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A greater yellowlegs feeds in a Northern California rice field that is part of The Nature Conservancy's "pop-up wetlands" project. Story on page 20.

PHOTO: Drew Kelly, courtesy of The Nature Conservancy

BREAKTHROUGHS

UC BERKELEY COLLEGE OF NATURAL RESOURCES • FALL 2014

Big Ideas

CAN GEOENGINEERING FIX THE PLANET? • THE PROMISE & PERIL OF NEWBORN GENOME SEQUENCING • POP-UP WETLANDS ON THE PACIFIC FLYWAY • COLORADO'S WARMING MEADOW • DIGITIZING ECOLOGICAL HISTORY • A GRAND VISION FOR UC DAVIS • THE NEXT CENTURY OF NATIONAL PARKS • CNR'S BIGGEST-EVER DONOR

LETTER FROM THE DEAN

There are ideas connected to the college that are so big or complex that they suggest some sort of special attention. We started to save up a few of these, and the Big Ideas issue was born.

A prime example: Professor and bioethicist David Winickoff has been contributing to the growing debate on geoengineering—environmental manipulations meant to lower global temperatures. While the topic has advanced far beyond old cloud-seeding and sci-fi schemes, Winickoff says there's a lot to think about before moving forward (page 8).

Sometime a huge issue starts with something small. Tiny newborns and their even tinier genomes have generated a new public health question: Should genome sequencing become part of standard newborn screening? As with geoengineering, the question we must ask is: Just because we can do this, should we? Enormous potential benefits must be weighed against unintended consequences (page 14).

Pilot programs are critical laboratories to test new ideas. Two Berkeley alumni working at The Nature Conservancy have tested a novel reverse-auction strategy that partners farmers and conservationists. If their success continues, the project could scale up to have an impact on the entire Pacific Flyway (page 20).

Other Big Ideas include Holos, a big-data project building access to 100 years of ecological research; the longest ongoing climate-change experiment in the world; a distinguished alumna's vision for CNR's UC Davis counterpart; and a celebration of UC Berkeley's past and future partnership with the U.S. National Parks Service—often called "America's best idea."

Perhaps the biggest idea of all is one that supports this fertile intellectual environment in perpetuity. It came, without fuss or fanfare, from forestry alumnus John Gross, whose $15 million gift is the largest in CNR history. Gross's generosity has truly inspired us and we hope it inspires you (page 24).

I welcome your comments at gilless@berkeley.edu.

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FALL 2014

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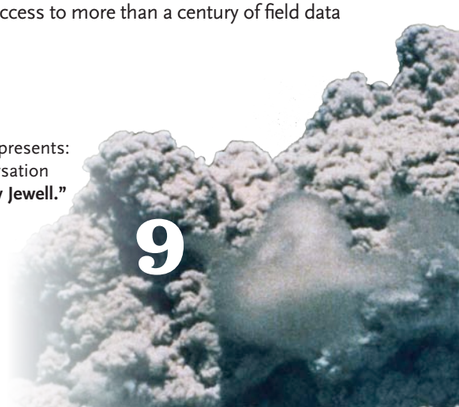
BREAKTHROUGHS

ONLINE

EVENT On March 27, the Spring 2015 Albright Lecture in Conservation presents: "America's Two Best Ideas—Public Education and Public Lands: A Conversation with UC President **Janet Napolitano** and U.S. Secretary of the Interior **Sally Jewell."**

Go to nature.berkeley.edu/breakthroughs.

COVER: Design by Ian Price



Grapefruit Juice Diet Stems Weight Gain in Mice

iStockphoto

Fad diets come and go, but might there be something to the ones that involve consuming grapefruit and grapefruit juice? New research suggests that a closer look at grapefruit juice is warranted.

A study published Oct. 8 in the journal *PLOS ONE* found that mice fed a high-fat diet gained 18 percent less weight when they drank clarified, no-pulp grapefruit juice compared with a control group of mice that drank water. Juice-drinking mice also showed improved levels of glucose, insulin, and a type of fat called triacylglycerol compared with their water-drinking counterparts.

If these findings sound somewhat familiar, it may be because the link between grapefruit juice and weight loss—or just decreased weight gain—has been touted in Hollywood diets before. However, the earlier studies behind those claims were often small, not well controlled, and contradictory, according to nutritional sciences and toxicology professors Andreas Stahl and Joseph Napoli, who led the new research.

This latest work was funded by the California Grapefruit Growers Cooperative, but the Berkeley researchers emphasized that the funders had no control or influence over the study design or research findings. Both Stahl and Napoli said they went into this research with some skepticism.

"I was surprised by the findings," said Stahl. "We even rechecked the calibration of our glucose sensors, and we got the same results over and over again."

Napoli added that "we see all sorts of scams about nutrition. But these results, based on controlled experiments, warrant further study of the potential health-promoting properties of grapefruit juice."

— SARAH YANG

Alameda County Enters Global Lyme-Light

Berkeley's own Alameda County is home to one of the highest diversities of tick- or mammal-associated spirochetes found in any county within the United States, according to a study led by ESPM professor emeritus **Robert Lane.** Spirochetes are spiral-shaped bacteria causing such well-known and dreaded diseases as Lyme disease, syphilis, and leptospirosis. In a study published online in July in the European journal *Ticks and Tick-Borne Diseases*, Lane's research team, in collaboration with Lucia Hui's group at the Alameda County Vector Control Services District, reported finding seven different *Borrelia* spirochetes among ticks surveyed at 71 sites and an eighth *Borrelia* species in the roof rat. **Natalia Fedorova,** a molecular biologist affiliated with Lane's lab and Hui's group, is the lead author.

Although Alameda County averages less than a handful of reported Lyme disease cases per year, a few woodland hotspots were identified in the warmer, drier south-central region, where tick-infection rates with Lyme disease spirochetes exceeded 17 percent. These findings inform health-care providers and the public that even in heavily populated counties where the Lyme disease incidence is low, isolated pockets exist where the risk of encountering potentially infected ticks is elevated.

