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FROM THE ARCHIVE
Molecular and cell biology professor **Daniel E. Koshland Jr.** (left) and colleagues, circa 1963. An eminent biochemist, Koshland spearheaded a large-scale reorganization of biology studies at UC Berkeley in the '80s and gave generously to support the construction of science buildings on campus. Koshland Hall, named in his honor, is home to plant, microbial, and molecular biologists.
PHOTO: Courtesy of the Bancroft Library

BREAKTHROUGHS

UC BERKELEY COLLEGE OF NATURAL RESOURCES • SPRING 2018

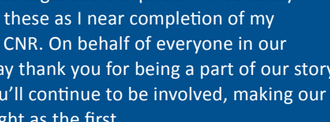
LETTER FROM THE DEAN

Chancellor **Carol Christ** has observed that the Berkeley campus "feels like a place where history happens—political, scientific, intellectual." This year we're reflecting on historical milestones as we commemorate the founding of the University of California in 1868, with UC Berkeley as the very first campus, and the founding of the College of Agriculture—the predecessor to the College of Natural Resources—that same year.

This special issue of *Breakthroughs* is a celebration of Berkeley's 150 years of excellence in education, research, and public service, and our College's role in that past. We tell how a previous generation gathered and preserved data, creating a baseline from which modern scientists can evaluate how California species are responding to changes in climate and land use. We also feature one researcher who is continuing the long-standing tradition of UC Cooperative Extension work that directly benefits the people, agriculture, and natural resources of our state. In addition, we look ahead to new gene-editing research with exciting applications that range from environmental preservation to human health to combating worldwide hunger.

The UC Berkeley sesquicentennial—themed "150 Years of Light"—evokes our nostalgia and our pride. I'm certainly experiencing both of these as I near completion of my final term as dean of CNR. On behalf of everyone in our community, let me say thank you for being a part of our story thus far. We hope you'll continue to be involved, making our next 150 years as bright as the first.

I welcome your feedback at gilless@berkeley.edu.



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A lab in Hilgard Hall, circa 1918.
PHOTO: Courtesy of the Bancroft Library

SPRING 2018

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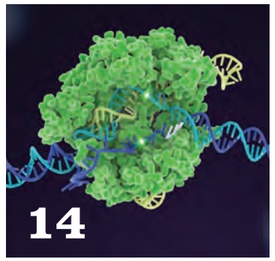
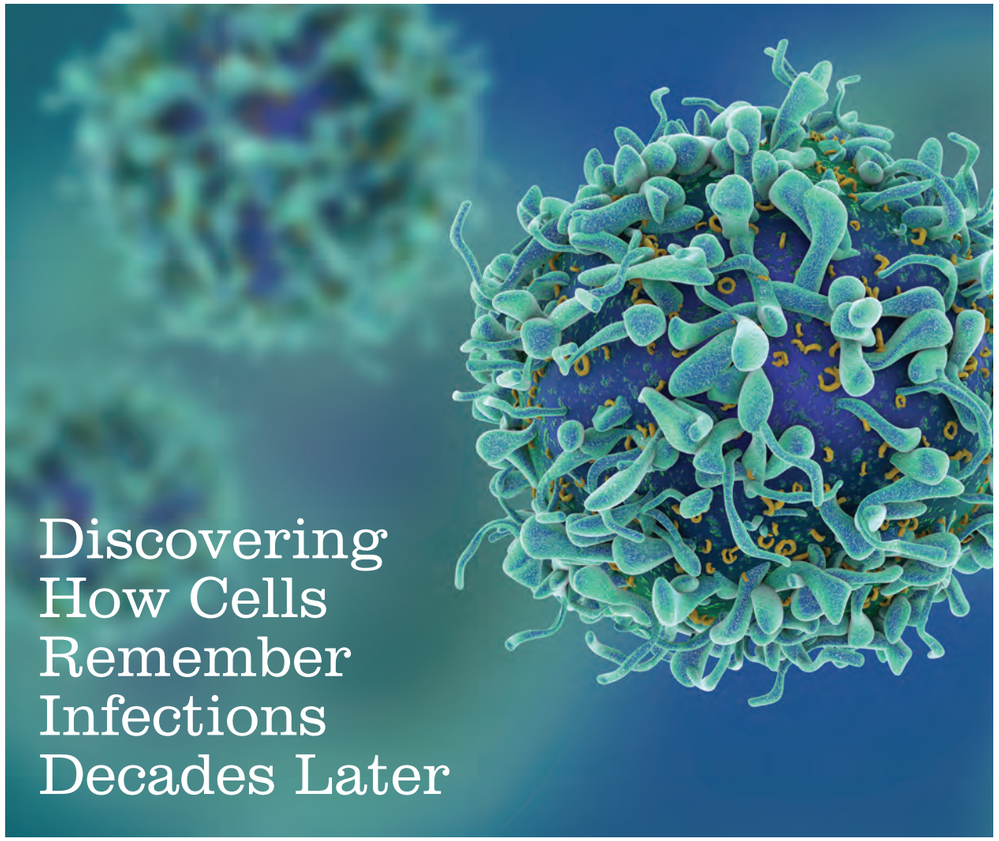
BREAKTHROUGHS



ONLINE

Sesquicentennial Stories
Throughout the year we'll be adding feature articles, interviews, photo essays, and more to our 150th anniversary site.
Go to nature.berkeley.edu/150

COVER: Photography by Elena Zhukova



Discovering How Cells Remember Infections Decades Later

Immunologists have long been perplexed by the question of exactly how immune cells remember an infection or a vaccination so that they can spring into action decades later. Research led by Professor **Marc Hellerstein** in the Department of Nutritional Sciences and Toxicology, in collaboration with investigators at Emory University, has found an answer: A small pool of the same immune cells that responded to the original invasion remain alive for years, developing unique features that keep them primed and waiting for the same microbe to reinvade the body.

Before this study, scientists knew that cells can remember an infection from up to 30 years earlier, but weren't sure how. To tease apart this mystery, the research team tracked a specific kind of immune cell through the human body in the weeks, months, and years following a vaccination that gives long-term protection.

Using a technique that Hellerstein developed for his HIV/AIDS research in the 1990s that monitors the birth and death of cells in humans over long periods of time, the researchers tracked T cells inside people's bodies after they were given the long-lasting yellow fever virus vaccine. They found that CD8+ T cells, responsible for long-term immunity against yellow fever, proliferate rapidly on exposure to the vaccine but then evolve, beginning about four weeks after the vaccination, into a "memory pool" of cells that live more than 10 times longer than the average T cell. Over time, the large pool shrinks to a small number of long-term memory cells, which are primed to provide late protection.

"This work addressed fundamental questions about the origin and longevity of human memory CD8+ T cells generated after an acute infection," said Hellerstein, senior co-author of the study, which was published last December in the journal *Nature*. "Understanding the basis of effective long-term immune memory may help scientists develop better vaccines, understand differences among diseases, and diagnose the quality of an individual person's immune responses."

— BRETT ISRAEL

PHOTO: Matthew Luskin

Palm Oil Plantations Fuel Pigs, Harm Forests

Increased demand for palm oil has caused widespread deforestation and biodiversity loss in Southeast Asia, and a new study by CNR researchers demonstrates that the impacts of expanding plantations of oil-producing palm trees are much worse than previously thought. Wildlife feeding on oil palm fruit can become overabundant and subsequently cause the chronic degradation of remaining nearby forests.

In a study lasting more than two decades, an international team of scientists observed immense shifts in tropical forests in Peninsular Malaysia. "We knew that forest understory was dying, but we didn't understand why," said **Matthew Luskin,** PhD '16 Environmental Science, Policy, and Management (ESPM), lead author of the study. "Once we started looking outside the forest to the surrounding palm oil plantations, the story became clear."

Oil palms produce fruit rich in an oil that can be found in a wide range of food and cosmetic products. Forest animals like monkeys and pigs also feed on the fruit, and with a proliferation of palm oil plantations their numbers can rapidly multiply.

In their study, published last December in the journal *Nature Communications,* the researchers found that the presence of oil palm fruit on such plantations led to a 100-fold increase in the number of wild boars living in the adjacent forests. In addition to eating tree fruits, wild boars have destructive behaviors such as rooting up soil for food and building nests, which can disrupt tree sapling density. By comparing such forests with forest areas that were fenced to exclude wild boars, the team found that wild boars reduced the number of small trees by over 50 percent, raising concerns about the future health of the forests.

"What's most concerning about these findings is that the negative impacts of palm oil plantations are occurring deep within what otherwise looks like pristine forest—miles from the nearest plantation," said ESPM professor **Matthew D. Potts,** a co-author of the study along with ESPM professor **Justin Brashares.**

Fresh Technology for Freshwater Research

Berkeley researchers are collaborating with the UC Natural Reserve System (NRS) to lead a new project that monitors changing freshwater resources across California. With a $2.2 million grant from the Gordon and Betty Moore Foundation, the California Heartbeat Initiative–Freshwater project will utilize drones and wireless sensor systems throughout the sites of the NRS, a network of protected lands covering more than 750,000 acres and representing many of the state's habitat types. The goal of the program, said lead investigator and ESPM professor **Todd Dawson,** is "to deepen our understanding of how changes to climate and water are affecting natural and agricultural lands, and to predict how characteristics of these landscapes may shift in the future." Other researchers involved in the project include **David Ackerly,** a professor in the Department of Integrative Biology, NRS director **Peggy Fiedler,** BS '80, PhD '85, Wildland Resource Science, and **Maggi Kelly,** an ESPM professor.

