place and ends where we are now.

For example, ruin-making in Greece is really a process of equilibrium. Soon after areas of the city were depopulated, people went back, so in the classical period there are not really any ruins. But in Rome, there's this strong cultural pressure against returning to the city's mythical source in Troy, the city from which Aeneas immigrated. If they re-found it, they might invoke this weird curse from Juno and be conquered by the Greeks again. That's coupled with an interest in making sure the empire has this trajectory toward growth, where all roads do lead to Rome. In medieval Islamic cities such as Baghdad, cities are ruined but not depopulated. Just neighborhoods become depopulated and people kind of learn to live with ruins next door. In Mexico, people deliberately made ruins during warfare. Creating ruins signified conquests, so much so that the glyph for a conquered city is a picture of its main temple burning. Modern Mexico City sits on the ruins of Tenochtitlan, in a way confirming the ruin of the old city.

With so many differences, are there also similarities? Yes, ruins reveal who's in power. Is the urban population allowed to control itself, or is it under somebody else's control? Thinking back to the Ostrogoth king Theodoric, there's a letter in which he tells all these people who've left their cities for fortified hilltops that they need to go back. He is the king of Italy at this point, so you would think he would be in a position of power. But it's clear in that letter that mid-level Roman aristocrats, people who belong to the senatorial class, actually have more control over where the population goes.

Human remains

What are the challenges of studying ruin-making via historical writings? It's challenging to come up with a language to talk about these sites that doesn't necessarily prejudice the results. Not only do all of these different languages have different words for ruins, but the words are often quite different in source and origin. In late antique materials, the Latin word is *ruina,* which refers to something which has collapsed. It stems from a verb that means to rush downward, or to collapse. Whereas in Greek, the word is *erepia,* which has to do with tearing something down. It's an active process that points us toward the agent of ruination. Another Greek word used is *edaphé,* which means basement or foundation, so the ruin is almost perceived as part of a building's architecture.

Why do these nuances matter? Realizing that other people used to think about these sites really differently is a good way of distancing ourselves from our own reflexively held views.

Top: The Ostrogoth king Theodoric (of Italy at the time) repurposed pillars from some ruins to construct new buildings. But he declared others, such as the Forum, as culturally significant monuments to be protected—one of the earliest known rulers to view ruins in this way. Credit: Benson Kua (CC BY-SA 2.0). Bottom: Detroit's Michigan Central Station lay abandoned for decades as the city sprawled outward. In 2018, it was bought by the Ford Motor Company, which has announced plans to repurpose and renovate the building. Credit: Rick Harris (CC BY-SA 2.0).

What is the reflexive, modern perspective on ancient ruins? We tend to think about them as things located in the past, something impossibly distant from us. This very past-focused attitude towards ruins is something that develops in the century where my book ends. It's especially coming into full bloom in the period of Romanticism, where you see this very stereotypical, modern attitude of ruin-gazing. We appreciate it purely aesthetically. It doesn't really matter to us, except in so far as we can look at it.

What are some ruins forming today, and how should we think about them? Fukushima in Japan has certainly emerged as a ruin during our lifetimes. There was one big disaster, but then why didn't people just move back?

There's an obvious answer, which is that it's not safe. But how do people know that? Compare that to the U.S., where people live in sites left unsafe as a result of the Cold War, ecological disasters, or pollution. Nobody has told them to leave. In Chernobyl, the Soviet government telling people they have to leave and can't come back was key to creating that ruin. The Japanese government has done it in a different way, because the relationship of Japanese culture to nuclear disasters is a lot more complicated. In both cases, the disaster presents an opportunity for something to happen. But what makes the ruin form is a quite specific set of cultures and attitudes.

Another example is Detroit, where in real time, wealthy and powerful elites have essentially depopulated the city by driving a move to the suburbs. You can see this in the way it's written and talked about in the media—the city is ruined so people are moving to the suburbs. We're no longer going to invest a lot of money in keeping this ruined city going. And then you have the really interesting case of ruin profiteers, who buy up ruined architecture and preserve it for photo shoots and the like. We should be aware that we are making the past too. We are creating a past for others to see all the time.

By Helen Santoro

Disparate impacts

As the pandemic surged, so did inequality

▶ One way or another, everyone has felt the pain of COVID-19. As the virus left its mark, people reeled—and continue to suffer—from the sudden and drastic changes caused by isolate-in-place policies, jobs lost or made more difficult, sickness, and the loss of loved ones. But some have felt the pain much more than others. People of color and low-income families have been disproportionately impacted by the pandemic, shining a spotlight on social, health, and economic inequities deeply rooted in the U.S.

Inequality has long been the focus of two UC Santa Cruz researchers, professor of developmental psychology **Margarita Azmitia** and professor of economics **Robert Fairlie**. Though they study different aspects of the issue, child and adolescent development for Azmitia and business and labor for Fairlie, both have kept a close eye on the pandemic's path, tracking how it has selectively struck the disadvantaged among us. By sharing their data and insights and giving disadvantaged people a voice, they're helping to ensure this suddenly escalated problem remains front and center for the policymakers tasked with solving it.

Paying attention

Azmitia has spent her career studying how peers, family, and schools affect the development of children and adolescents. In early 2020, she joined the rapid response network of the advocacy organization Research-to-Policy Collaboration (RPC). Initially assembled to brief legislators on the impacts of deportation and immigration detention policies, the network quickly shifted gears to explore how the pandemic was affecting vulnerable children and adolescents.

Azmitia's role included digging into the academic literature, providing feedback on drafts, and helping to write parts of the team's May 2020 policy brief. In addition to educating lawmakers about the scope of the problem, *Mitigating the Implications of Coronavirus Pandemic on Families* provided research-informed policy recommendations on how to best support students' needs. Over the past year, many families, particularly those in low-income and rural areas, struggled to keep up with remote schooling during the pandemic, thus exacerbating prior resource gaps. "This was an opportunity to say

Top: As the pandemic halted in-person classes, children needed to learn virtually. However, more than 21 million people in the U.S., mostly in low-income and rural areas, have unreliable access to internet and digital devices, making online classes difficult or impossible to attend. To fix this problem, the Research-to-Policy Collaboration brief that professor of developmental psychology Margarita Azmitia helped develop suggests a range of policy shifts, including more technological support and extended internet hotspots. Credit: August de Richelieu (public domain).

there are a lot of people that we're missing, and we need to do something," said Azmitia.