— ROBERT LANE

PHOTO: Olin Feuerbacher, courtesy U.S. Fish & Wildlife Service

Tiny Survivor

Group of Devils Hole pupfish in the Ash Meadows Fish Conservation Facility, hatched from eggs that were removed from Devils Hole in November 2013.

Scientists estimate that fewer than 100 Devils Hole pupfish remain in their Mojave Desert home, but conservation biologist **Steven Beissinger,** a professor of environmental science, policy, and management, is guiding the efforts to rescue them by establishing a captive breeding program.

Considered the world's rarest fish, with one of the smallest geographic ranges of any wild vertebrate, the tiny pupfish (*Cyprinodon diabolis*)—about 1 inch long as an adult—lives only in a 426-foot-deep limestone cavern in Devils Hole, a 93°F geothermal pool that's part of Death Valley National Park. The fish neared extinction in spring 2013 when populations dropped to an all-time low of 35 observable pupfish. While more recent fish counts showed some recovery, the species is considered critically endangered.

The dire situation spurred the U.S. Fish and Wildlife Service to open the Ash Meadows Fish Conservation Facility near Devils Hole. Previous attempts to establish refuge populations of pupfish have not fared well, either because the transplanted fish did not survive or because they cross-bred with other species of pupfish. Biologists from the agencies managing the pupfish captive breeding program wanted to determine which methods have the highest chance of success.

Beissinger found that to reduce the impact on the wild population, it was better to transfer pupfish eggs rather than adults to a captive breeding facility. And, he found, it was preferable to move fish in the fall when the population tends to be larger, rather than in the spring. He also found that moving more than six adults per year for three consecutive years rapidly increases the risk of extinction. The results, published Sept. 9 in the open-access journal *PeerJ*, showed that the wild pupfish faces a 28–32 percent risk of extinction over the next 20 years.

"The study really puts out more empirically the risk of extinction for this fish," said Kevin Wilson, an aquatic ecologist at Death Valley National Park who is working on the recovery of the pupfish. "These findings are providing us with very good tools for our toolbox." (See Q&A, page 23.)

— YANG

NewsMakers

"Oh, it's the fish."

Justin Brashares, *Associate Professor, Environmental Science, Policy & Management*
In a July 24 *New Yorker* article covering Brashares's research on causal relationships between biodiversity and social issues, Brashares quotes a Ghanaian farmer who first explained to him the connection between depleted fisheries and children being kept home from school. The story covered a *Science* article in which Brashares documented multiple examples of such causal chains, including HIV-positive Kenyan women exchanging sex for fish that they were otherwise priced out of, exacerbating the region's AIDS problem. (See News Briefs, page 5.)

"The grapefruit juice lowered blood glucose to the same degree as metformin."

Joseph Napoli, *Professor (quoted), and* ***Andreas Stahl,*** *Associate Professor (pictured), Department of Nutritional Sciences & Toxicology (NST)*
A UPI article was part of worldwide news coverage of the authors' controlled study, published Oct. 8 in *PLOS ONE*, which found that mice consuming a high-fat diet gained less weight and had healthier glucose and insulin levels when they drank grapefruit juice compared to water. The authors then tested grapefruit juice against the glucose-lowering drug metformin and were surprised to find that it was equally as effective as the drug. (See News Briefs, left.)

"These products are essentially sodas without the carbonation."

Patricia Crawford, *Director, Atkins Center for Weight and Health; Cooperative Extension Specialist, NST*
The *San Jose Mercury News* was one of dozens of media outlets covering an Atkins Center for Weight and Health report released on Aug. 6, which showed that the health claims of 21 products such as Snapple, Vitamin Water, and Red Bull were false. In most cases, researchers found that the sugar- and caffeine-laden drinks provide little or no health benefits and might even be dangerous to children and teens, whom marketers specifically target.

Farming Practices Can Save 600 Million Years of Biodiversity

A new study by biologists at Stanford University and UC Berkeley highlights the dramatic hit on the evolutionary diversity of wildlife when forests are transformed into agricultural lands.

The researchers studied nearly 500 species of birds in Costa Rica in three types of habitat and calculated the birds' phylogenetic diversity, a measure of the evolutionary history embodied in wildlife. "If you have an area with lots of closely related species, you won't have a lot of phylogenetic diversity," said co-lead author Luke Frishkoff, a biology doctoral student at Stanford. "The further apart species are on the evolutionary tree, the more phylogenetic diversity your system represents."

The study, published in the Sept. 12 issue of *Science,* found that the phylogenetic diversity of the birds fared worst in habitats characterized by farmlands consisting of single crops. Such intensive monocultures supported 900 million fewer years of evolutionary history, on average, compared with untouched forest reserves.

The researchers found a middle ground in diversified agriculture—farmlands with multiple crops adjoined by small patches of forest. Such landscapes supported on average 600 million more years of evolutionary history than the single-crop farms.

"The loss of habitat to agriculture is the primary driver of diversity loss globally, but we hadn't known until now how agriculture affected diversity in an evolutionary context," said study co-lead author **Daniel Karp,** a postdoctoral research fellow working in the lab of ESPM professor **Claire Kremen,** one of the study's senior authors. "We found that forests outperform agriculture when it comes to supporting a larger range of species that are more distantly related, so by maintaining patches of tropical trees and multiple crops on their land, farmers can enhance evolutionarily distinct species," he said.

"While we knew that a diverse range of crops supports more species than monoculture agriculture, we had no idea until this study that these species comprise much more of Earth's evolutionary history than those found in monocultures," said Kremen, who is also faculty co-director of the UC Berkeley Food Institute. "It shows how important it is for biodiversity conservation to surround protected areas with productive forms of diversified agriculture, whenever possible."

Karp began work on this project while he was a PhD student in biology at Stanford. He continued the research at Berkeley as a NatureNet fellow, funded through The Nature Conservancy.

— SARAH YANG

PHOTOS: Daniel Karp

Left to right: The collared trogon declines in agriculture but thrives in tropical rainforests. The pale-billed woodpecker can be found in tropical rainforests but declines in agricultural areas. The fiery-billed aracari declines in intensive monocultures but thrives in forest reserves and diversified farms.

PHOTO: Jessica Pociask, WANT Expeditions

A child grabs sleep wherever possible after a long day of labor in West Africa's struggling fishery.