Where There's Smoke…

For years, CNR researchers have been studying fire, its causes and its repercussions. Now, in the wake of last fall's wildfires, their work has become more important than ever. By Kirsten Mickelwait

Changing the Trajectory of Land Management

The recent epidemic of catastrophic wildfires across California could be the beginning of a new normal, warned a paper by College of Natural Resources fire scientists published in *Bioscience* in January. Tens of thousands of acres of deadened trees—victims of drought and insects like the bark beetle—stand ready to ignite during the next dry season. And conditions will only worsen in the next 5 to 10 years as the trees fall to the ground, threatening more urban areas and watersheds.

Among land management agencies and researchers, two schools of thought have emerged: One advocates focusing on already-dead trees as the next target of wildfires. But the other side, represented in the recent study, argues for replacing triage with more proactive measures to make live forests more resilient. It suggests removing small-to-moderate-sized trees by mechanically thinning forests and setting more prescribed fires.

"While the majority of green California forests are extremely vulnerable to fire, drought, and bark beetle attack, there's still time to act," said **Scott Stephens,** professor of fire science in the Department of Environmental Science, Policy, and Management (ESPM) and co-author of the study. "The next 10 to 20 years will be critical—we must change the trajectory of our land management before fire and bark beetles do it for us."

In recent years, Stephens and his colleague **Bill Stewart,** an ESPM Cooperative Extension specialist in forestry, had already been interacting with state lawmakers frequently, hosting them at UC's Blodgett Forest Research Station and testifying at legislative hearings. Since the fall's disastrous wildfires, they have held several meetings with California legislators' senior staff to discuss specific ideas for reforming fire and forest management, especially near highly populated areas.

"It would be a valuable step forward for California to emphasize policy development and energize prescribed-fire programs from both operational and legal perspectives," Stephens said.

Fungi and Forest Recovery

Tom Bruns, a professor in the Department of Plant and Microbial Biology, is currently conducting research focusing on saprobic fungi that colonize soil after a wildfire. Using genomics, his lab is trying to understand what saprobes—which feed on dead material—do in postfire environments, with the long-term goal of using this data to facilitate postfire recovery and carbon storage.

According to Bruns, forest fires often leave behind areas of soil that repel water, owing to waxes in natural plant litter that congeal in cooked soil. "Recovery crews are interested in these hydrophobic soils because they lead to eroding hillsides," he said. "If we understand the microbes involved in degradation of postfire hydrophobic compounds and learn to facilitate their activities, we may be able to reduce the risk of erosion."

PHOTO: Tom Bruns

Using Light to Predict Fire Behavior

Public forest managers have long used behavior modeling to predict severe fire areas and take preventive measures like tree thinning and prescribed burns. In California, such modeling has been particularly challenging, because the state's forests are so complex and diverse in their topography, composition, volume, and quality. So local researchers have been employing new technologies and approaches to fire behavior modeling.

In December 2017, CNR researchers reported in the open-access journal *Remote Sensing* on new technologies and approaches that may be effective for fire behavior modeling. Co-authored by **Maggi Kelly, Stefania Di Tommaso, Danny Fry, Brandon Collins,** and **Scott Stephens,** among others, the article specifically focuses on the potential of LiDAR—light detection and ranging—technology.

"It's an active sensor that sends light pulses, usually from an aircraft, to penetrate the forest canopy," said Collins, a research scientist at Berkeley's Center for Fire Research and Outreach who also works with the U.S. Forest Service. "The time it takes for those pulses to hit something in the forest and bounce back to the sensor has been related to the height of the vegetation that they're hitting. From a fire standpoint, it's describing the arrangement and the quantity of potential fuel. This allows us to better target our management to reduce hazardous fuel conditions, which ultimately improves our chances at minimizing impacts from future wildfires."

On the Front Lines of Firefighter Health and Safety

Research has shown that firefighters experience higher rates of many cancers, owing to their greater exposure to hazardous materials. In 2013, **Rachel Morello-Frosch**—a professor in ESPM and the School of Public Health—became the principal investigator of the Women Firefighters Biomonitoring Collaborative Study.

A partnership of six science, advocacy, and firefighting-safety organizations, the study is the first to focus specifically on female firefighters and their exposures to carcinogens that could lead to breast cancer. Morello-Frosch's team has been analyzing chemical measurements taken from blood samples provided by female members of the San Francisco Fire Department and comparing chemical levels with those in samples provided by female office workers.

Then came the October wildfires that ravaged Sonoma, Napa, and Mendocino Counties. Since many Bay Area municipal fire departments provided mutual aid during the wildfires, Morello-Frosch and her collaborators saw an opportunity to collect unique exposure data from both male and female firefighters on the scene.

"Because our study of women firefighters was already up and running, we were able to amend our protocols to collect blood samples from firefighters who went to help with those wildfires," said Morello-Frosch. The researchers also collected samples from firefighters who did not serve at those sites, to conduct a comparative analysis of chemical levels in the two groups.

"The last few fire seasons have taught us that it's not a matter of *if* another of these wildfire events will happen but *when,*" said Morello-Frosch. "Now we'll be even better prepared, with protocols in place before the next fire season so we can get out in the field and do sample collection more quickly. As researchers, we must also be rapid responders, ready to collect critical data that can help firefighters protect themselves from hazardous chemical exposures."

IN THEIR OWN WORDS

By Kate O'Neill

Where Will All the Plastic Go?

Until March of this year, China was by far the world's largest importer and recycler of scrap metals, plastic, and paper. According to one study, the country received 56 percent of global scrap-plastic exports in 2014. But increasing restrictions and bans on what China's environment ministry calls "foreign garbage" may change all that, potentially redirecting the cross-border flows of scrap that underpin recycling markets worldwide.

Cargo ships carry goods from China to Western countries and then carry scrap back in a process known as "reverse haulage." China's booming industries are hungry for plastics they do not yet produce at home, so they willingly pay for high-quality imported scrap to reuse. For U.S.-based waste collectors, selling scrap to China is cheaper than having it recycled at home.

China's plastics-recycling rate, 22 percent in 2013, is far higher than the United States' annual average of 9 percent. However, it is not clear under what conditions plastics are recycled in China, or what happens to the rest. Some likely is diverted to subpar incinerators for energy recovery or winds up in the oceans.

Chinese leaders have concerns about the nation's environmental crisis and image as "the world's dump site." On March 1, 2018, therefore, they enacted stringent restrictions on imports of 24 kinds of scrap, including paper and plastic. Although the global scrap industry is fighting back, China's actions are forcing other industrialized nations to rethink their dependence on overseas disposal. The United States has not built a new high-quality plastics-recycling facility since the early 2000s, and very few of its existing plants can cost-effectively process harder-to-recycle, often dirty postconsumer plastics. Moves are under way to improve U.S. capacity, but they will take years to implement. In the meantime, plastic scrap is already being diverted to other ports in Southeast Asia, where its fate is unclear.

Mass production of bioplastics is a long-term solution, but is probably years off. Other priorities include expanding markets for recycled products and improving consumer education. In my view, losing China as a primary consumer of Western scrap could and should finally spur other industrialized nations to take more responsibility for the waste they generate.

Kate O'Neill is a professor of global environmental politics in the Department of Environmental Science, Policy, and Management (ESPM).
A longer version of this article originally appeared in the online publication *The Conversation*.

Communicating Climate Change Through Sound

As part of Data Science for the 21st Century—a new training program at UC Berkeley funded by the National Science Foundation—CNR graduate students **Hal Gordon, Valeri Vasquez,** and **Kate Pennington** were recently challenged to visually communicate their scientific research to a general audience. For a capstone project, the students were partnered with San Francisco public broadcasting station KQED. But they realized that an expression of their chosen science—climate change—would be more appropriately revealed through sound and opted to work with KQED-FM radio. "It was exciting to consider explaining data sets about climate change through a new medium," said Vasquez, a student in the Energy and Resources Group. "We saw the opportunity to help people pick up nuances in the data that they might not consider when viewing a graph."

The group teamed up with Chris Chafe, director of Stanford's Center for Computer Research in Music and Acoustics, to create a piece of music based on the climate data they had compiled. They also recruited climate science expert and ESPM professor **Inez Fung** to provide audio commentary on the sources of the data: growth rings in trees and pollen counts in mud-core samples from the bottoms of lakes.

Representing the past 1,200 years, the finished piece begins with a drone—representing the concentration of carbon dioxide in the atmosphere—punctuated by plucking sounds that denote annual average temperature. "There's a temporal element of sound," said Gordon, a student in the Department of Agricultural and Resource Economics (ARE). "We had to find the right pace and length to help people understand the data without getting bored." Moving through time at four years per second, the sounds remain relatively steady for a while. "For most of the piece, the sound is very stable, almost relaxing," commented ARE student Pennington. "You get a sense of the state of the world before anthropogenic climate change."