The brief highlighted how more than 21 million people in the U.S. have unreliable access to internet and digital devices, making online classes difficult or impossible to attend for many children and youth. And if they do have access, families may just have one laptop. In many cases, it's the parent working from home "who needs to bring in the paycheck that must use the device, potentially interfering with the kids' online classes," said Taryn Morrissey, professor of public administration and policy at American University. "It's a terrible decision that families have to make." According to Morrissey, whose work centers on improving public policy for vulnerable children, Azmitia's research on how resource gaps impact kids' overall development is crucial for informing future legislation aimed at addressing this disadvantage.

In the RPC policy brief, Azmitia and her collaborators cited research showing that—even before the pandemic—youth without access to technological devices and the internet already performed worse in school than those with such access. Kids living in poverty were also more likely to live in crowded homes with little-to-no space for them to engage in their now online classes. Additionally, decreased

Deep roots

The fact that the pandemic has disproportionally impacted people of color and low-income families is no surprise for those who have been keeping up with American history. As former president Barack Obama said during his 2020 virtual commencement speech to graduates of historically Black colleges and universities, "Injustice like this isn't new. What is new is that so much of your generation has woken up to the fact that the status quo needs fixing." Now, laid bare by the pandemic, the extent of this injustice has become harder to disregard.

Before COVID-19 hit, the Pew Research Center found that the income gap between white and Black Americans grew, as measured in 2018 dollars, from about $23,800 in 1970 to $33,000 in 2018. Middle-class incomes have also increased at a slower rate than upper-class ones over the past five decades, putting more than half of all Americans at a clear disadvantage.

Income inequality translates to big differences in early childhood education, according to research from the Economic Policy Institute, a Washington, DC, non-partisan, nonprofit think tank that studies the impact of economic trends and policy on working people. Their work shows persistently large achievement gaps, including test scores, high school graduation rates, and college attendance, between children of high- versus low-socioeconomic class across the U.S. Strategies to address kids' needs before kindergarten, such as prenatal and pre-K programs, have been shown to shrink these gaps, yet they remain poorly funded. "The U.S. government invests less in children under the age of five than do most other developed nations," write Morrissey and her three coauthors in their 2021 book, *Cradle to Kindergarten: A New Plan to Combat Inequality* (Russell Sage Foundation). "Child care and preschool in the U.S. are scarce, prohibitively expensive, and inadequate in quality for most middle- and low-income families."

Yet families still depend on child care in order to work full-time jobs. And COVID-19 has caused mass closures of these centers, many of which may not reopen after the pandemic ends. "So many child care programs that operate on razor thin margins in good times are struggling or can't make it work now," said Morrissey. This will further exacerbate the educational divide that Azmitia and others study. "Programs that support families, including child care, help kids and families reach their educational goals," said Azmitia.

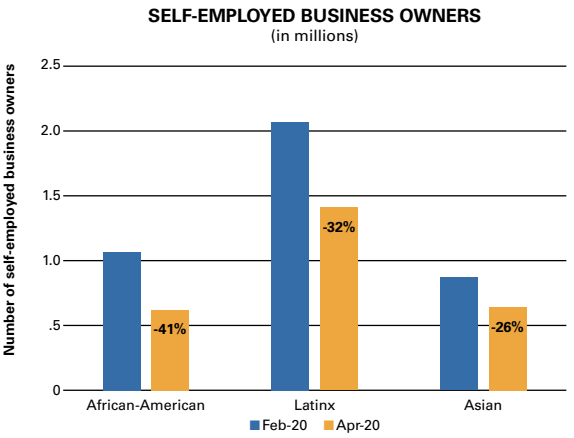
Studies performed by Azmitia and others have shown that prenatal and pre-K programs can provide an effective way to shrink achievement gaps between advantaged and disadvantaged children. Yet the U.S. invests less in children under the age of five than most other developed nations. As centers closed during the pandemic, access to child care decreased, exacerbating the problem. Credit: Cottonbro (public domain).

access to child care meant older kids were often expected to take care of their younger siblings, further impeding their ability to engage in virtual learning. "The pandemic made the resource gap incredibly apparent," said Azmitia. "It has done away with all of these resources, leaving kids basically on their own."

The situation will likely have lasting consequences, Azmitia said. As detailed in the policy brief, losing that connection to school means low-income and rural students are at higher risk for dropping out, suffering mental health issues, and being less employable than their peers. "I think we're going to see an increase in high school dropouts," said Azmitia. "I also worry about the increase in mental health issues. There are lots of kids reporting anxiety, depression, and disordered eating, and we don't have the support systems for that." Kids are resilient, she said, but that may not be enough to keep the more vulnerable ones from suffering longer-term difficulties in the absence of school and community programs and other support.

Lights off

The pandemic has Fairlie worried as well. Rather than kids, however, Fairlie, whose study of racial inequities in business spans 25 years, sees the increased suffering of adults in the workforce. Based on data from the Bureau of Labor Statistics and the U.S. Census Bureau, his early pandemic research revealed drops last February to April in the number of Black-, Latinx-, and Asian-owned businesses of 41, 32, and 26 percent, respectively. In addition, female business owners were disproportionally hit, with 25 percent of them shutting down. Fairlie saw firsthand the early impact of the pandemic on businesses on Mission Street in San Francisco. "Lights were off. Chairs were on top of tables. We were starting to see then that this was going to be long lasting," he said.



Early in the pandemic, in April 2020, the number of Black-, Latinx-, and Asian-owned businesses dropped by 41, 32, and 26 percent, respectively, according to Fairlie's analysis of data from the Bureau of Labor Statistics and the U.S. Census Bureau. Overall, the number of business owners dropped from 3.1 million to 2.0 million. Credit: National Bureau of Economic Research, courtesy of Robert Fairlie.

Across the country, businesses—disproportionately those owned by people of color—were forced by the pandemic to shut their doors, like this barbershop in Lake Elsinore, CA. The work of professor of economics Robert Fairlie showed that the first round of the federal government's Paycheck Protection Program largely failed to reach minority-owned businesses, compounding the pain of those already disadvantaged. Credit: Larry Costales (public domain).

In another study published in January 2021, Fairlie and a colleague found evidence that the first round of the $659 billion Paycheck Protection Program, or PPP, to help struggling businesses did not go towards minority communities. Instead, the money was doled out to established banks, which were then expected to loan the money to businesses in need. The problem is that minority-owned businesses don't often work with big banks. "They tend to work with smaller community lenders instead," Fairlie said. After a public outcry, the second round of PPP loans seemed to be more evenly distributed, according to Fairlie. Currently, he is watching as the third round of PPP data slowly rolls out to see if this trend continues.