Wildlife Declines Driving Crime, Slave Labor

Global decline of wildlife populations is driving increases in violent conflicts, organized crime, and child labor around the world, according to a policy paper led by **Justin Brashares,** associate professor of ecology and conservation. The authors call for biologists to join forces with experts, such as economists, political scientists, criminologists, public health officials, and international development specialists, to collectively tackle the complex challenge.

The paper, published July 24 in *Science*, highlights how losses of food and employment due to wildlife decline increase human trafficking and other crime, and also foster political instability.

"This paper is about recognizing wildlife decline as a source of social conflict rather than a symptom," said Brashares. "Billions of people rely directly and indirectly on wild sources of meat for income and sustenance, and this resource is declining. It's not surprising that the loss of this critical piece of human livelihoods has huge social consequences. Yet, both conservation and political science have generally overlooked these fundamental connections."

Laborers—many of whom are children—are often sold to fishing boats and forced to work 18–20 hour days at sea for years without pay, the authors said. "As more labor is needed to capture scarce wild animals and fish, hunters and fishers use children as a source of cheap labor. Hundreds of thousands of impoverished families are selling their kids to work in harsh conditions," said Brashares.

The authors tied the rise of piracy in Somalia to battles over fishing rights, and compared wildlife poaching to the drug trade, noting that huge profits from trafficking luxury wildlife goods, such as rhino horns, have attracted guerrilla groups and crime syndicates worldwide. — YANG

SUBJECT:

Why I Do Science

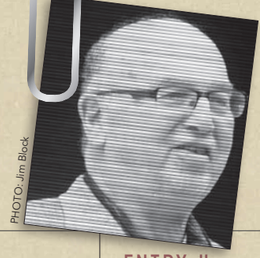


PHOTO: Jim Block

ENTRY BY: **David Zilberman**

ENTRY #: 012

I am an agricultural and environmental economist, analyzing policies and patterns of behavior and their implications (gainers and losers) while suggesting ways to improve policy choices. My research strategy is to identify major policy problems, study the principles of science associated with them, and analyze behavior and policy.

When I studied water, I found that farmers underinvest in conservation technologies partially because they cannot sell the water they save. I also found that water trading can increase production while providing water for environmental services. When I studied GMO varieties that control pests, I realized that in the United States they mostly replace pesticides, but in developing countries, where pesticides are not available, they increase yield, increasing production and reducing commodity prices substantially.

My early life prepared me for where I am today. When I was a kid, I wanted to be a basketball player, but very soon learned that I was better at counting points than scoring them. I learned agriculture while working on a kibbutz in Israel, and I worked full time in computers while in college, where I enjoyed speaking with customers, solving their problems, and designing programs to meet their needs. I learned that designing good solutions requires understanding human systems, so I decided to study economics in graduate school.

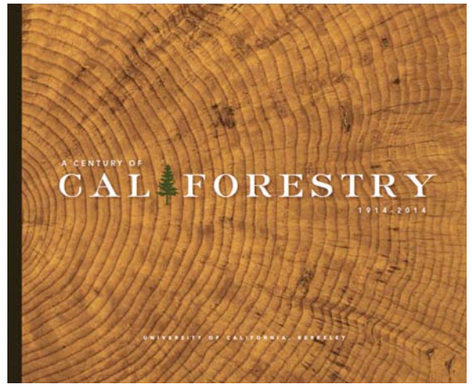
I was attracted to agricultural economics at Berkeley because I knew agriculture, and Berkeley was "cool." I did my dissertation on animal waste—a major problem that no one else wanted to touch.

My research interests have evolved over the years. I've studied technology, environmental services, pesticides, biofuels, and risk. I enjoy tackling complex problems and finding solutions to relevant questions, and I treasure being part of a team and preparing a new generation of researchers and scholars.

David Zilberman holds the Robinson Chair of Agricultural and Resource Economics. He established the Berkeley Master of Development Practice and the Beahrs Environmental Leadership Program at CNR. He is a fellow of the American Agricultural Economics Association and the Association of Environmental and Resource Economists.

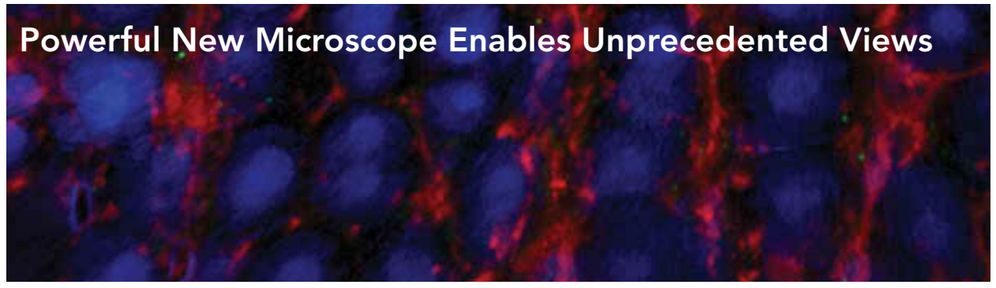
Forestry Centennial Book Unveiled

A Century of Cal Forestry is a special publication celebrating the UC Berkeley Forestry Program's enormous contributions to both the study and practice of forestry in California, the United States, and the world. With a preface by Governor Jerry Brown, the book is an informative and visually rich keepsake honoring the centennial and our influential faculty and alumni. Contact forestry100@berkeley.edu to request your free book. Supplies are limited.



KUDOS: On August 27, 2014, the California State Board of Forestry and Fire Protection presented the UC Berkeley Forestry Program with its highest honor, the Francis H. Raymond Award for Outstanding Contributions to California Forestry.

Powerful New Microscope Enables Unprecedented Views



A transverse section of a mouse retina, at the depth of the outer nuclear layer. Image courtesy of Steve Ruzin

Microscopy expert **Steve Ruzin** has won a grant to purchase an Elyra PS.1 Super Resolution microscope, a powerful new tool that allows scientists to study the tiniest of organisms.