As the piece progresses past 1760 and the Industrial Revolution, however, listeners can detect subtle shifts. The drone starts to rise in pitch as Co_2 levels rise, which drives the pings of temperature higher too, racing upward to a dramatic screech at the piece's abrupt end in 2016.

"Based on graphs of the data, we knew it would end with a rise in pitch, but it was surprising how alarming the sound became at the end," said Vasquez. "It's really appropriate, actually, to help convey the extremity of climate change."

— JULIE GIPPLE

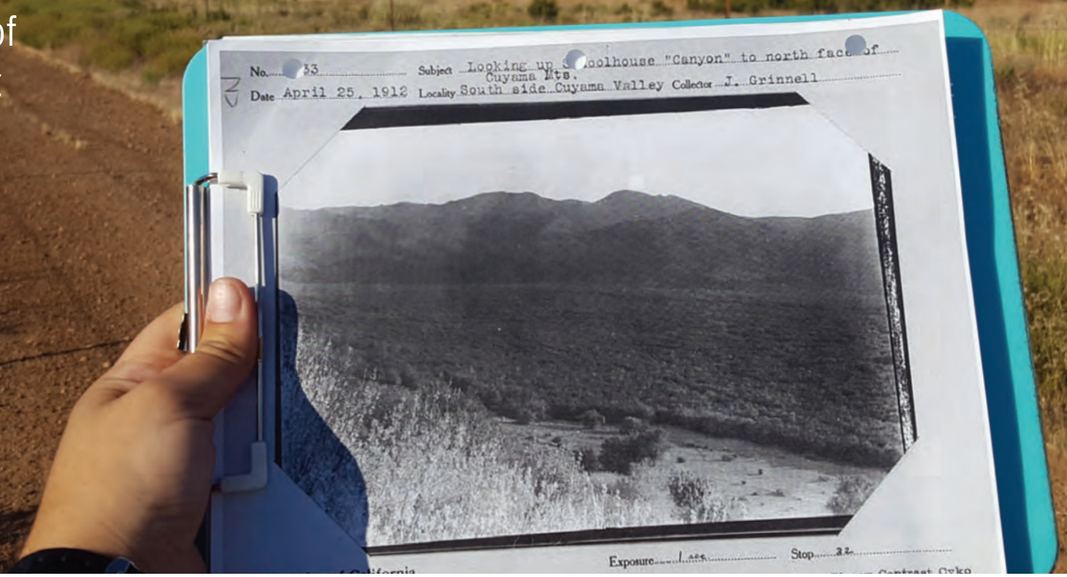
Listen to the KQED story online at: nature.berkeley.edu/breakthroughs

In *U.S. News & World Report*'s "Best Global Universities" rankings for 2018, UC Berkeley was rated No. 1 in Environment/ Ecology and No. 4 in Plant and Animal Science.

Across a Century of Change, the **Gift of a Baseline**

Retracing the steps of pioneering naturalist Joseph Grinnell

By Jonathan Mingle
MS '09 Energy and Resources Group



For an ecologist, **Sarah MacLean** has found herself in some unlikely places over the past three summers. Binoculars in hand, she has navigated highway overpasses and garbage-littered lots, prowled suburban streets around Los Angeles, and explored farmers' yards in the Central Valley.

Wherever she went, MacLean maintained the same daily routine. Starting before dawn, she would make her way along a predetermined route, stopping at 10 fixed points. For seven minutes she'd count every single bird she could see or hear. "In some places, there'd just be one house finch. In other places, I couldn't write fast enough, so I kept a mental list and caught up when they all stopped flying by."

A graduate student in the Department of Environmental Science, Policy, and Management (ESPM), MacLean is part of a community of scientists who are retracing the steps of Joseph Grinnell, the pioneering naturalist and founding director of UC Berkeley's Museum of Vertebrate Zoology (MVZ). They're searching for insights into how a century of change—both in the climate and in the way humans use the land—has affected the biodiversity of California. Between 1904 and 1940, Grinnell and his colleagues surveyed birds, mammals, reptiles, and amphibians across the state's length and breadth, from Mount Lassen to Death Valley to the hills above his native Pasadena. They brought back more than 100,000 specimens and filled more than 74,000 pages of field notes with detailed counts and descriptions of every creature they came across.

Their efforts yielded a trove of information for future scientists, just as its primary author intended. **Steve Beissinger,** an ESPM professor of conservation biology, has led the 15-year-long project of resurveying Grinnell's sites throughout the state. This work has been made possible entirely by the rich archive of data housed in the MVZ.

Grinnell's efforts were largely motivated by the human encroachment into wildlife habitat that he was already witnessing. In a 1910 article in *Science,* he described what he believed would prove to be the greatest value of his museum. "This value will not, however, be realized until the lapse of many years, possibly a century, assuming that our material is safely preserved. And this [value] is that the student of the future will have access to the original record of faunal conditions in California and the west, wherever we now work."

That quote, which has long hung on the wall of the MVZ, inspired the resurvey. "Grinnell definitely had a sense that he was giving us a record of what California was like in the early 1900s," Beissinger says. "He gave us the gift of a baseline."

"Put it all down!"

To make full use of that gift, contemporary researchers had to do some detective work to retrace Grinnell's steps. Fortunately, his specimens provided key clues. They searched the museum's public database to find out where and when certain specimens were collected, then cross-referenced that information with descriptions in the field notes. Grinnell often made annotated maps, but not all of his students were as exacting.

A western meadowlark, spotted in the San Luis National Wildlife Refuge.
PHOTOS: Sarah MacLean

"Sometimes they'd say, 'We walked the Yosemite Falls Trail,' and you'd know exactly where to go," Beissinger says. "Sometimes it would just say, 'Horse Mountain.' Well, there are three Horse Mountains in California. So you'd have to look at the verbal description to figure it out."

Having spent so much time buried in Grinnell's notes, Beissinger has developed a sense of the man. "He was very much a workaholic," he says. "He would go on vacation with his wife and still be writing field notes. God only knows what he would have done if he had a computer."

Grinnell's philosophy was simple: Record as many sights and sounds as possible. That included seemingly ancillary details, such as weather conditions and vegetation types.

“Grinnell was in the same place we are—he just knew it was important to create as robust a baseline as he could.” — Sarah MacLean

“He never traveled one inch but what he had that notebook open,” recalled the late Ward Russell in a 1992 interview. Russell served as the MVZ’s preparator for 40 years, gathering specimens with Grinnell all over the state. “He said over and over, ‘Put it all down! You may not think it’s important, but somebody may.’”

An excerpt from Grinnell’s notes from May 5, 1907, in Glendora shows that philosophy in action. He jots down everything he notices in an extremely detailed narrative: the types of bushes birds alight on, the swoops and swerves of their mating performances, the exact interval in seconds of a male valley quail’s hollering call and a lazuli bunting’s “hurried shrill song from the top of an oak.”

More than a century later, the picture of change captured by the resurvey is both sobering and complex, even as Grinnell’s methods have proved, in a sense, to be timeless. Resurvey participants have replicated his omnivorous approach to information gathering. “The Grinnellian method is the gold standard,” MacLean says, “so we’ve tried to emulate that note-taking style.” But they’ve also updated it, incorporating modern data-collection methods.

Beissinger, MacLean, and their colleagues have also benefited from the use of new, sophisticated statistical methods called occupancy models, which allow them to account for improvements in modern researchers’ observational capabilities relative to Grinnell’s. “He was an amazing naturalist, but technology has progressed,” MacLean notes. “We have better, clearer binoculars. I’m out there with my smartphone. If I hear an unfamiliar birdcall, I can use an app to identify it.” These aids increase the likelihood of their detecting birds; the models help them establish the probability of detecting a species independent of the probability that the species is actually there (technically known as “occupancy”).

While the resurvey has examined the occupancy of both birds and small mammals in every eco-region of California, the most recent wave of findings to emerge from the project has to do with how the avian species of the deserts and the Central Valley have fared since Grinnell’s day.

Kelly Iknayan, another ESPM PhD student in Beissinger’s lab, has led the resurvey of birds in the Great Basin and Mojave Deserts. Where Grinnell maneuvered his Ford Model T, Iknayan drove a Ford Explorer. In addition to the field notebooks that she compiled using Grinnell’s exacting standard, she lugged around 75 pounds’ worth of audio-recording equipment. “We have a record of anything singing at these sites,” she says. “That’s 10 terabytes of data that offers ample opportunities to anyone looking at it in the future.” And with a GPS unit, she digitized the precise coordinates of her survey locations, to assist future researchers retracing *her* steps.

Drivers of decline

While most of those desert sites have been relatively undisturbed by development, climate change is already making inroads—especially in the Mojave. “Across the board,” Iknayan says, “bird species are declining.” The result is a collapse of the entire bird community, to a new baseline with fewer species per site. At all but 3 of her 61 sites, Iknayan recorded a significant decline in the number of species found. And of 135 breeding species she surveyed, all but 3 showed a negative trend in occupancy compared with that observed by Grinnell and his team. The only bird that has increased in numbers is the common raven, which famously thrives on disturbance.