"This work highlights how the COVID pandemic and its related recession has disproportionally impacted people of color," said Connie Evans, president and CEO of the Association for Enterprise Opportunity (AEO), an organization that helps underserved entrepreneurs grow their businesses. Fairlie contributed original analyses to AEO for their 2017 report *The Tapestry of Black Business Ownership in America*, which "paints a picture of the diversity of Black businesses and discusses three major challenges impeding Black business development: a massive wealth gap, a credit gap, and a trust gap

fueled through bias." An understanding of each of these challenges is needed, said Evans, to build effective solutions that fit the unique needs of Black-owned businesses. "That's how you drive towards inclusive business ownership and an inclusive economy."

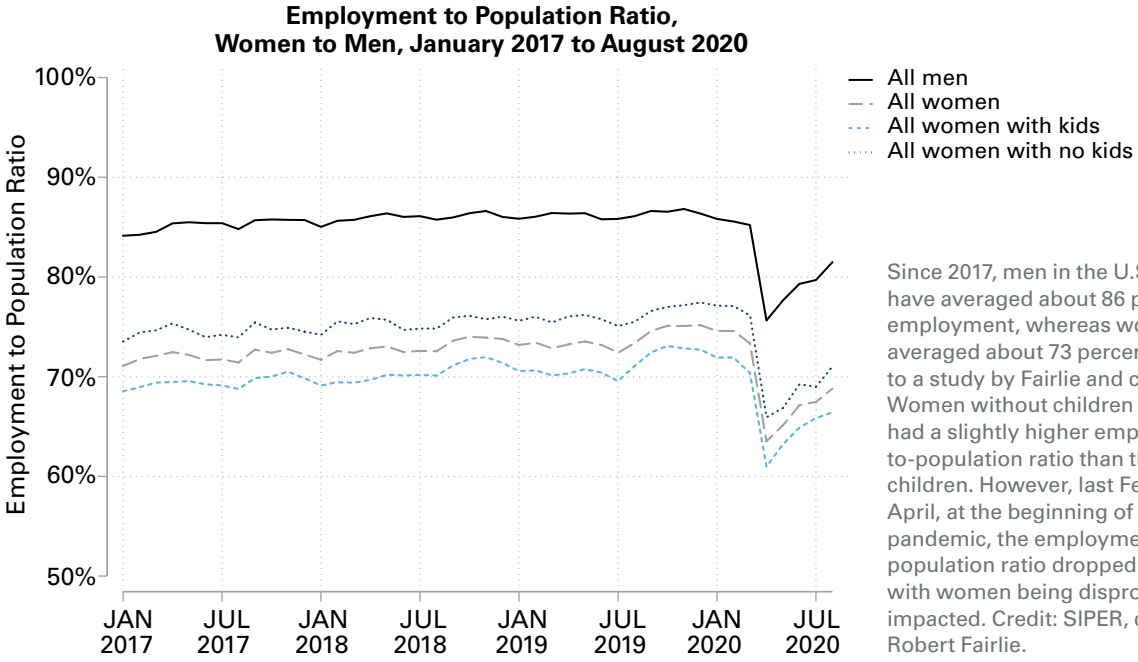
Moving forward, Fairlie intends to dig deeper into the government data to further investigate the racial disparities laid bare by the pandemic. "There are variations in PPP loans given to businesses across states, cities, towns," he said. "And we have to look at those people who did get early investments before shutting things down. Were they able to reopen faster? It's a huge question."

Pushing progress

Both Azmitia and Fairlie aim to influence policy by getting the word out about their research. The RCP brief contributed to calls for a range of policy shifts, including more technological support for students who are learning remotely, extending internet "hotspots" for increased access, supporting students with learning disabilities and differences, and plans to address the learning gap that many students have inevitably experienced once the pandemic eases up. Fairlie's work has been cited in a bill to expand the Minority Business Development Agency, a federal agency tasked with promoting growth of minority-owned businesses, and he was asked to testify in front of the U.S. House of Representatives and California State Assembly. He has also provided data on businesses and COVID-19 for some of Vice President Kamala Harris's speeches and helped the U.S. Senate in its analysis of PPP loans.

The March 2021 federal passage of the $1.9 trillion COVID-19 relief package appears to offer promise. The American Rescue Plan directs more than $120 billion towards K-12 schools, expands subsidies to help Americans afford health insurance, gives families up to $3,600 per child as a tax credit, and makes millions more people eligible for unemployment insurance. This is a major step up from previous pandemic responses by the federal government, including the $2 trillion Coronavirus Aid, Relief, and Economic Security (CARES) Act, which, according to Azmitia, had major flaws and did not sufficiently address the needs of children and students.