"This new microscope will enable researchers to see objects that are impossible to see using technology available at Berkeley today," said Ruzin, who is the director of the CNR-based Biological Imaging Facility, which serves thousands of faculty, students, and staff. Not only are a wide variety of microscopes available for researchers to use, but the lab also teaches students and other researchers about microscopy, the technical field of using microscopes to view samples and objects that cannot be seen with the naked eye.

The new $600,000 instrument, purchased with a National Institutes of Health grant, is a "structured illumination microscope," which allows researchers to image and differentiate various parts of a cell using fluorescent dyes.

"Cells have bustling shipping centers," said **Amita Gorur,** a graduate student in the lab of Nobel laureate **Randy Schenkman.** "The Elyra PS.1 Super Resolution microscope will allow me to track and visualize cargo on a freight car moving along cellular railroads from destination A to B in real time. These cellular shipping units are so small that only the resolution achieved by this microscope will allow us to see them. That's powerful!"

Unlike traditional microscopes, whose resolution is limited to the wavelength of light used to illuminate the sample, structured illumination induces a complex light pattern that is emitted from the sample. Subsequent computer processing of the emitted pattern reveals sub-resolution structures. The new microscope has a resolution of 100nm and can see objects that are 10 times smaller than a bacterium, or 10,000 times smaller than a period.

— ADAPTED FROM AN ARTICLE BY KARYN HOUSTON

INQUIRING MIND: Nature writer Sharman Apt Russell '76 explores self-driven scientific inquiry in *Diary of a Citizen Scientist*, released this fall by Oregon State University Press.

ABUZZ: *California Bees & Blooms: A Guide for Gardeners and Naturalists* **is a user-friendly new guidebook that shows readers how to encourage native bees to thrive in an urban environment. Coauthors are entomology professor Gordon Frankie, Rollin Coville, PhD Entomology '78, University & Jepson Herbaria curator Barbara Ertter, and UC Davis professor emeritus Robbin W. Thorp.** Above: A sweat bee collects pollen from a California poppy. PHOTO: Rollin Coville.

Over-Achievers

Ag-Econ Student Wins Innovation Fellowship

Agricultural and resource economics PhD candidate **Gavin McCormick** is the recipient of this year's Echoing Green Climate Fellowship for WattTime.org, his innovative nonprofit company that empowers people and business to control their own energy choices.

WattTime combines real-time electricity data and the Internet with groundbreaking predictive algorithms to inform and engage consumers, as well as to enable smart devices to automatically prioritize cleaner power sources in real time. Echoing Green's Climate Fellowship targets next-generation social entrepreneurs committed to working on innovations in mitigation and adaptation to climate change. Winners receive a stipend of up to $90,000, plus leadership development and network access.

Ray to Co-Lead Rural Water Initiative

The Institute for South Asia Studies was selected for a prestigious Obama-Singh 21st Century Knowledge Initiative Award, one of only four U.S. universities to earn the honor in 2014. A UC Berkeley team, led by energy and resources associate professor **Isha Ray** and civil and environmental engineering (CEE) professor **Kara Nelson,** will collaborate with faculty at the Centre for Technology Alternatives for Rural Areas in the Indian Institute of Technology, Bombay, Maharashtra, on the three-year project "Sustainable Indian Water Infrastructure Project: A Systems Approach." CEE professors **David Sedlak** and **Ashok Gadgil** are also on the Berkeley team.

Junior a USDA/World Food Prize Fellow

Conservation and Resource Studies junior **Nicole Wong** completed a prestigious World Food Prize fellowship this summer at the Western Human Nutrition Research Center in Davis, Calif., part of the Agricultural Research Service. Wong was one of 33 students nationwide—and the only UC Berkeley student—selected to participate in the Wallace-Carver Fellowship, a program hosted by the U.S. Department of Agriculture and the World Food Prize Foundation.

Can Extreme Science FIX the Planet?

By Anne Canright

Pumping sulfate particles into the stratosphere could mimic the effects of the 1991 Mt. Pinatubo eruption, when sulfate aerosols in the atmosphere helped lower average global temperatures by preventing sunlight from reaching the ground.

PHOTO: Getty Images

If someone asked you whether we humans should engage in large-scale manipulation of the earth's environment, what would you say?

Assuming you've been following the scientific and social discussion these past few years or even decades, you might well point out that we are already doing that. It's called anthropogenic climate change, or global warming. Our release of greenhouse gases, particularly CO_2 through the burning of fossil fuels, amounts to a vast, uncontrolled geoplanetary experiment with potential consequences that we are only beginning to fathom: melting icecaps, rising sea levels leading to coastal flooding, regional drought and famine, shifting ocean currents, and thawing permafrost releasing additional greenhouse gases into the atmosphere.

But what if you were asked about *deliberate* large-scale manipulation of the earth's environment, intended specifically to offset such events? That changes the discussion. Another word for this deliberate manipulation is geoengineering. And it is becoming a hot topic.

"Geoengineering research is not normal science. It is characterized by high stakes and scientific and political uncertainty," wrote **David Winickoff**, associate professor of bioethics and society in the Department of Environmental Science, Policy, and Management, in an *Issues in Science and Technology* article calling for a government advisory committee on the topic. "It raises many red flags, especially in light of the checkered history of efforts to apply technological fixes to complex problems. And it animates larger issues at the heart of climate change politics, engineering ethics, and the problem of democratic governance in a technically complex society."

The idea of deliberate climatic modification arose as early as the 1830s with the dream of infusing clouds with particulate matter to stimulate rain. Cloud seeding was also explored during the Cold War on both sides of the Iron Curtain in what came to be called "climatological warfare." One of the first mentions of geoengineering to mitigate the effects of greenhouse gas emissions came in 1965, in recommendations of a presidential advisory panel under Lyndon Johnson. Proposals ranged from the dreams of mad scientists to some that appeared quite doable.

Today, geoengineering looks down two basic paths. One is carbon dioxide reduction—anything that directly cuts the amount of CO_2 in the atmosphere, such as massive plantings of forests, capturing emissions from power stations, and fertilizing the oceans with iron to induce massive plankton blooms, which would absorb carbon and take it to the ocean bottom.