Changes in precipitation best explain these declines for desert birds. With climate change likely to increase the frequency of heat waves, the outlook is grim for native birds of the Mojave. “Projections show many more days in the future when birds could experience lethal heat and dehydration,” Iknayan says.

Creatures in California’s other ecosystems are coping with these compounding changes in complex ways, but a common thread is emerging from the data. In this arid state, where water has long preoccupied people, early findings suggest it’s a dominant story for the resident birds and mammals, too.

“Water is emerging as a key variable in how species are shifting their geographic range in relation to climate change,” says Beissinger. “One of the things we learned from our resurvey work in the Sierras was that temperature change and precipitation change can act as opposing forces.” Half of the 28 small mammal species resurveyed in Yosemite National Park have shifted their range upward, in response to warming temperatures. But as Yosemite is drying out and warming, climate change is making other

Archival photos courtesy of the Museum of Vertebrate Zoology, University of California, Berkeley. Contemporary retakes by John D. Perrine and Sarah MacLean.

PHOTO: Steve Beissinger

"Across the board, bird species are declining."

— Kelly Iknayan

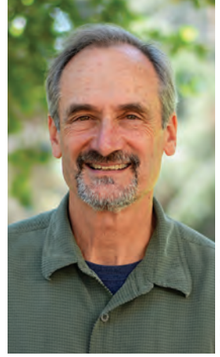


PHOTO: Julie Gipple

"With Grinnell's data, it was like we were taking the field trip with him."

— Steve Beissinger

places rainier. On Mount Lassen, for example, wetter conditions have resulted in many species moving downslope. Even in Yosemite, other species have moved downward, a sign that certain mammals might be responding more strongly to changes in precipitation than to rising temperatures.

MacLean also found that water availability was the most important factor determining birds' distributions in the Central Valley. "We saw a minimal effect of urbanization and agriculture in determining occupancy, which is surprising because the Central Valley is a hugely modified landscape. Water mainly exists where people allow it to, and where there's water, there is greater richness of bird species."

In the Los Angeles Basin, however, the effects of urbanization have been more alarming. Some birds that were ubiquitous in Grinnell's time, such as the house finch, are still around in huge numbers today. But others that were common characters in his notes, such as the yellow-breasted chat, are now almost completely missing. Exotics like red-crowned parrots, red-whiskered bulbuls from India, and peacocks proliferate instead.

These changes have less to do with water and more to do with human tastes. Whereas many birds native to the Central Valley can still find habitats in native trees like cottonwoods and sycamores, around farmhouses and parks, the native birds of LA have seen their familiar roosts replaced by exotic trees such as date palms and magnolias. "This loss of a very diverse native bird community in LA is startling," MacLean says, "because it's such a hot spot for biodiversity."

Collaborating across eras

It's impossible to predict what the "students of the future" will find when they resurvey California a century from now—or sooner. "I'm hoping they come back in 25 or 30 years, when climate change has really kicked in," Beissinger says. Whenever they do, like his forerunner, he has a message for them. "Make sure you're collecting data in a way that the next generation will be able to use it beyond your specific study," he says.

He thinks that Grinnell's approach to close observation will always be relevant to ecological research, even in the age of remote sensing and sophisticated spatial-mapping software. "Capture as much on-the-ground information as you can, and make sure to preserve it," he adds. "With Grinnell's data, it was like we were taking the field trip with him."

As she trekked through dramatically transformed landscapes, furiously taking notes, MacLean was ever mindful that she was collaborating with colleagues across eras, contributing to a collective effort to understand subtle but momentous shifts happening in the natural world.

"Our main goal is to collect as much as we can and far more than we need for our current projects," she says. "It's a challenge, because we don't know what people are going to need in the future, what questions they'll be asking, what technology they'll have at their disposal, what statistical methods they'll develop. Grinnell was in the same place we are—he just knew it was important to create as robust a baseline as he could. We're trying to mirror that, and hope it will be as much as they need."

In the meantime, Berkeley's new Institute for Parks, People, and Biodiversity will help draw lessons from the resurvey's findings for park managers and wildlife conservation planners working to identify and connect "refugia"—places that are buffered from the effects of climate change, where unique physical or ecological conditions help species persist.

Grinnell trained many of the first scientists who conducted pioneering research in the national parks. Today, his gift of a baseline is enabling their successors to understand how different species are managing in the face of climate change—and to help those species adapt and survive. It's a legacy that even Grinnell could not have foreseen, but one he'd likely applaud.

11 Things You Might Not Know About the College of Natural Resources

By Mackenzie Smith

PLANTS WITHOUT SOIL

In 1938, professors **Dennis Hoagland** and **Daniel Arnon** developed the first hydroponic nutrient solution, which contains everything plants need to thrive—all without a single clod of dirt.

CHOPPING DOWN BARRIERS

UC Berkeley first awarded a forestry degree to a woman in 1928, but by 1965 only nine women had graduated from the forestry program and just three had attended Forestry Field Camp. Today, nearly 60 percent of forestry majors are women.

A SPARKLING DISCOVERY

A new species of the colorful dancing peacock spider was discovered in 2015 in eastern Australia by **Maddie Girard,** PhD '17 Environmental Science, Policy, and Management, who nicknamed it Sparklemuffin.

THE BONUS THAT BUILT GIANNINI HALL

In 1928, Bank of America's founder, Amadeo Peter Giannini, was awarded a $1.5 million bonus by the bank's directors in honor of his 60th birthday. Giannini donated the entire sum to UC Berkeley—a gift that funded the construction of Giannini Hall and established the Giannini Foundation of Agricultural Economics.

A MODEL WEED

Professor emeritus **Athanasios Theologis** and a team of CNR researchers completed the sequencing of the first plant genome, of a mustard weed known as *Arabidopsis thaliana.* Finished in 2000, the plant's genome serves as a model genetic organism for studying population genetics and plant development.

RESEARCH NEAR AND FAR

CNR faculty and students can conduct research at UC Berkeley's 15 field stations—some of which are as close as Richmond Field Station, north of the Berkeley campus, and others as far away as the Gump Research Station in Moorea, French Polynesia.

THE PENTHOUSE STUDIES

In 1963, professors **Doris Calloway** and **Sheldon Margen** transformed the "penthouse"—a model three-bedroom home on the top floor of Morgan Hall—into an in-patient metabolic unit. This laboratory became the site of some of the first well-controlled human nutrition research, which later helped the U.S. government develop recommended dietary allowances.

THE SWEETEST THING

The world's most widely eaten pineapple was developed by alumnus **Frank Dillard,** BS '47 Agricultural Science, who named the variety MD-2 after his wife, Millie.

27 YEARS AND COUNTING

Since 1991, professor emeritus **John Harte** and his students have been artificially warming a meadow in Colorado—a study that has become the world's longest-running controlled active-heating experiment on climate change.

DRINK UP

In the 1880s, **Eugene Hilgard,** the first professor of agriculture at UC Berkeley, played a pivotal role in creating California's wine industry—both by promoting Napa Valley's soils as a fertile location for vineyards and by developing varieties of grapes that were resistant to phylloxera, a widespread pest that attacks the roots of the plants.

CHOCOLATE'S SAVIOR

Professor **Brian Staskawicz** leads a team that is using the CRISPR-Cas9 genome-editing system to help save the world's cacao crops, which could go extinct by 2050 if the plant does not adapt to our changing climate (for more on CRISPR research, see page 14).

From Genes to **Global Solutions**

CNR faculty lead wide-ranging research initiatives at the Innovative Genomics Institute

By Zac Unger, MS '00 Environmental Science, Policy, and Management
Photography by Elena Zhukova

It's often said that the relationship between science and the natural world follows a five-step process: observe, describe, explain, predict, and control. Over the past 50 years, the effort to control has increasingly been focused on the molecular level, with labs racing one another to achieve ever more sophisticated feats of genetic engineering. But long before "genetic engineering" was a buzzy phrase—and even before anyone knew what a gene was—humans were using the process to feed themselves more efficiently.

The first time a nomadic tribe bred an especially large ram with a particularly tasty ewe, for example, or the first time a society cultivated wild wheat so that it would grow when and where they wanted—both were practicing early forms of genetic engineering.

While the College of Natural Resources' 150-year history is a blink of time from an evolutionary perspective, CNR's land-grant mission has placed it at the forefront of agricultural genetic engineering since the beginning. In the early 1900s, that might have meant laboriously developing new cultivars for California's booming orchards, but now Berkeley is taking the lead with a new genome-editing technology that promises to reshape the future of agriculture, medicine, and the meat and dairy industries.

Commonly known as CRISPR—an acronym for Clustered Regularly Interspaced Short Palindromic Repeats—the genome-editing technique takes elements of adaptive bacterial immunity to viruses and makes highly targeted alterations to the genome of a plant or animal. To make DNA edits, scientists wield the Cas9 protein like a "molecular scalpel," slicing out mutated DNA and adding in a healthy genetic patch. Although CRISPR technology is still in relative infancy, the possibilities are staggering—from the creation of drought-resistant crops to new treatments for cancer and sickle cell anemia.