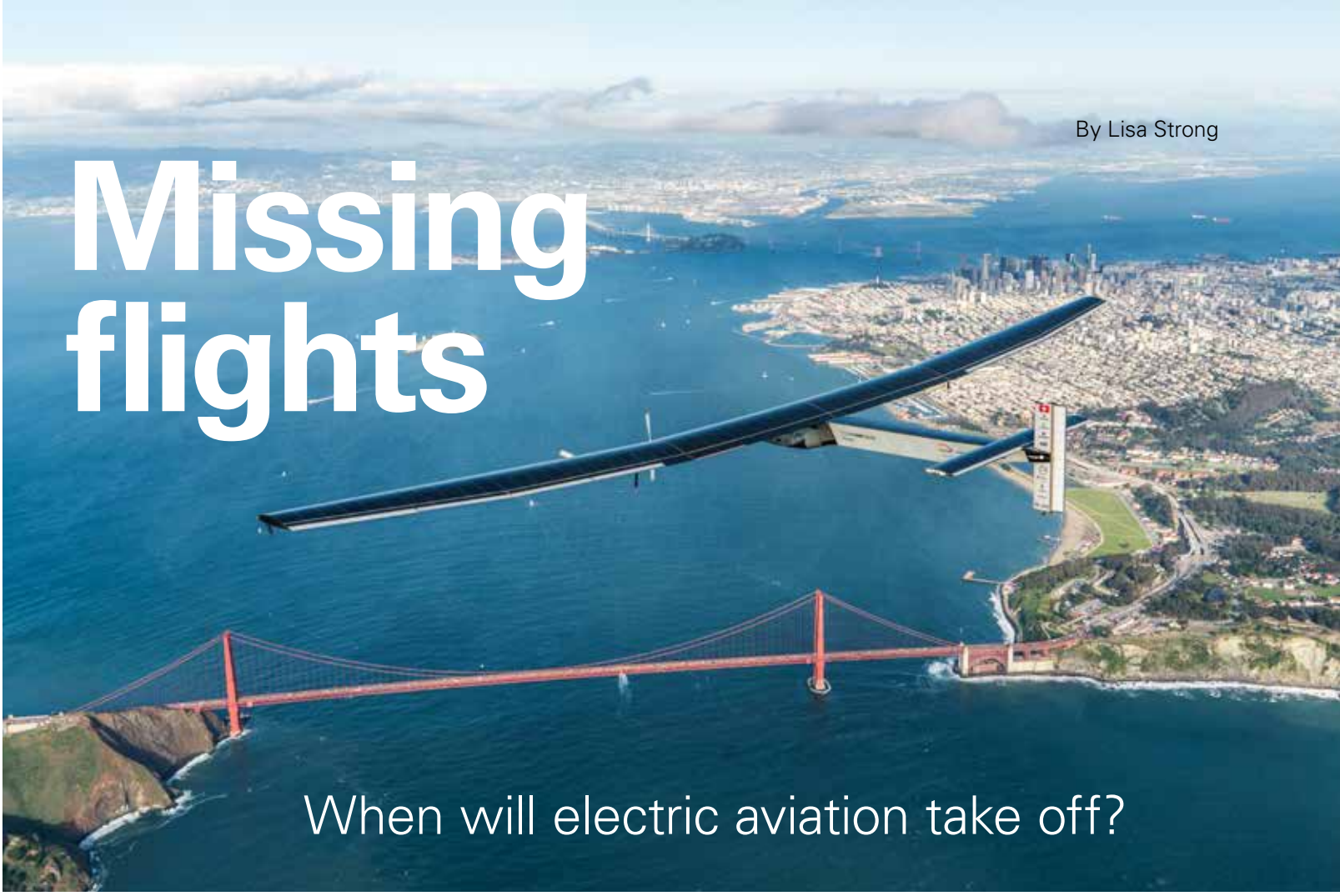
Azmitia said she is encouraged on a local level by how teachers in Santa Cruz have stepped up: "They've mastered the idea that we can't have kids learning on screens for long periods, so they're using other methods." It's the same at the university level, where professors are rethinking learning and testing, she said; we all expect life to go back to a new normal eventually, but hopefully more people now see that minority groups who have been left out of the conversation for so long deserve a voice. "We need to appreciate their backgrounds, their struggles, and what they can add. This pandemic has cost everybody."



Since 2017, men in the U.S. have averaged about 86 percent employment, whereas women have averaged about 73 percent, according to a study by Fairlie and collaborators. Women without children have also had a slightly higher employment-to-population ratio than those with children. However, last February to April, at the beginning of the COVID-19 pandemic, the employment-to-population ratio dropped for all groups, with women being disproportionately impacted. Credit: SIPER, courtesy of Robert Fairlie.

By Lisa Strong

Missing flights



When will electric aviation take off?

▶ As a photographer, I adore the aerial perspective. So much so, I thought it'd be cool to learn how to fly. When I finally got my private pilot license, though, I stopped flying. As a student pilot, I took a dozen photos with my iPhone and realized I'd need a lot more practice to get good enough to fly and shoot at the same time. The environmentalist in me overrode my aerial ambition. I couldn't justify the carbon emissions.

In fact, I've since curtailed all my flying in an effort to reduce my personal carbon footprint. Although aviation accounts for only about 2.6% of the world's total greenhouse gas emissions, a couple of round-trip, cross-country flights to conferences would add up to roughly 40% of my annual contribution to the climate crisis. I haven't flown now for five years. I miss it. With all the electric cars now on the roads, I wondered, is aviation far behind?

In my pilot training, I learned about the four forces of flight: lift, weight, thrust, and drag. Versus driving, flying has a tricky extra problem to solve—lift. A Tesla Model X weighs 2,458 kg. The extra heft from batteries provides stability. But that kind of excess weight grounds flight. What's required for lots of people to fly electric? Technically, three things, each of which poses its own daunting challenges: light-weight parts, robust, efficient power for propulsion, and an energy-dense source for that power.

Top: The Solar Impulse 2 flies over San Francisco's Golden Gate Bridge on April 23, 2016, during the North America leg of its circumnavigation of the globe, powered only by the sun, with no use of any fossil fuel. Credit: ©Solar Impulse/ Jean Revillard/Rezo.ch (public domain).

Green flight, for one, has been done. During my flight training, I followed the adventures of a Swiss team flying the Solar Impulse, an experimental, solar-powered plane. Solar cells—17,248 of them—covered its wings. Efficient electric motors provided thrust. Onboard batteries stored energy for night flight. The albatross-like plane had a wingspan of a 747 but weighed less than the Tesla. In 2016, it circumnavigated the planet, a breathless press covering each step. But Solar Impulse carried only a solo pilot, plodding along at an average air speed of 75 km/h. The exploit certainly raised awareness. But providing a viable, carbon-neutral alternative to today's carbon-spewing aviation sector? Not so much.

Going for it

The Advanced Research Program Agency-Energy—ARPA-E for short—is, however, working on that, and so is UC Santa Cruz professor of electrical and computer engineering **Leila Parsa**. A U.S. Department

Missing flights

Before its time

For a moment in late 1950s England, the Fairey Rotodyne promised airborne intercity mobility even more ambitious than that now envisioned by today's developers of electric air taxis. An all-in-one helicopter, airplane, and gyrocopter (a helicopter-like aircraft with an unmotorized, autorotating rotor), the Rotodyne took off and landed vertically like a helicopter by virtue of jets on the tips of its rotors. In horizontal flight, the rotors auto-rotated like a gyrocopter, turned by just the horizontal air flow, providing half the lift for the aircraft while it cruised like an airplane, powered by the two engines on its wings. To land, the pilot fired up the rotor tip jets again. A full-scale prototype flew 350 successful test flights, establishing its safety. Capable of carrying 18,000 lbs, the Rotodyne was expected to ferry 40 passengers at a speed of 372 km/h over a range of 700 km.

The fish-nor-fowl craft had two serious problems, however, one technical, the other financial and fatal. The rotor tip jets screamed ambulance-siren-loud at 113 db. Engineers reduced that to 96 db with "silencers," but then the money ran out. Having funded much of the project's decade-long development, the British government in 1962 balked at the additional £10 million (~$14 million) needed to proceed to full production, sweeping the Rotodyne into the dustbin of history.