The second is solar radiation management (SRM), an array of techniques aimed at reducing the amount of solar energy that reaches the earth. These methods include pumping sulfate particles into the stratosphere, high above where jets fly; brightening marine clouds through the addition of superfine water particles; and, more benignly, painting roofs white—all in an effort to reflect sunlight back into space.

Currently, the most keenly debated option is sulfur-aerosol injection—pumping sulfate particles into the stratosphere—potentially a cost-effective technique that, in essence, mimics the cooling effects of a good-sized volcanic eruption. Consider the real-world test case of the Philippines' Mt. Pinatubo, which blew in 1991. The sulfate aerosols that entered the stratosphere, acting like tiny mirrors, prevented a very small portion of sunlight—perhaps 1 or 2 percent—from reaching the ground. The result was a decrease in average global temperature by 0.5°C for roughly two years.

In 2006, Paul Crutzen, winner of the 1995 Nobel Prize in chemistry for his exploration of the chlorofluorocarbon–ozone depletion link, submitted an editorial essay to the journal *Climatic Change* suggesting that it was time to begin testing the sulfur-aerosol strategy. "If sizeable reductions in greenhouse gas emissions will not happen," he wrote, "then climatic engineering . . . is the only option available to rapidly reduce temperature rises and counteract other climatic effects." His proposal was met with resistance. Only after several other scientists contributed balancing papers was his essay, "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?" accepted for publication. The accompanying papers ranged along a spectrum of skepticism to tentative support.

Critics point out that SRM is basically a tactical, not a strategic, option—a Band-Aid that treats one symptom (rising temperatures) but not the root cause (greenhouse gas emissions). Nor does it treat other symptoms, such as ocean acidification, and it

Winickoff compares geoengineering to other "tough terrains" such as biotech and biofuels, where "you have the need for a lot of technical calculations behind policy."

could well have side effects, such as a tweaked global water cycle. Arguably more important, many fear that achieving symptomatic relief will kill what little political will now exists to treat the disease itself.

Indeed, the most difficult aspect of SRM—in particular, sulfur-aerosol injection—is perhaps not the technology; it is the nature of the potential risks and concomitant political and ethical issues of responsibility, fairness, timing, and cooperation.

These are the questions Winickoff is investigating as part of a grant funded by the National Science Foundation. Accepting that certain science—the modeling, the methodology—is already fairly advanced, he worries about larger outdoor research and deployment. "We know we need to mitigate and reduce carbon," he said in a recent National Public Radio talk show appearance. "And we know we need to prepare for changes that are certain to come." But, he continued, we also need "more public dialogue. And we need to find institutions in which we can deliberate on these questions."

Among the questions are: Should we look to cost-benefit analysis to decide whether to employ SRM? Should we emphasize basic moral principles, cultivating a more humble relationship with nature? Should we let "the people" decide, and if so, which people and through what mechanisms? Who should fund and direct the research?

"I think we should recognize that research is already happening," said Winickoff. "But from my point of view, it should only proceed under certain kinds of institutional circumstances. And I'm interested in building those institutional capacities . . . in a controlled manner that promotes transparency and cooperation."

Oversight and governing of research should occur at multiple levels, Winickoff believes. Nationally, he would like to see an advisory committee, perhaps modeled on President George W. Bush's Council on Bioethics, which, rather than proposing specific policy recommendations, promoted public discussion of moral disagreements, potentially laying the groundwork for compromise down the road. Such a committee would recommend principles, policies, and practices that help legitimize research and make it safer and more ethical. It would be composed of experts from the natural sciences, social sciences, and humanities; government officials, environmentalists, businesspeople, community organizers, and military leaders with practical experience addressing complex political challenges; and representatives of constituencies with a potential stake in the issue, including people with knowledge and experience of diverse regions around the globe. It would represent diverse political viewpoints.

At an international level, he suggests, a G-20 sort of group of countries might do research and develop norms together, or even, ultimately, propose a moratorium. But, he says, it's important to have in place mechanisms that promote deliberation in a way that doesn't get derailed by strident special interests. And global inclusion remains critical, ensuring that all stakeholders have some sort of say and are heard. "Part of my larger research trajectory is to study how science meets the political process in advising and collective decision-making."

Winickoff compares geoengineering to other "tough terrains" such as biotech and biofuels, where "you have the need for a lot of technical calculations behind policy. And there's the big question of buy-in and how you negotiate whose science we should act on."

While mitigation, innovation, and adaptation must play a greater role in our research and deliberative efforts as a global society, large-scale climate intervention—in the form of geoengineering, for one—should claim a place in our public discourse. How, or even if, we deploy it remains to be seen.

Geoengineering is "a big idea," Winickoff says, because it's contemplating an extreme intervention on an extreme problem. "The big challenge is how to cope with that idea. And we need to have the capacity to say no."

This summer, Winickoff introduced a dialogue on geoengineering as part of the College of Natural Resources–based Beahrs Environmental Leadership Program, which trains 40 to 50 mid-career environmental professionals from around the world. PHOTO: Jim Block

1977 BIOLOGY OF NATURAL RESOURCES

HELENE DILLARD

In February 2013, UC Davis Center for Watershed Sciences researchers released tens of thousands of young hatchery salmon into flooded rice paddies on a Yolo County farm, in collaboration with fishery conservation groups and the California Department of Water Resources. The experiment resulted in a fast and dramatic increase in the size of the salmon. "Stock the rice paddies!" reacts Helene Dillard, revealing her love of catch-and-release fishing for trout, salmon, bluegills, bass, and "just about anything" that swims. "This is really good."

Story and photos by Molly Oleson

Dillard was appointed dean of the UC Davis College of Agricultural and Environmental Sciences (CA&ES) in January. The experiment's success in using an agricultural practice to address a fishery issue isn't exciting to her just as an avid angler, or as a scientist who sees potential for the growth of struggling fish populations, but as the leader of a top-ranked college in the areas of agriculture and the environment—CNR's counterpart at UC Davis.

"This is a place that a dean can come and make a difference," says Dillard, who is happy to return in a new role to CA&ES, where she earned both an MS in soil science and a PhD in plant pathology, after earning a BS in biology of natural resources from UC Berkeley.