Just as UC Berkeley helped pioneer the land-grant college system and the Cooperative Extension programs a century and a half ago, a new powerhouse, the Innovative Genomics Institute (IGI), is poised to lead the charge on CRISPR and other emerging technologies. It's a joint effort between UC Berkeley and UC San Francisco, bringing together a team of professors and researchers to advance genome engineering with the ambitious goals of curing disease, ensuring food security, and preserving the environment.

Combining four broad research areas—biomedicine, agriculture, microbiology, and society—the IGI is an interdisciplinary hub with wide-ranging potential. **Jennifer Doudna,** the UC Berkeley professor of chemistry and molecular and cell biology who co-developed CRISPR genome editing just a few years ago, serves as executive director. And CNR faculty play critical roles on the scientific team, working toward advances in the fields of agriculture, microbiology, and the societal and economic challenges of bringing CRISPR technology into widespread global use.

REVOLUTIONIZING AGRICULTURE IN THE DEVELOPING WORLD

One of the core members of the new institute is **Brian Staskawicz,** a professor in the Department of Plant and Microbial Biology (PMB) and the scientific director of the IGI's agricultural research. Staskawicz, who earned his PhD in plant pathology at Berkeley in 1980, has been on the faculty here for 34 years.

His contributions to the field of plant disease and immune response stretch back decades. In 1984, his was the first lab to publish on the fact that plant pathogens deliver proteins—now widely known as effector proteins—that actively suppress the immunity of the plant host. Ten years later, his lab broke new ground again by cloning one of the first disease-resistance genes.

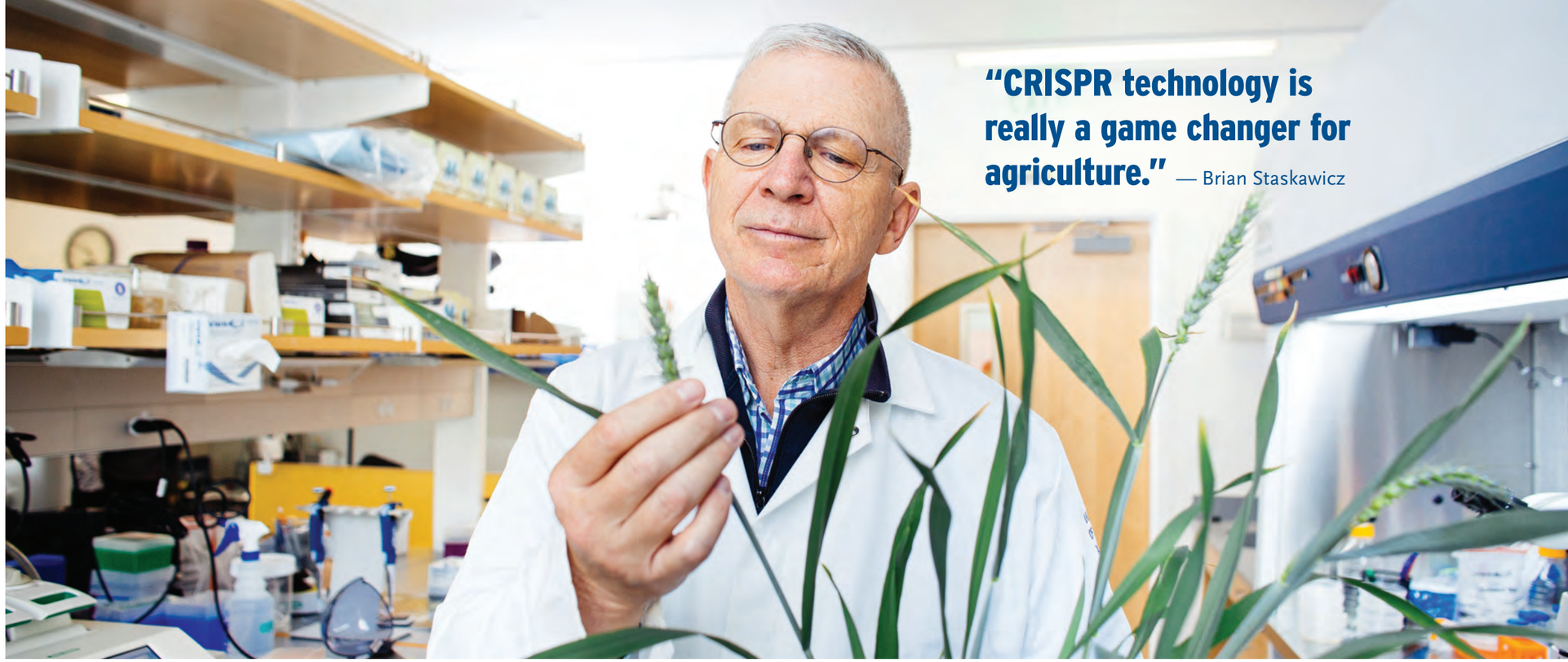
Two years ago, Staskawicz immediately recognized the potential of CRISPR to rapidly introduce genetic disease resistance into crops, possibly overcoming many significant problems in modern agriculture. "This technology is really a game changer for agriculture," says Staskawicz, whose group is working with genome editing to make plants more sustainable in an environmentally friendly manner. "We think we can use CRISPR to make plants more drought resistant," Staskawicz says. "We can also edit in resistance to disease, and maybe even make plants more efficient in the way they use nitrogen." Given that the Food and Agriculture Organization of the United Nations has predicted that population growth will require food production to increase by 70 percent by 2050, the promise of greater efficiency isn't just a nicety but a life-sustaining necessity.

Part of CRISPR's great potential is the speed with which new plant types can be produced. In classical plant breeding, introducing a trait from a wild species takes years of backcrossing to achieve the desired result. But with CRISPR, says Staskawicz, "we'll take the same genes we normally use to do genetic crosses, but now we're going to be able to introduce them singly or in groups precisely into the already high-yielding variety that we want and not bring in all the baggage that we don't." This is likely to prove especially valuable in the face of rapidly changing environmental conditions such as global warming. "A lot of the genetic-disease-resistance traits break down at high temperatures," Staskawicz says, "so we're going to start seeing new epidemics coming. We're going to see changes in populations of pathogens." While traditional responses might be to add more pesticides or deforest more land for agriculture to produce greater crop yields, CRISPR may be able to quickly create disease-resistant seeds for farmers.

And while the science is fascinating and papers are being published at a rapid clip, CNR faculty aren't losing sight of the fact that the ultimate goal is to get these products into the fields where they're most needed. "We've purposely chosen to work on wheat, rice, and other crops that affect developing countries and that have been ignored by companies because they don't make money," says Staskawicz. One of his current projects involves cassava, among the most important food crops in the tropics. Although it's drought tolerant and relatively productive in marginal soils, cassava also produces cyanide, which in turn causes konzo, a so-called disease of poverty that affects 100,000 people per year. Currently, farmers remove toxins using laborious (and often imperfect) postharvest techniques; gene editing could revolutionize the way millions of people safely feed themselves.

To advance the plant-genomics research agenda at Berkeley, the IGI has been scaling up its team—hiring four postdoctoral researchers in that area last year. The Department of Plant and Microbial Biology is working to hire at least three new faculty members who will be involved in the IGI as well.

"I was attracted to Berkeley because it's now the center of genome-editing technology," says **Ksenia Krasileva**, BS '05, PhD '11, Microbiology, one of the new hires, who starts as an assistant professor in PMB this summer. At the moment, Krasileva—based in the UK and partnering with an NGO in Kenya—is working with wheat, which requires heavy doses of fungicides to combat afflictions of yellow rust. As wheat was domesticated from wild relatives, she explains, "selection was made for size rather than the health of the plants, and the natural diversity that allowed them to withstand pathogens got lost." The ability to introduce very targeted disease-resistance genes hasn't been perfected yet, "and that's the research that's happening at Berkeley," she says. "We'll figure out how best to do very precise changes to make disease-resistant crops."



HARNESSING MICROBIAL COMMUNITIES TO MEET SOCIETAL NEEDS

It's easy to talk about CRISPR as an exciting new tool that scientists have just invented, but **Jill Banfield**, the scientific director of the microbial arm of research at the IGI, points out that the technology long preexisted human knowledge of it. A geomicrobiologist with appointments in the departments of Environmental Science, Policy, and Management (ESPM) and Earth and Planetary Science as well as at Lawrence Berkeley National Laboratory, she is quick to give credit where credit is due. "Let's back up and say the CRISPR-Cas system was invented by microbes and used by microbes as a defense system against viruses and plasmids. We anticipate that there are many different genome-editing tools present in the genomes of microbes that have not yet been discovered."

So it would be more accurate to say that the scientists at the IGI are piggybacking on a system that has been used by bacteria since the earliest days of life on Earth and adapting it for a different use in plants, livestock, and humans. It had been speculated that the microbial genetic feature that came to be known as CRISPR actually works as an immune system, and research from Banfield's lab helped scientists understand. "If you remove this system from microbes," she says, "they'll die of viral infections."