In the late 1950s, the British company Fairey Aviation developed the part helicopter, part gyrocopter, part airplane Rotodyne with intercity air mobility and military applications in mind. Although its safety was established in more than 350 test flights, the novel aircraft was scrapped for lack of financial backing. Credit: Tom Wigley (CC BY-NC-SA 2.0).

of Energy agency, ARPA-E funds research and development on ambitious energy technology that's too early to attract private-sector investment. "We focus on relevant problems that reach the national scale," said ARPA-E program director, Peter de Bock. Since almost half of our domestic aviation emissions come from regional flights of 600 miles or less, ARPA-E has set its sights on decarbonizing an aircraft similar in size and capability to a Boeing 737.

As part of this effort, the agency's program "ASCEND" (Aviation-class Synergistically Cooled Electric-motors with iNtegrated Drives) has challenged engineers to design an electric powertrain that converts electricity into propulsion with a "power density" greater than 12 kW/kg, an ambitious goal. Power density measures the maximum power output (kW) by component weight (kg), a critical concern due to that extra force—lift—that flight needs to deal with.

Parsa leads one of nine teams funded to work on ASCEND. Her team is designing an innovative integration of three main components—a drive that converts DC voltage into variable frequency AC voltages, which feeds a highly efficient electric motor that turns electrical energy into mechanical work, and a way to keep the whole apparatus from overheating. "When you're pushing that much current, you need to keep it cool," Parsa said. Their design also includes a super-conducting coil, which requires extremely low temperatures, making thermal management a critical component. On this part of the project, Parsa is relying on her Air Force Research Lab partners at the Wright-Patterson Air Force Base in Ohio to provide their expertise. If Parsa and her collaborators are successful, their system will deliver significantly more power density than anything available today.

Heavy, man

But batteries are not feathers. As opposed to power density, "energy density" is a measure of how much power a fuel source can provide over time, expressed as kW per hour per kg (kW-h/kg). Jet fuel is quite energy dense, about 60 times more so, kg for kg, than the best batteries. That's hard to give up. But conventional internal combustion engines are only about 35% efficient, wasting the rest as heat, noise, and vibration. ARPA-E currently isn't envisioning a battery-operated 737, but a series hybrid one. "A turbine will convert some kind of fuel into electricity, and then the part we're working on will convert that electricity into propulsion," said **Keith Corzine**, professor of electrical and computer engineering and a member of Parsa's UCSC team. "The big advantage is efficiency."

Joby Aviation's five-seater eVTOL prototype has articulating propellers for vertical take-off and landings, and a wing for horizontal flight. It can travel up to 240 km on a single charge at a top speed of 320 km/h. Credit: Joby Aviation/Olivia Kristiansen (public domain).

Coupling the energy density of a liquid fuel to the improved efficiency of souped-up power-dense electric powertrains like the ones Parsa and others are designing seems to be ARPA-E's plan. A concurrent parallel program to ASCEND is "REEACH" (Range Extenders for Electric Aviation with low Carbon and High efficiency), which—along with confirming ARPA-E's fondness for acronyms—is looking for economical, carbon-neutral methods to convert energy-dense liquid fuels into electricity to hand off to those efficient electric powertrains. If the results of these efforts aren't immediately applicable to large commercial aircraft, the technology might sooner find use in more efficiently electrifying other modes of transportation, like ships, trains—or, say, much smaller, short-hop air taxis.

Above it all

The dream of flying up and over teeth-grinding, stop-and-go commuter traffic in urban areas has long captured the imagination (see sidebar). Recently, this dream has also captured large amounts of capital investment. Several companies have developed "eVTOL" (electric Vertical Take-Off and Landing) prototypes for intended use as air taxis, tapping current battery technology, because they don't need to lift much or go very far. In February 2021, two such companies, Archer Aviation and Joby Aviation, both announced plans to go public—at eye-popping valuations of $3.8 billion and $6.6 billion, respectively. Electric air taxis are expected to run cleaner, much more quietly, less expensively, and potentially more safely than helicopters. The latter, however, remains to be judged by the stern arbiter of U.S. aviation safety—the Federal Aviation Administration (FAA). Extremely serious about its mandate to ensure safety, the FAA rules U.S. airspace, enforcing rigorous standards for certifying new aircraft. While experimental planes like the Solar Impulse face a lower hurdle, any aircraft intended to fly commercial passengers over populated areas receives strict scrutiny. In a talk at the CAFE (Comparative Aircraft Flight Efficiency) Foundation's 2019 Electric Airplane Symposium in Oshkosh, WI, Earl Lawrence, the FAA's executive director of aircraft certification, urged patience while awaiting the future: "We have titanium silos—aircraft certification, flight standards, air traffic, airports, and we don't talk to each other very well. New tech needs to mitigate risks in all these areas."

Me? I'm not holding my breath. I'll continue to be mindful about flying for the foreseeable future. The pandemic forced a lot of conferences to go virtual, which has helped all of us reduce our carbon footprints. And while current technology may be good enough for short-hop eVTOLs, ironing out certification and other FAA safety considerations will take time and may disappoint those eager to hop onboard (and the investors who already have). In the meantime, though, there is one electric aircraft that has changed my world, a mini-miracle that became affordable just as I finished my pilot training. With my camera drone, I can take the most amazing aerial shots without ever leaving the ground.

With camera drones, aerial photographers can take off without leaving the ground. Seen here from drone height while docked in the San Francisco Bay in April 2021 is The Energy Observer, a zero emissions catamaran, the first energy-autonomous ship, powered by hydrogen generated via solar energy. Credit: Andy Black, with permission.

By Alla Katsnelson

Tomorrow's forecast

Tiny fossils yield big clues on climate change

The vast expanses of deep freeze we see today haven't always covered the Earth's polar regions. For much of our planet's past, the poles sported no caps of snow and ice. In fact, about 56 million years ago, one could describe polar conditions as downright balmy, with alligators, turtles, creodonts, and tapirs frolicking amidst towering palm trees and humid, lush swamps.

Thanks for creating this polar idyll goes to a massive release of carbon into the atmosphere over roughly 5,000 years. This big exhale caused the Earth at the time to spike a 150,000-year-long fever, with temperatures rising more than 5° C. Scientists think an enormous wave of volcanic eruptions triggered this warming event, known as the Paleocene Eocene Thermal Maximum, or PETM. The heightened volcanic activity occurred as the Earth's crust fragmented at the transition between the Paleocene and Eocene epochs when the continental land masses were moving to their current positions. Floods of magma combusted organic matter buried in sediments, releasing a surge of CO_2. The resulting warming of a few degrees started a positive feedback loop, jacking up ocean temperatures to drive further releases of greenhouse gases, and further warming.