Climbing out of the throes of budget cuts, UC Davis's founding college—committed to addressing critical issues related to agriculture, the environment, food systems, and human and social sciences—has been growing steadily and is poised to be strengthened by Dillard's experience as an accomplished scientist and administrator. The Bay Area native left Davis in 1984 to join the faculty of plant pathology at Cornell University's New York Agricultural Experiment Station in Geneva, and later became associate dean of Cornell's College of Agriculture and Life Sciences and the College of Human Ecology, as well as director of its Cooperative Extension program.

CA&ES, like CNR, is affiliated with the multi-campus UC Division of Agriculture and Natural Resources, which provides a research- and outreach-focused partnership between the U.S. Department of Agriculture and land-grant institutions. "When you put it all together, it's greater than the sum of its parts," Dillard says of the college's three synergistic components: teaching, research, and outreach.

She has grand visions for each. Goals for the academic component range from improving laboratories and fostering multidisciplinary collaborations, to guiding students in discovering what they're passionate about, to ensuring that the dean's office is a place that enables growth in the faculty's work. "We [the administration] tend to become the people that have all the rules—'Here's what you *can't* do,'" Dillard says. "I'm looking for ways to make us more the kind of place faculty can come to help get what they need to go for their next grant."

Dillard's love of discovery was evident when she was a kid studying the cells of onion skins and moldy bread under a microscope that her parents had given her. But it wasn't until she became exposed to different aspects of biology at UC Berkeley that she knew she was headed into the plant world. She credits her plant pathology professor, the late **Robert Raabe,** for igniting the spark that led to her research on topics like the fungal pathogens that cause diseases in vegetable crops. "He was *absolutely* amazing," Dillard says of Raabe.

"When you put it all together, it's greater than the sum of its parts," Dillard says of the college's three synergistic components: teaching, research, and outreach.

Outreach and extension are just as important to Dillard as teaching and research. "If all we ever did was conduct the research and never tell anybody about it, it wouldn't have any meaning," she says. Through Cooperative Extension, the college is able to broadly share knowledge with farmers, researchers, and the general public that might otherwise end up buried in scientific journals.

"The vision is to make sure we keep that component strong," Dillard says. To illustrate, she cites the work of plant sciences professor and researcher Jorge Dubcovsky, who is currently doing field trials of drought-tolerant wheat varieties. "I'm hoping that we can apply some of the concepts he's learning to other crops we grow in California," she says. "When I look at our work, what's so exciting is that it's not only applicable here and in neighboring western states, but it could also be useful to Europe, Africa, and other countries where drought is becoming a problem."

Dillard believes that the college can make a huge difference by addressing the interface between agriculture and the environment.

"There's always a point where these areas meet," she says, mentioning the graceful symbiosis in the rice paddies, where scientists have figured out how to create a productive coexistence among fish, rice, and water. "My goal is that we do more of that kind of work—where there could have been a major conflict, and instead, we found a solution."

At left and above: Dillard, a plant pathologist, feels at home in the UC Davis greenhouse.

Bringing up Baby

A study investigates the promise and peril of newborn genomic sequencing

By Sally Lehrman

Like many other parents, **Steven Brenner** decorates his Koshland Hall office with colorful drawings in a child's hand. On his desk, propped up alongside the phalanx of computers, are sunflowers, a bird, and a paper plate transformed into an orange pumpkin with crooked eyes. And as with other parents, too, a key moment from Brenner's children's births is seared into his brain. "It's definitely very traumatic to have someone come and poke holes in the little baby's foot," he recalls, grimacing.

Brenner, a professor in the Department of Plant and Microbial Biology, heads up the computational genomics portion of a five-year research program that may deeply influence how states use that heel prick, the first step in newborn screening. While a baby may appear healthy, a hidden metabolic disorder may quickly rob her of her vigor. Most state public health departments check the infant's blood after the first day of life to see if something is dangerously wrong. However, as genome sequencing becomes faster and cheaper, the push is on to unravel a baby's entire DNA code instead.

Proponents of complete sequencing at birth speak of the dawn of "precision medicine," a time when doctors will be able to go directly to the genome to predict and address a person's health needs. One day, they envision, information about a person's DNA could be merged with her health record, and perhaps even details about environmental exposures as life unfolds. Diagnoses and treatment plans, they propose, might become more a calculation than an art. And when doctors write up prescriptions at any stage of life, they could be guided by knowledge of gene variants that influence drug response.

Brenner and his collaborators from UC Berkeley, UC San Francisco, and several other Bay Area institutions advise caution. They are testing whether analyzing the exome, which includes the portions of genes that are transcribed into proteins, could offer useful medical information more efficiently than the current biochemical screens. "Can we do this? What are the limitations and capabilities?" Brenner asks. Of equal importance, they want to address critical ethical and legal issues that may arise should states require the collection of such personal and powerful data.

Infancy until now has been mostly a protected space, with screening limited to conditions in which doctors can quickly intervene to save a life. Proposals for new tests tend to be contentious. "We tried to not start from the idea that whole genome analysis is the best thing since sliced bread," explains Barbara Koenig, co-director of UCSF's Translational Genomics and Ethics Center and a graduate of the joint UCSF-UC Berkeley medical anthropology PhD program. She is one of three principal investigators and leads the ethics arm of the study. "The history of newborn screening is such that there is a real tension between meeting public health goals and using new technologies that push for more and more analysis." [The

Baby photos above and in table of contents: Courtesy of a CNR family.

Plant and microbial biology professor Steven Brenner. PHOTO: Jim Block

Big Ideas ISSUE

UCSF's Barbara Koenig leads the ethics arm of the research program. PHOTO: Courtesy of the Mayo Clinic

author participated in two collaborative symposia on genomics issues led by Koenig at Stanford University, one of which resulted in *Revisiting Race in a Genomic Age,* a book co-edited by Koenig.]

The first newborn screening tests were widely considered a public health breakthrough. The steady increase in disorders targeted over the years, however, has raised concerns about unintended consequences. A debate in the medical and scientific literature describes the concerns: After a positive test, both diagnosis and appropriate treatment can be uncertain. Follow-up care, central to ensuring benefit to patients, is not always available. People with the relevant markers for a disease—whether biochemical or genetic—might not ever show the symptoms. They become "patients-in-waiting," entangled uncertainly with the medical system, learning to live with caution and foreboding.