In the course of her research, Banfield discovered that CRISPR systems in nature have evolved incredibly rapidly. That led her to collaborate with Doudna in the heady early days of explaining CRISPR's potential to the worldwide scientific community. Banfield's current involvement in the IGI is not so much in the eventual applications of CRISPR technology, but in building up a tool kit for other scientists to use. "Our group is looking for new CRISPR-Cas systems that could have value for the purposes of genome editing," she says.

To do this, Banfield and her students are making use of vast amounts of sequence information that they've obtained from the natural environment. While most of us look at the world and assume that life consists of the plants and animals we're familiar with, Banfield points out that the majority of organisms are actually the bacteria and archaea we rarely consider.

"Food is so much more than calories; it's culture. And that's why it can be so polarizing." — Matthew Potts

"The genomes of most organisms in the world have not yet been sequenced," she says. And even when the sequencing has been done, "in some organisms, 50 percent of the genes have no known function. There's enormous potential there." Banfield and her collaborators—including Doudna—have already discovered simple systems similar to CRISPR-Cas9 in previously unexplored bacteria. These new systems are highly compact, and if they can be reengineered as CRISPR-Cas9 has been, their small size could make them easier to insert into cells to edit DNA.

Banfield's search for new organisms has led the world to reconsider and expand its understanding of the biological "tree of life," demonstrating that the great majority of species are invisible to the naked eye. This work has taken her to some unlikely places, from a sweltering underground acid mine to a high-intensity dairy farm in the Central Valley, where the team pumped up groundwater while slogging through cow pies and sewage lagoons. In addition to being the basis of new genome-editing tools, microbes have great potential in their own right, as sources of novel antibiotics, as instruments of wastewater treatment, or as part of the process of creating sustainable sources of bioenergy. "Microbial communities can be harnessed to meet societal needs," Banfield says. "They mediate our air quality, our water quality, and so much more."

"POLICY AND SCIENCE GO HAND IN HAND"

It may turn out that the greatest impediment to the use of CRISPR is not scientific but political. Although the USDA considers CRISPR crops differently than it does genetically modified organisms, some of the same cultural battle lines are beginning to emerge. "Food is so much more than calories; it's culture. And that's why it can be so polarizing," says **Matthew Potts**, an ESPM associate professor. Potts and **David Zilberman**, a professor in the Department of Agricultural and Resource Economics, are working together as part of a project funded by the IGI that focuses on maximizing the social, economic, and environmental benefits of using gene-editing technologies in agriculture. "We already have many different technologies to modify crops," Potts continues. "So part of what we're doing is trying to understand how to get this new technology rolled out by learning from why GMOs weren't widely accepted."

Zilberman is a little more blunt, focusing on the risks of not using CRISPR. "The U.S. can survive without CRISPR technology, without GMOs," he says. "But how about developing countries? To me, the hope of gene editing is for people in places like Africa, to help them deal with malaria, with sleeping sickness, and to improve agricultural productivity."

Zilberman's work often focuses on supply-chain issues, and he believes that the advent of CRISPR technology holds the potential to solve many problems humanity has created for itself. "Plants are incredible chemical factories," he says. "We can go from relying on chemicals we mine to ones that we grow. We can go from deforestation to carbon sequestration. With plants doing most of the work, we can transition to a renewable economy."

Across all the IGI's program areas, getting the technology to the end user is a primary goal, which is where policy comes in. "Policy and science go hand in hand," Zilberman says. "CRISPR without institutions and without policy is not as valuable." To that end, the IGI is ensuring that the technology does not become bound up in bureaucracy.

"The initial work is all being supported by philanthropic funds," says plant biologist and IGI managing director **Susan Jenkins**, PhD '96 Plant Biology. "Projects won't be siloed off due to funding coming in from different corporate partners. The things we develop can get out to the people who can use them, not become the property of one entity that would control it." From a practical perspective, the IGI has established a Plant Transformation Facility to perform rapid, large-scale trials. "Our ability to do industrial-scale transformation and gene editing in important agricultural crops gives us an edge," says Staskawicz.

With top-notch faculty steadily joining up to work together in creative, interdisciplinary ways, the IGI is poised to be a world leader in CRISPR and whatever genome-editing technologies follow it. "The IGI is becoming the frontier of what can be called the bioeconomy," says Zilberman. "CRISPR is the most important tool enabling us to use the capacity of biology to solve global problems in a sustainable manner." With 150 years of proven success, it's no surprise that CNR's faculty will lead the way. After all, innovation for the public good is in Berkeley's DNA. 31

Q&A

Reflections from the Dean

By Julie Gipple

After 11 years leading the College of Natural Resources, Dean **J. Keith Gilless** will step down from his post in June. As dean, Gilless has been dedicated to supporting CNR's diverse research, teaching, and outreach activities. He has led the College through major growth, launched a number of interdisciplinary initiatives, and tackled infrastructure-renewal projects. After completing his second term, Gilless—who has been a professor of forest economics at Berkeley since 1983—will continue to teach, conduct research, and serve as the chair of the California Board of Forestry and Fire Protection.

Looking back on the past 11 years, what are your proudest moments?

The entire CNR community has a lot to feel proud about. We've doubled the number of undergraduates in the College by responding to students' intellectual and career interests and creating a strong culture of advising and student support. Despite budget constraints, we found ways to create two new cross-campus centers: the Berkeley Food Institute and the Institute for Parks, People, and Biodiversity. We launched the Master of Development Practice program. We became more successful and sophisticated in our fundraising efforts, allowing us to increase graduate student support and make some much-needed improvements to our infrastructure. We expanded our network of research forests at a pivotal time for understanding the effects of climate change on California's ecosystems. And we've been a major contributor to campus-wide initiatives in biofuels and gene editing.

Beyond this long list, what makes me proudest is that UC Berkeley has come to recognize CNR as one of its most successful and dynamic centers of excellence. Our college embodies the relevance in modern society of the vision that created the land-grant universities. We share the mission of Berkeley—and of public education generally—to serve society through problem-solving research and discovery, instruction that enables students to realize their potential, and public service. Here, we really do aspire to "See the bigger picture and make a better world."

"My own education—and my participation in the research and educational mission of UC Berkeley—transformed my life and my understanding of society and the environment around me."

Favorite memory of being dean?

That's easy: congratulating students at commencement. Education transforms lives. My own education—and my participation in the research and educational mission of UC Berkeley—transformed my life and my understanding of society and the environment around me. Berkeley students are overwhelmingly the first or second generation in their family to attend college. When they cross the stage in cap and gown, and their families and other loved ones applaud and cry, I feel privileged to have been allowed to be a part of their joy on that day.

What are the needs and opportunities you see for the College going forward?

Continued success for CNR depends on our ability to continue to grow our philanthropic base. Success here will help us to improve our facilities, fund cutting-edge research, and achieve strong financial support for our graduate students. We must also ensure that all members of our community feel they are heard, valued, and respected. I firmly believe that we can meet these challenges, in part because what we do is so directly relevant to many of the difficult problems facing our world—these are problems people want to solve. Complex issues require interdisciplinary solutions, and that's something at which this College excels.

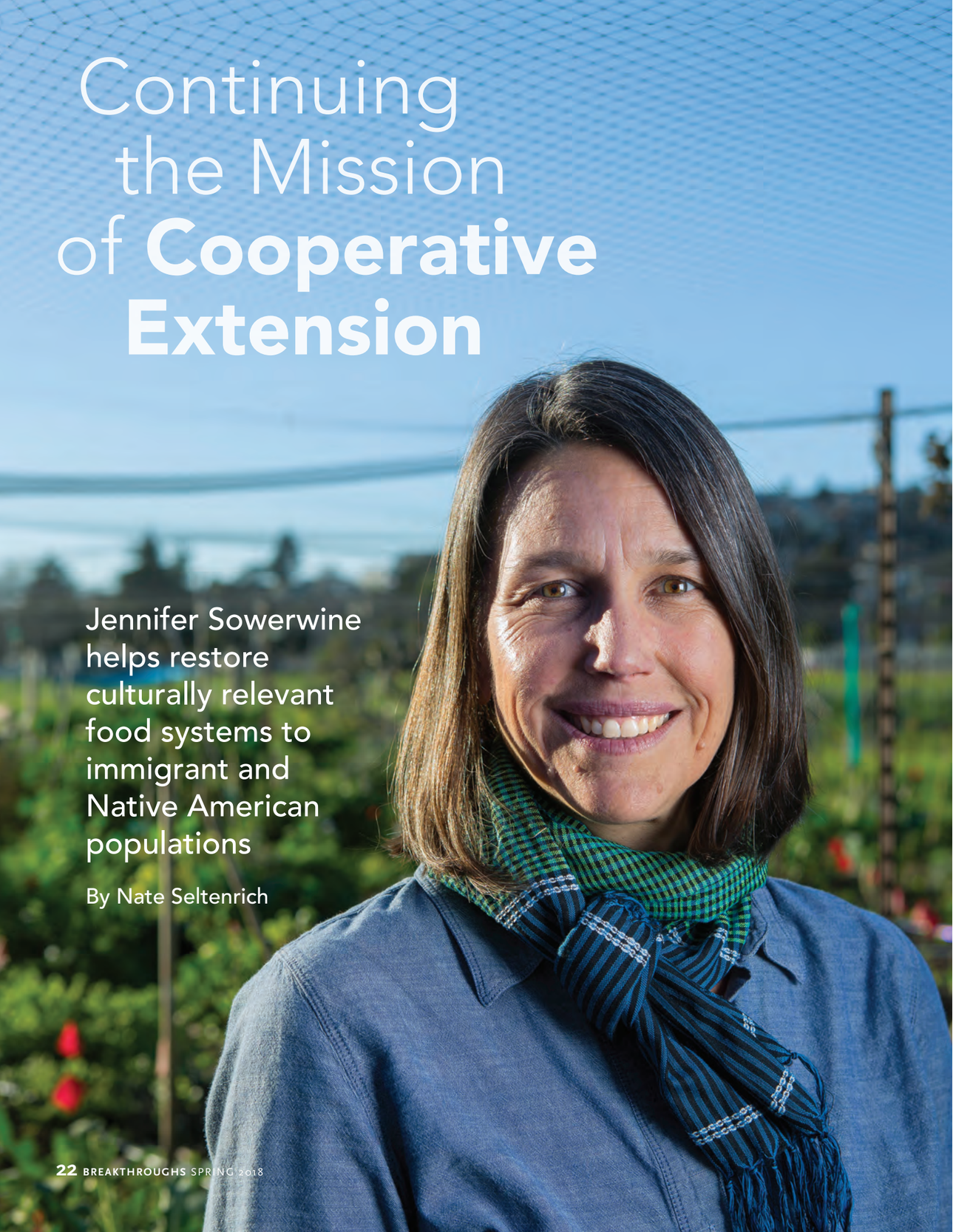
CNR doesn't exist in a vacuum. Our fate is inextricably tied to the fate of the campus, and the fate of public education. No single unit can succeed without collaborating across administrative boundaries—and without the campus successfully addressing its financial challenges with respect to aging infrastructure, accessibility, and housing, among other issues. CNR needs to help Berkeley thrive in order to thrive itself.