Top: An artist's depiction of a scene from the early Eocene Epoch, roughly 55 million years ago, a warming period during which many mammals and the first primates appeared. Credit: Jay Matternes, National Museum of Natural History (public domain).

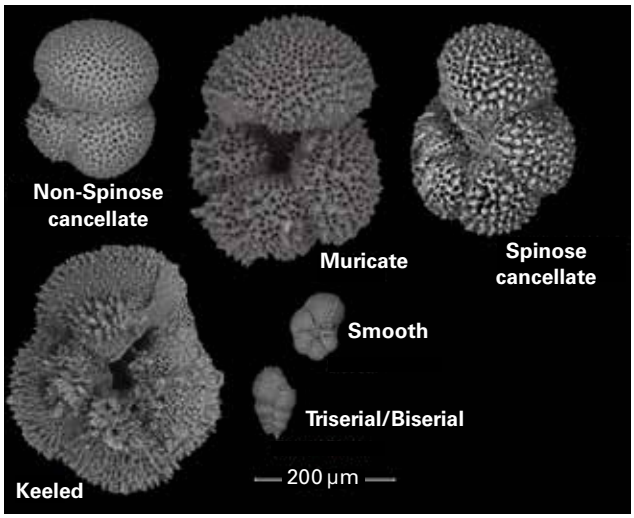
How do we know this? Much of it from the work of distinguished professor of Earth and planetary sciences and Ida Benson Lynn professor of ocean health **James Zachos**, one of the first scientists to delineate PETM-related climate changes and what caused them. Using advanced analytical chemistry and marine geology tools, Zachos's research looks back in time to reconstruct the details of how the Earth's climate fluctuated in the distant past. In addition to improving our understanding of the links between global temperature, ocean acidification, and the carbon cycle, the research importantly hints at the future challenges we might face from the potential fallout of our current climate crisis.

Although the 5,000 years that began the PETM sounds like a long time, it's a mere blink of an eye on a geological scale. Today, the Earth's climate is changing perhaps 10 or even 100 times faster than it did then, as our burning of fossil fuels and other activities continue to dump roughly 5.5 petagrams (1 petagram = 1 billion tonnes) of carbon into the atmosphere each year. "We know now that even if we were to shut off carbon emissions today, the effects will last for thousands of years," Zachos said. "We are leaving a legacy for many future generations of humans."

Sudden shake-ups

In the late 1980s when Zachos was a graduate student, scientists had just begun exploring the idea of using the ratios of different isotopes of carbon and other elements in fossils to detect and characterize past geological events. For his doctoral dissertation, Zachos applied the idea to zero in on the end of the Cretaceous period, 66 million years ago, when an extinction event—most think a meteorite impact—wiped out the dinosaurs and many other terrestrial and marine organisms. The work involved tracking the ratio of carbon 12 to carbon 13 present in the fossilized shells of tiny free-floating ocean organisms called microplankton. Essentially, the fossilized shells record the chemistry of the seawater their makers lived in. Having settled on the ocean floor, they create an archive in the sediment.

Reading his shell fossil samples from the end of the Cretaceous, Zachos found that the ratio went haywire. Biologically sustained patterns in carbon isotope ratios suddenly disappeared, suggesting a major breakdown in carbon fixation in the ocean. "That started me thinking about the connection between environmental perturbations and the carbon cycle," he said. As Zachos recollects, he noted at the time that most boundary transitions between geological epochs were associated with sudden shake-ups in animal and plant life. And unlike the meteorite-doomed Cretaceous, most other transitions weren't associated with a clear event. Might these boundaries reflect dramatic changes in climate, he wondered? And might that change be encoded in the geological record?



Fossil microplankton shells from marine sediments provide an archive from which Zachos and collaborators can determine—by analyzing the ratio of heavy to light isotopes of carbon and boron—carbon levels in the atmosphere at the time the shells were formed by their live inhabitants. Credit: Tali Babila, courtesy of James Zachos.

In the PETM, while many marine and other organisms went extinct, many of the mammals, including primates, that still exist today first appeared on the planet. The period has provided a fascinating test case that Zachos continues to study to this day. Initially, though, he teamed up with distinguished professor of Earth and planetary sciences and dean of physical and biological sciences **Paul Koch**, then a postdoc at the Smithsonian National Museum of Natural History, to probe the carbon isotope ratio shifts in mammalian fossils from the period. At first, they couldn't quite put it together, Koch said. "Jim actually called me and said, 'Hey, the numbers look really weird.'"

In mammalian fossils and soil nodules from the Bighorn Basin in Wyoming, professor of Earth and planetary sciences James Zachos and dean of physical and biological sciences Paul Koch identified a carbon isotope anomaly corresponding to sudden rise in atmospheric carbon and the jump in temperature that characterized the PETM. The work was published in a seminal 1992 paper in the journal *Nature*. Credit: Scott Wing, with permission.

But then, Koch said, a breakthrough study was published that used a similar carbon analysis on a sediment core from the ocean near Antarctica to link—for the first time—a temperature jump during the PETM of as much as 7° C to a major perturbation in the carbon cycle. "They identified this event in the ocean, and we quickly realized that we had found the same event on land," he said. "It was crystal clear."

Six months later, in 1992, Koch, Zachos, and colleague and now professor emeritus at the University of Michigan Philip Gingerich published their own paper in the prestigious journal *Nature*. It was the first to connect a major global warming event with large-scale carbon cycle fluctuation, speciation, and mass extinction. "It was like two pieces of a puzzle snapping together," said Scott Wing, research geologist and curator of paleobotany

Tomorrow's forecast

Working with an international venture called the Ocean Drilling Program, Zachos and colleagues collected marine sediment cores in oceans around the world to track the extent of ocean acidification that occurred during the PETM. Here, in 2003, University of North Carolina postdoc Deborah Thomas (now professor and dean of geosciences at Texas A&M), Zachos, and UCSC postdoc **Stephen Schellenberg** (now professor of geological sciences at San Diego State University), analyze samples collected in the South Atlantic during a voyage aboard the program's research vessel, the Resolution (right). Credits: K. C. Lohmann, courtesy of James Zachos; Ocean Drilling Program (public domain).

at the Smithsonian National Museum of Natural History, who began an ongoing collaboration with Zachos shortly afterwards.