Scoping Down Massive Data

The UC Berkeley–UCSF study is one of four research programs around the country funded by the National Institutes of Health to explore the expansion of infant screening to whole genome, or exome, sequencing. The Bay Area team is taking a conservative approach by limiting itself mainly to a direct comparison with current methods used by the California Department of Public Health, plus two case examples.

Brenner's group is responsible for building the technical foundation—the computational tools—needed to analyze the exome for the 25 metabolic disorders that are now a part of California's newborn screening program, the largest in the United States. To begin, they plan to unravel the DNA captured within dried blood spots from about 1,500 infants who were already tested by the state.

From all this material and multiple DNA databases that serve as a reference tool, Brenner's group aims to sort out the gene variants involved in the 25 disorders and assess what roles they play. First, they will look closely within 40 target genes already known to be involved. Then they expect to fold in 200 new ones that their collaborators have found to modify or interact with the targets, possibly influencing the severity of a disease.

Do specific changes sometimes or always cause problems? Can they be used to predict severity? Which ones are just normal substitutions? "Basically we're trying to learn the features of mutations that tend to cause disease. And then when we find a new genetic variant, does it have those same features?" Brenner explains.

Reading out the sequence is a complex process, let alone describing all the relevant variants in each gene and what they mean, stresses Robert Nussbaum, chief of genomic medicine at UCSF Medical Center, who oversees all three parts of the complex study. Once that step is complete, researchers will compare their exome analysis to the results that were already captured for the sample newborn population through biochemical screens. Are both equally accurate, comprehensive, and inexpensive?

The team also plans to test sequencing results against clinical follow-up data linked to each genome, with individuals' names removed. Following the initial assessment, the team can refine its methods using details such as each child's record of height, weight, intellectual ability, and the number of times he was in the emergency room or hospitalized.

Brenner is skeptical. "I think sequencing will, initially, not be nearly as effective," he says. "The current approach that's in place has been honed for a very long time, so they've really optimized it." More importantly, biochemical screening looks for the actual symptoms of a disorder, while genetic analysis may pick up suspicious variants never to be expressed. Eventually, however, Brenner suggests, as genome analysis advances, it will probably best the biochemical route.

As a case study of conditions that current screening does not detect, the team will work with blood spots from 50 children receiving care at the UCSF Immunology Clinic for rare, often fatal immune deficiency disorders. These children might have late-onset severe combined immunodeficiency (SCID) or a condition like it. Because they are born without key immune system cells, they are highly susceptible to dangerous infections. The group will search for genetic markers that may work better than current SCID screens to identify these conditions at birth.

Proponents speak of the dawn of "precision medicine," a time when doctors will be able to go directly to the genome to address a person's health needs.

The Ethics of Information

Even if whole genome analysis is more precise, it may suffer from the same lack of standardization and other weaknesses that trouble current screening practices. For example, in an editorial in the August 2014 *JAMA,* Neil A. Holtzman points out that before all states adopt SCID screening, it will be important to make sure that children who test positive can be referred to physicians with the expertise to confirm the condition, and also that the appropriate therapy is clear.

As whole genome analysis develops, the temptation to expand testing beyond urgent needs in infancy will grow. "If you have the entire genome sequence, you can very readily, for low marginal cost, test for lots of other things. And that's where it becomes more of an ethical question," Brenner says. "Should we revisit the scope of newborn screening and look for other things as well?"

Koenig's ethics team plans to conduct focus groups to see how expecting mothers feel about learning extra findings from whole exome analysis. They'll test the same questions with the immunology clinic parents, asking specifically if they wish to find out about nine gene variants known to be involved in drug metabolism. Doctors may be able to use this information throughout the child's life in deciding which drugs to use and at what dose.

The American College of Medical Genetics recently proposed that as part of sequencing for any purpose, laboratories should always search for dangerous alterations in 57 genes that ought to prompt medical attention. The Bay Area research program has set its scope more narrowly on genes involved in drug response because of the special circumstances of newborns. "We're not going to go rummaging through the genome to see what we find," Brenner says. But the truth is, even if technicians put on blinders to focus attention only on target areas of the genome, they may run across unexpected discoveries that are possibly quite important to people's lives. "You might stumble across them, and do you have to look?" probes Koenig.

The focus groups and other pieces of the ethics research will help support a larger discussion by an advisory board of historians, sociologists, clinicians, ethicists, and other experts pointed toward policy recommendations about expanded newborn screening based on sequencing.

Whole genome sequencing as part of newborn screening raises special questions because, in most states, the process is nearly always mandatory, points out Ellen Wright Clayton, who directs the Center for Biomedical Ethics and Society at Vanderbilt University. Neither the parent nor, of course, the child has a chance to object. As a result, should the criteria for going forward be more stringent? The genome contains a wealth of information, far more than today's targeted biochemical tests deliver. And because the DNA is a record of inherited traits, biological parents would learn about not just their child's health but also their own. They could learn about conditions that might affect both themselves and their children that do not show up until later in life. Finally, knowledge about the activity and the influence of the genome is still unfolding. A reading of it is certain to deliver news of multiple variants with unclear ramifications.

Program leader Nussbaum isn't very enthusiastic about rolling out the technology just yet. "First, we can't actually interpret most variants. We're going to be finding stuff that we don't know what to do with," he says. "Second, we are going to find stuff we know what do to with, but it's not going to affect children; it's going to affect adults," he adds, referring to variants that may reveal unwanted details about a parent, or about a child's potential future health issue.

A professor of both law and pediatrics, Clayton is a member of the research program's policy advisory panel, and says the UC Berkeley–UCSF work will clarify urgent issues.

"The big question is always, just because you can do it, doesn't mean you should," says Clayton. "I think this is going to provide some interesting insight."