Any other thoughts?

I've been part of the Berkeley and CNR community for 35 years and have enjoyed it all. I never cease to be amazed at the opportunities to interact with brilliant and inquisitive students; faculty colleagues who set the bar for excellence in research, teaching, and service; and dedicated staff who keep the College running no matter how difficult things get. I have never known what to expect at each new stage in my career here, other than that I would find myself working with people who inspire me to try harder to do a good job. As I change my business card back to reading simply "Professor of Forest Economics," I know this feeling will continue.

Dean J. Keith Gilless in discussion with students in the Beahrs Environmental Leadership Program. PHOTO: Jim Block

Continuing the Mission of **Cooperative Extension**



Jennifer Sowerwine helps restore culturally relevant food systems to immigrant and Native American populations

By Nate Seltenrich

PHOTO: Saul Bromberger & Sandra Hoover Photography

The Karuk Tribe once lived on more than a million acres in remote Northern California. Legally, their ancestral land along the middle section of the Klamath River in Siskiyou County was in the public domain, as the Karuk did not have a reservation. But on May 6, 1905, when President Theodore Roosevelt created the Klamath Forest Reserve, the tribe lost any claim to its aboriginal territory.

Less swiftly but just as conclusively, the tribe also lost access to much of what the rivers and mountains provided: deer and elk, salmon, tan oak acorns, mushrooms, berries, medicinal herbs. And it lost its ability to manage the landscape through prescribed fire in order to ensure the survival of the plants and animals it needed. The Karuk's food system had been broken almost overnight, and has yet to recover. But **Jennifer Sowerwine** (PhD '04 Wildland Resource Science)—an assistant Cooperative Extension specialist with the College of Natural Resources since 2014—believes it still can.

In direct collaboration with Karuk tribal leaders and community members, as well as with the nearby Yurok and Klamath Tribes, Sowerwine has helped put millions of dollars from the United States Department of Agriculture (USDA) to work restoring food security—defined as access to sufficient, healthy, and culturally appropriate foods—among those from whom it was once taken.

While this is a challenge to which one could easily dedicate a career, Sowerwine's broader mission to support equitable food systems across the state has also led her to other projects and other communities. In the Central Valley, she has spent years working with Southeast Asian farmers.

"The goal is to inform policy and create opportunities for tribal communities and small-scale family and urban farmers, to maintain the continuity of their cultural food heritages."

— Jennifer Sowerwine

Lisa Hillman, Pikyav Field Institute program manager for the Karuk Tribe, at the Karuk Herbarium. PHOTO: Bari Talley

Closer to home, she recently began studying how community farms and gardens improve food security among at-risk populations in the urban East Bay.

RESTORING ANCIENT RELATIONSHIPS TO FOOD

Sowerwine's body of work is a manifestation of the University of California Cooperative Extension's long-standing mandate to aid the "welfare, development, and protection of California agriculture, natural resources, and people." CNR is the home of Cooperative Extension at UC Berkeley, which—now celebrating 150 years since its founding as a land-grant university—is intended to benefit all residents of our increasingly populous and diverse state.

That includes California's first residents: Native tribes like the Karuk, the Yurok (located along the lower stretch of the Klamath River), and the Klamath (upriver, across the border in Oregon). All three were traditionally non-agrarian, hunter-gatherer communities. Loss of ancestral lands that had sustained them for millennia affected not only their diet—leading to a reliance on institutional and heavily processed foods that have contributed to persistent health problems—but also their culture.

In working with the tribes, Sowerwine first had to listen. "One of the main philosophical approaches in my work is to collaborate with the community to identify what the problems are, co-create research questions, and then support, on the extension side, the kinds of programs they need to attain their goals," she says.

Among the Karuk, the tribe with which Sowerwine works most closely, "the community is actively engaged in exploring ways to revitalize their eco-

"The original idea [of land-grant universities] was to provide support and training for people in professions like agriculture. It's part of the health of rural communities." — Ruth Dahlquist-Willard

cultural system," she says. "That includes managing the landscape with traditional methods to improve the productivity and availability of cultural foods and fibers, and restoring some of the relationships around Traditional Ecological Knowledge (TEK)."

Beginning in 2012, through a five-year, USDA-funded grant, Sowerwine partnered with all three tribes to help them reclaim control over their food systems using a holistic, community-centered approach. This took a variety of forms, including designing K–12 curricula for local schools around traditional food systems; opening two new herbaria to preserve and share specimens of native food plants; hosting workshops on subsistence skills like butchering, bread making, and canning; and finding appropriate ways of reintroducing sustainable local agriculture into communities for whom traditional farming is linked with colonialization.

This work now serves as a model for tribes across the country. "There's a lot of interest in all of our programs," says Karuk tribal member and Pikyav Field Institute Program Manager Lisa Hillman. In particular, the tribe created a digital library to offer easy access to information about traditional foods and ecological knowledge, which has attracted significant acclaim and earned Hillman invitations to discuss it at national conferences. "Working with [Jennifer] opened a whole lot of doors for our tribe," Hillman says. The project's success also led to a second, three-year USDA grant that should continue to point the way forward and help mitigate some past harms for the Karuk Tribe.

INTERVENTIONS FOR SOUTHEAST ASIAN REFUGEE FARMERS

Sowerwine began her career studying food security among marginalized residents of a very different part of the world, who nonetheless have much in common with her current collaborators. As a doctoral candidate in the Department of Environmental Science, Policy, and Management (ESPM), she spent two years in the highlands of Vietnam learning how land-use laws and economic policies affected indigenous local farmers from the Mien minority ethnic group and their ability to sustain agrarian practices that were vital to their culture and food security.

After earning her PhD, Sowerwine continued at Berkeley as a postdoctoral researcher. A vibrant community of Mien immigrants exists not far away, in Sacramento, where refugees of the Vietnam War first arrived from Laos in the late 1970s. They were joined by fellow refugees from the Hmong ethnic group, many of whom settled in Fresno. Both groups had traditionally worked the land in Southeast Asia, and they soon developed robust farming networks here in California.

Using a proficiency with the Vietnamese language honed overseas, Sowerwine initially set out to assess the productivity and economic viability of these small farms operated by Southeast Asian refugees. "I wanted to understand the barriers they were facing in terms of farming in the Central Valley of California, which is arguably the most industrialized agricultural landscape in the world," she says.

Approximately 100 Mien farmers—part of a Sacramento-area Mien population of about 15,000—work small plots of land, averaging about eight acres each, outside the state capital. They primarily grow strawberries to sell at roadside stands, but also produce a wide variety of traditional foods, like "sticky" corn, *yu choy, gai lan,* purple long beans, and bitter melon—mostly for home consumption.

Hmong farmers, who are concentrated in Fresno and Sacramento Counties, grow conventional vegetables like cherry tomatoes, green beans, onions, and lettuce—in addition to their own cultural and traditional foods—to sell at farmers markets, Asian grocery stores, and wholesale markets.

The two groups' successes have not come easy, owing to such challenges as language barriers, differences between traditional and modern farming techniques, and informal labor practices that often clash with state regulations.