Finding connections

That study provided an entry point into understanding how warming events can affect different aspects of the Earth's biosphere. The first step involved seeing whether some of the carbon that drove the surge in temperature was absorbed by the ocean, as evidenced by an increase in its acidity. To find out, Zachos submitted a proposal to conduct a study with the Ocean Drilling Program, a multinational venture aimed at establishing a basic understanding of ocean basins and the Earth's crust underlying them. Zachos and his colleagues set out to sample sediment cores from deep in the ocean floor at multiple spots across the Atlantic and the Pacific in order to try and detect a change in the ocean's carbon chemistry. Within a decade, the effort had gathered enough evidence to document, in the brief period of the PETM's first 5,000 or so years, dramatic ocean acidification, evidence of the release of as much as 5,000 petagrams of carbon into the atmosphere. "On a geologic time scale, a petagram of carbon per year is a lot," Zachos said. "It's enough that the system can't buffer itself."

Since then, Zachos and his team have worked to improve their measurements, which has allowed them to quantify a variety of climate parameters at finer time intervals and with increased spatial precision. For example, Zachos collaborated with Bärbel Hönisch, professor of Earth and environmental sciences at Columbia University, to more accurately measure ocean acidification in different places and times in the geological record. Using mass spectrometry, they measured the ratio of boron-11 to boron-10 in the fossilized shells of foraminifera, a popcorn-shaped type of microplankton. At higher pH, the ratio increases, such that it provides a quantifiable measure of ocean pH, Hönisch said.

Such increasingly sophisticated techniques have allowed Zachos and his team to ramp up the speed and types of measurements they can make. Meanwhile, computer models created to predict current climate trajectories have also grown more sophisticated, able to account for potentially confounding climate variables such as cloud cover and ocean circulation. Of course, conditions 56 million years ago are not the same as today, so the effects of rising atmospheric carbon won't match up exactly. But by comparing their increasingly precise real-world—but old-world—data from the PETM and other warming events in geological history with the results of today's computer modeling, Zachos and his colleagues are anchoring future climate predictions

in the context of a past reality. In a way, said Wing, understanding the fine details of how climate change played out in the past allows researchers to test how well current models of future climate change actually work. "If you are interested in what's going to happen in the next 1000 years, you need to be able to describe the past at a similar resolution," he said.

The forecast?

What the data show is a rate of carbon emission about an order of magnitude higher today than during the PETM—which translates to us taking a few hundred years versus a few thousand to belch the same amount of carbon into the atmosphere. How might this affect us? "We are recognizing that the rate of global warming and sea-level rise will be faster than we had predicted in the past," said Zachos.

The data also provide an answer to the question of how long it might take for the planet to recover. During the PETM, naturally occurring chemical processes such as rock weathering—in which rain, which is slightly acidic, gradually breaks down rock to form calcium bicarbonate that then gets stored in the ocean—eventually returned the carbon cycle to a more even keel. "What we found is that it took tens of thousands of years for the excess carbon to be removed through such natural processes," Zachos said.

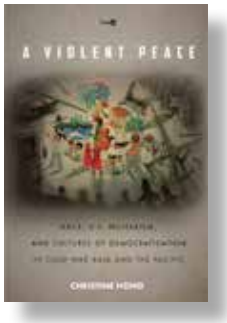
The specific mechanisms—the roles played, for example, by changes in vegetation, or carbon absorption in the deep ocean—that drove the return to baseline during the PETM and other more recent climate cycle fluctuations remain an active area of investigation for Zachos and his collaborators. Another major focus is how greenhouse-induced changes in the hydrologic cycle—the transfer of water from the surface to the atmosphere and back again—might drive changes in precipitation, such as more frequent and intense storms. Many aspects of the climate physics involved in this question remain unclear. But unraveling how factors like energy, ice, and water moving between the different layers of the atmosphere shaped the dynamics of past climates could provide important insights on what our future might hold.

While the PETM saw a surge in the diversity of mammals, including our first primate ancestors, researchers have surmised that—even for creatures cavorting in the then subtropical polar climes—life was difficult. Extinctions aside, fossils from the period reveal abnormal dwarfing in animals and plants with reduced levels of nutrients. And the sedimentary studies of Zachos and others indicate it was a period marked by an enormously variable climate, with intense precipitation, flooding, and landslides. In answer to his own question, "Is that what our future will look like, but exaggerated?" Zachos said, "Yeah, I think the evidence from the past suggests that's exactly what's going to happen."

The toll will be heaviest on the most vulnerable, said Hönisch, on those—humans and other living creatures alike—without the means to move to cooler or higher regions as the planet heats up and the oceans rise. But just as it did 56 million years ago, the planet will make it through, Hönisch said. "The planet will help itself," she said, "and I hope we will survive as a species, too."

In February 2021, Zachos and team conducted fieldwork in the Tumey Hills, just east of the San Joaquin Valley, to investigate how the regional hydrologic cycle responded to the PETM. They collected, for analysis in the lab, samples of the markedly red PETM clay layer, initially deposited in a shallow marine setting and since uplifted by tectonic processes. Credit: James Zachos.

By Emma Hiolski

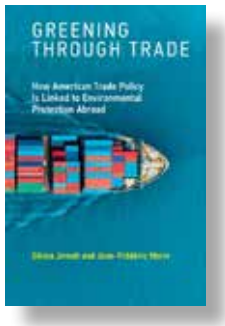


War and… Peace?

The militarization of the United States in the 20th century changed the world, but not always for the better. In **A Violent Peace: Race, U.S. Militarism, and Cultures of Democratization in Cold War Asia and the Pacific** (Stanford University Press, 2020), associate professor of literature and critical race and ethnic studies **Christine Hong** chronicles the U.S. war machine's evolution post–World War II, both abroad and on U.S. soil.

While this militarization supported a strong antifascist program in postwar Europe, its legacy in the Pacific theater remains an open question, said Hong. "How do you begin to understand the impacts of the Korean and Vietnam wars within this era of supposed peace?"

Citing the several million, mostly civilian, Asian deaths during the Cold War, Hong argues that what the U.S. called "democratization" was more akin to fascism. "There are deep interconnections between U.S. foreign policy and militarized violence," Hong said, "including domestic police brutality."



Eco-friendly Trade

More than a decade ago, a brief agenda item at a United Nations meeting sparked the interest of associate professor of environmental studies **Sikina Jinnah**. After decades of ignoring the Convention on International Trade in Endangered Species (CITES), the Peruvian mahogany trade was suddenly in compliance.

The catalyst? A trade agreement with the U.S. requiring Peru to comply with CITES. In **Greening through Trade: How American Trade Policy is Linked to Environmental Protection Abroad** (MIT Press, 2020), Jinnah and co-author Jean-Frédéric Morin (Université Laval, Quebec City) discuss such links between international trade policies and environmental objectives.

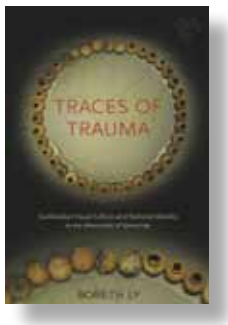
While such pacts can drive environment-friendly changes, they can also have unintended consequences. For example, Peru's rapid implementing of its CITES obligations bypassed many public participation processes. "Trade agreements can be useful tools," Jinnah said, "but they should be used with careful attention to domestic contexts."

Digital Necropolis

After working on a UCLA-led digital reconstruction of the ancient Egyptian temple site of Karnak, associate professor of history **Elaine Sullivan** set her sights on Saqqara, a complex, deeply studied necropolis, home to Egypt's first pyramid. Sullivan wanted to explore the site in a new way and recreate for modern viewers the landscape ancient people might have experienced.

She spent five years crafting a digital, three-dimensional reconstruction that joins modern data with legacy data from excavations dating back to 1850. The resulting "born-digital" publication, **Constructing the Sacred: Visibility and Ritual Landscape at the Egyptian Necropolis of Saqqara** (Stanford University Press, 2020; https://constructingthesacred.org/), spans 2,700 years of ancient Egyptian history and includes 3D models that readers can explore through both space and time.

"This is a visualization of our archeological knowledge of Saqqara," Sullivan said, "a tool to help us think about and hypothesize about the site in new ways."

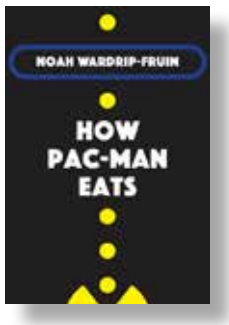


Healing Through Art

Between 1975 and 1979, the Khmer Rouge in Cambodia exterminated roughly two million people. Today, the nation and its diaspora continue to live with the lasting legacy of this trauma.

"How do we keep going on? What strategies have we developed to cope?" asked associate professor of history of art and visual culture **Boreth Ly**, himself a survivor of the genocide. For the deeply personal **Traces of Trauma: Cambodian Visual Culture and National Identity in the Aftermath of Genocide** (University of Hawaii Press, 2019), Ly interviewed Cambodian artists around the world to explore the potential for—and limitations of—art to facilitate healing.

In one poignant exchange, an artist sent to the U.S. for adoption at age two tells Ly of her return to her father's village at age 40 for a work of performance art. Ly recounts her "symbolic act of healing" in which she broke 40 clay pots and painstakingly pieced them back together over six days.



Meaningful Mechanics

Video games are often the primary media consumed by many people. But what are games actually doing when we play them? Professor of computational media **Noah Wardrip-Fruin** distills this question into two parts: How do games work? And how do we make them say what we want? "Those might sound like two quite different levels, but they are deeply interconnected," said Wardrip-Fruin, whose **How Pac-Man Eats** (MIT Press, 2020) explores how video games meld mechanics with broader meaning.

In the titular example, Pac-Man "eats" because a game designer expanded the meaning of a collision. In a more complex example, Wardrip-Fruin describes the game *Dys4ia*, in which speech bubbles take on physical form to illustrate the power of words.

Wardrip-Fruin said the book will appeal to people interested in video games with cultural, political, and personal themes, as well as those wishing to understand how games operate "on a deeply detailed level."

Sarah Derouin ('17)
Amanda Heidt ('20)
Emma Hiolski ('17)
Jesse Kathan ('20)

Alla Katsnelson ('07)
Jack Lee ('20)
Jyoti Madhusoodanan ('14)
Mary-Russell Roberson ('88)

Priyanka Runwal ('19)
Helen Santoro ('19)
Ben Shouse ('01)
Lisa Strong ('93)

Cameron Walker ('02)
K. M. Watson ('84)
Jennifer Welsh ('10)
Marcus Woo ('07)

**Names are listed left to right.*

As **Mary-Russell Roberson** ('88) writes in our cover story "Adaptable academics" (p. 14), the coronavirus pandemic forced the UC Santa Cruz community to devise new ways to learn and work. That included the students and alumni of the renowned Science Communication master's program, which has now trained former scientists in the art and craft of science journalism for 40 years—including all of the authors shown here, as well as editor **Dave Egerter** ('88).

Graduates of the program played key roles in responsibly covering the pandemic amid relentless misinformation. They included **Laura Helmuth** '98, named in March 2020 as editor-in-chief of *Scientific American*; **Nsikan Akpan** ('14), named in January 2021 as health and science editor at WNYC public radio in New York; and **Eva Emerson** ('94) and **Rosie Mestel** ('91), the editor-in-chief and executive editor at highly regarded *Knowable Magazine* in Palo Alto. Scores of other alumni reported on the coronavirus for publications, radio stations, and university news offices across the U.S. and in Europe.

And in a first for the program, alumna **Julia Calderone** ('14) contributed to a large team at the *New York Times* that received journalism's top honor for its reporting on COVID-19: the 2021 Pulitzer Prize for Public Service. Calderone, a senior staff editor for the newspaper's health and family section, performed in-depth data analysis for the project.

Meanwhile, SciCom lecturers, led by director **Erika Check Hayden**, pivoted to virtual instruction for this year's graduates. Save for socially distanced workshops in photojournalism and video production, students studied remotely and reported for their news internships from home. Their teachers via Zoom included three program alumni: multimedia journalist **Lisa Strong** ('93), author and essayist **Evelyn Strauss** ('98), and former director **Robert Irion** ('88).

The talent and versatility of the program's graduates is on display in these pages. We hope you and yours stay well as you enjoy the stories we've unfolded in this 7th annual issue of *inquiry@UC Santa Cruz.*

Learn more: **news.ucsc.edu**

Meet Jacob Martinez: Opportunity maker

Jacob Martinez, a University of California, Santa Cruz, alumnus (Oakes '04, evolutionary biology) and an entrepreneur, knows what it means to build bridges and create opportunities.

Founder of a lively technology learning center in Watsonville, California, called Digital NEST, Jacob devotes his time and energy to creating a place for young people from rural areas to master their digital skills and connect to professional opportunities. He is a leading voice in technology access and education and a trusted UC Santa Cruz partner advising campus leadership on economic opportunity, community empowerment, and digital innovation.

UC SANTA CRUZ

ucsc.edu

Ranked among the **top 3%** of national universities for social mobility.
—U.S. News & World Report

One of only four members of the Association of American Universities (AAU) designated as a Hispanic Serving Institution.