In response, Sowerwine designed and led an array of interventions to support the farms' continued viability. These included offering hands-on, native-language training to help Hmong and Mien farmers comply with complex labor and food-safety regulations; teaching farmers how to achieve organic certification or to make and sell "value-added" foods like jams; and providing assistance in accessing new markets for fresh produce, including schools, farmers markets, and wholesalers.

Throughout her career, Sowerwine has worked closely with Cooperative Extension advisors around

PHOTOS (from left): Jennifer Sowerwine, Saul Bromberger

A Hmong farmer selling yam leaf and bitter melon at a farmers market.

Jennifer Sowerwine discusses plantings with Jon Hoffman, farm manager of the UC Gill Tract Community Farm in Albany.

the state, including Richard Molinar—a small farms and specialty crops advisor in Fresno County—and his successor, Ruth Dahlquist-Willard. "We accomplished a lot, and we helped hundreds, if not thousands," Molinar says.

Protecting farmers' livelihoods is only the start, Sowerwine notes. Positive outcomes ripple out to the broader immigrant community, which sees strengthened food security through a steady supply of affordable, culturally appropriate produce, and to the entire regional economy and food system, which benefit from a robust and diverse network of local food producers.

"The land-grant universities were founded for the ordinary people, and not just the elite," Dahlquist-Willard comments. "The original idea was to provide support and training for people in professions like agriculture. It's part of the health of rural communities."

THE POWER OF SMALL-SCALE URBAN AGRICULTURE

Yet as Sowerwine's work in the East Bay has shown, small-scale agriculture can also be critical to the health and well-being of urban residents—especially recent immigrants. In 2016, she and a team of 12 undergraduate research assistants—several of whom were supported through CNR's Sponsored Projects for Undergraduate Research—surveyed more than 100 community, school, and for-profit farms and gardens between Hayward and Richmond. A dozen of the community gardens were included in a subsequent pilot study to learn more about how urban farms can provide immigrants with reliable access to affordable traditional foods.

Despite a combined area of just 10.5 acres, these plots were producing more than 300 distinct crops. Many of these plants have direct ties to specific culinary and medicinal traditions, including nine varieties of edible cactus used for *nopales* (cactus pads) and *tuna* (cactus fruit) in Mexican cuisine, and even as a diabetes remedy; *gandana,* also known as Afghan leek, a critical ingredient in the traditional dishes *bolani* and *ashak;* and *chinsaga* (*Cleome gynandra*), a plant used by Kenyan women for postpartum healing and infant health.

Late last year, in collaboration with the Berkeley Food Institute, Sowerwine received a grant from the national nonprofit Foundation for Food and Agriculture Research to further promote and study Bay Area urban farming. Along with ESPM faculty members **Timothy Bowles** and **Céline Pallud,** as well as **Charisma Acey** from the College of Environmental Design, she'll delve even deeper into urban agriculture across the Bay Area.

The team plans to address a diverse and thought-provoking array of questions, most of which have never been studied so thoroughly in the Bay Area. For example, what is the role of urban farms in supporting beneficial insects and improving soil health? How does food from urban farms find its way to consumers and how can waste along the way be minimized? What cultural or structural barriers may prevent locals from accessing urban-farming products?

As with all of Sowerwine's work, from the Oregon border to the East Bay, the goal is not simply to learn more, but to make a difference. "There's a need to elevate an understanding of the value and importance of these spaces to local, state, and national government, to figure out ways of securing them for the long-term benefit of our diverse California public," Sowerwine says. "The goal is to inform policy and create opportunities for tribal communities and small-scale family and urban farmers, to maintain the continuity of their cultural food heritages."

CNR Women of **Distinction**

By Mackenzie Smith

In 1874, Rosa L. Scrivner became Berkeley's first female graduate when she earned a degree from the College of Agriculture, the predecessor to the College of Natural Resources. Since that time, CNR has been home to many innovative female scientists, thinkers, and educators. Read about a few of them below and find many more online at nature.berkeley.edu/150.

As the first female provost at UC Berkeley and a groundbreaking scientist whose research on dietary needs shaped nutrition policy and programs, **Doris Calloway** improved the quality of life for people around the world.

Carolyn Merchant is a science historian whose writing—including the foundational book *The Death of Nature: Women, Ecology, and the Scientific Revolution*—is considered part of the essential canon of eco-feminist literature.

Irma Adelman was one of the first women to hold an economics appointment at a university. Her policy analysis helped shape South Korea's economic structure and cemented her status as a leading development economist.

During her 30 years at CNR, **Loy Volkman** studied how baculoviruses infect their insect hosts—research that has led to advancements in vaccine manufacturing.

The first woman in the United States to hold an academic appointment in range management, **Barbara Allen-Díaz** was also the first woman to lead UC's Division of Agriculture and Natural Resources—a position equivalent in responsibilities to that of a chancellor in the UC system.

Cooperative Extension Specialist **Peggy Lemaux** has dedicated her career to creating innovative science communication tools and educating the public about genetically modified foods.

Biochemist **Agnes Fay Morgan** was a pioneer among women in American science. Her service to UC Berkeley has been recognized in many ways, including the naming of Agnes Fay Morgan Hall—now home to the Department of Nutritional Sciences and Toxicology—in her honor.

Rural sociologist **Louise Fortmann** became the first-ever female faculty member in forestry at Berkeley in 1984. Her work champions collaborative research practices and equitable resource access.

Esther Parsons Perry, '39, was the first woman in the United States to receive a PhD in soil science. After graduation and until her retirement, she worked in and ran the soil-survey lab on campus.

PHOTOS: Courtesy of: Department of Nutritional Sciences and Toxicology, Robert Holmgren, Queena Xu, UC Berkeley, Julie Gipple, University of California Agriculture and Natural Resources, Bancroft Library

Right: **Kathy (Ohlson) Hartzell,** BA and BS '72, and **Julie (Asher) Palladino,** BA '69, in their room at the Berkeley Student Cooperative in 1968. The two remain close friends today. Left: Kathy at a meeting of the CNR Alumni Association Board.

PHOTO (left): Jim Block

FOR THE NEXT 150 YEARS

CNR's annual fund provides unwavering support

When the University of California was founded in 1868 as a land-grant institution, it was assumed that the school would always be state supported—but time and economics have changed that equation. A 2014 *Daily Cal* article on the history of tuition at UC revealed that by 1970 the free tuition that had previously been granted to state residents was to be modified with a new "educational fee" of $150 per year for undergraduates and $180 per year for graduate students. Since then, all UC students have experienced a deepening financial burden as state support has continued to shrink and the cost of living has risen.

One of the undergrads who paid that $150 fee was **Kathy (Ohlson) Hartzell,** BA and BS '72, for whom UC Berkeley has played a multigenerational role. Hartzell has fond childhood memories of her father, **Robert V. Ohlson,** BA '39, MA '40, History, singing Cal songs while she and her sisters played them on the family piano. Years later, she graduated with joint degrees in geography and conservation and resource studies when the latter was a brand-new experimental major in the College of Agriculture. And her daughter, **Georgina Hartzell,** graduated from CNR with a degree in nutritional sciences–metabolic biology in 2009. "I love that the College of Agriculture I attended eventually evolved into CNR to address the growing needs of the broader world and the education of more students," Kathy Hartzell says.

As a leadership volunteer, Hartzell currently serves on CNR's advisory board and as honorary chair of the Berkeley Fund for Natural Resources, the College's annual fund. "Gifts to this fund help us educate tomorrow's leaders," she says. "They allow the dean the flexibility to apply funds where they're most needed to support our outstanding students and faculty, providing them with great opportunities for research and collaboration."

Today, philanthropy is playing an increasing role in keeping a Berkeley education both excellent and accessible to all. Back in the day, Hartzell paid for her Berkeley education with $1,000 annually from her grandmother and a part-time job. "If I were attending Berkeley now, there's no doubt I'd be in debt," she says.

Hartzell encourages CNR's alumni and friends to deepen their support of the College with a "stretch gift" during our sesquicentennial year, increasing donations to 150 percent of their previous gifts to make an even greater impact. "Giving to the Berkeley Fund for Natural Resources is a way for alumni and other donors to show their steadfast support year after year," she says. "Everyone can be a part of CNR's next 150 years by making an annual fund gift. Please join us!"

— KIRSTEN MICKELWAIT

Flying by Fire | Photo by NASA/MODIS, courtesy of Earthrise Media

Captured during the October 2017 West Coast wildfires, this image comes from Earthrise Media, a new project that gives journalists easy access to satellite imagery to support reliable news about the environment. Founder **Dan Hammer,** PhD '17 Agricultural and Resource Economics, recently won UCLA's inaugural Pritzker Emerging Environmental Genius Award. He is also a co-founder of the Earth Genome and a fellow of the National Geographic Society. Hammer collaborates on Earthrise Media with three other Berkeley alumni, including **Steve McCormick,** BS '73 Agricultural Economics, former CEO of the Nature Conservancy and the Gordon and Betty Moore Foundation. "There is nothing more unbiased than the flyby images from a small piece of metal in low Earth orbit traveling at 10,000 miles per hour," writes Hammer.