ON THE GROUND

BY LINDA FOGEL

Colorado's Warming Meadow

For almost a quarter of a century, Energy and Resource Group (ERG) professor **John Harte** and his students have been artificially warming a meadow at the Rocky Mountain Biological Laboratory in Colorado and watching it change and decline in biodiversity. The extraordinary length and prescience of the project, launched 16 years before Al Gore won the Nobel Prize for his film and education campaign on climate change, has yielded novel information about the impact of global warming. Harte, who is also affiliated with the Department of Environmental Science, Policy, and Management, is a physicist-turned-ecologist focusing on global change ecology and spatial patterns of species distributions.

The Experiment Running continuously since 1991, the warming meadow is the world's longest operating controlled experiment on climate change, baking an existing, ungrazed subalpine meadow with large electric heaters. The experiment consists of ten adjacent plots, with half serving as a control. Heaters hang above the other five plots, exposing plants, animals, microbes, and soil to a climate resembling what the entire region is projected to experience by 2050. Every two hours, the soil temperature and moisture are measured at various depths.

Encroaching Sagebrush At the start, both heated and unheated plots were dominated by forbs—non-woody flowering plants, such as glacier lilies and larkspur—and dotted with occasional sagebrush. Just a few years into the experiment, Harte and **Rebecca Shaw**, PhD '97, ERG, reported in the journal *Science* that the above-ground biomass of *Artemisia tridentata* (a sagebrush) increased, while the forb biomass decreased.

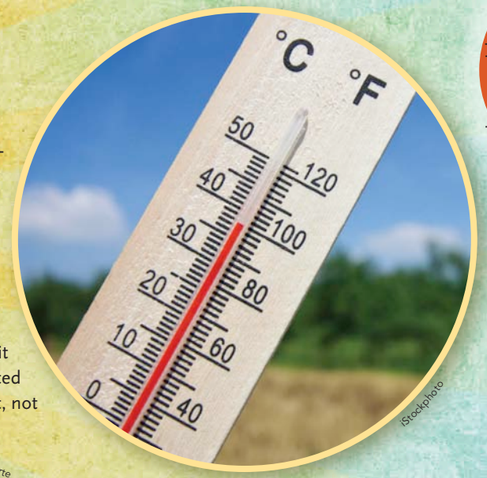
Brightness Cools; Darkness Warms The doubling of the atmospheric concentration of carbon dioxide (CO_2, the greenhouse gas primarily responsible for climate warming) was shifting the meadow habitat to less-reflective woody sagebrush, the pair reported in the *Science* article. Whereas the light-colored flowers reflect the sun's energy back into the atmosphere, the darker sagebrush bark absorbs it, making the meadow even warmer and providing the conditions for more sagebrush, ultimately crowding out the forbs. Similar to the melting of the polar ice caps, the loss of mountain meadows is both an indicator of global warming and a contributing cause.

The Carbon Cycle Wildflowers are active photosynthesizers, taking carbon from the atmosphere and converting it to leaves, flowers, and stems. In the fall, they shed the above-ground material. The decomposing plant material enters the soil, where microbes change it back into CO_2 to reenter the atmosphere, maintaining a balanced cycle of taking CO_2 out of the atmosphere and releasing it in equal measure. By comparison, sagebrush is less active at photosynthesis and produces far less plant material. As the sagebrush spread on the heated plots, the CO_2 in the soil continued to be released by microbes, but was no longer being replaced. The meadow, once at carbon equilibrium, has become a carbon emitter.

Sagebrush in Colorado. iStockphoto

Glacier lilies at Glacier National Park in Montana. iStockphoto

Ecological Feedback Loops Encroaching sagebrush causes a cascade of reinforcing changes, with warming leading to more warming. A small increase in temperature leads to an increase of CO_2, which in turn leads to even higher temperatures and more CO_2. Climate change begins the process, but feedbacks accelerate it. These biological feedbacks are not factored into global warming models. If they were, the upper-limit increase in global temperature currently projected by 2050 would be closer to 10 degrees Fahrenheit, not 6 degrees.



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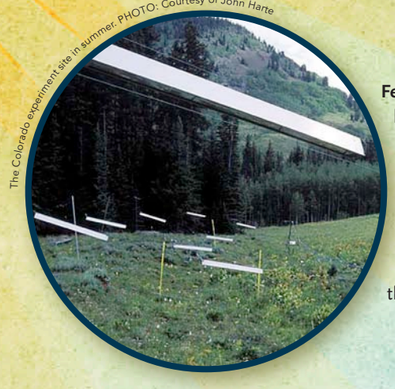

The Colorado experiment site in summer. PHOTO: Courtesy of John Harte

Feeling the Heat The responses to the warmed environment have been dramatic. Spring comes weeks earlier because the snow melts faster, and the soils are hotter and drier than in the unheated plots. The warmer weather affects plant reproductive cycles and duration, both for late- and early-blooming species, from bud formation to seed dispersal. Between 1990 and 2010, heated plots lost about a fourth of all the organic carbon formerly stored in the soil; it was released into the atmosphere as CO_2.

The Colorado experiment site in winter. PHOTO: Courtesy of John Harte

Control Plots Are Catching Up In a 2014 article submitted for publication, Harte, **Scott R. Saleska**, PhD Energy and Resources '98, and biologist Charlotte Levy noted that the control plots, due to climate-induced reduced snowpack and earlier snowmelt, are now slowly exhibiting the same patterns of change seen in the heated plots, with woody plants replacing forbs and altering soil carbon sources and sinks, confirming many of the observations and findings of the long-running experiment.

Revising Warming Predictions The study's key finding so far: The ways in which ecosystems alter the climate exacerbate warming. It is increasingly important to include these transformations when predicting the effects of climate change, Harte says. He emphasizes that this experiment is crucial for understanding the causal processes linking local climate and vegetation and how these factors influence the carbon cycle.

Big Ideas ISSUE

Pop-Up Wetlands: A Success Story

By Anne Canright

Each year since time immemorial, California's Central Valley has witnessed a miracle: the beating wings and raucous calls of millions of birds—waterfowl and shorebirds—as they scud into wetland resting spots, en route from their seasonal homes in the Arctic to points south each autumn, and then back again come spring. Not that long ago, these birds numbered between 20 and 40 million, and their watery destination covered four million acres—over 6,000 square miles—in the Sacramento and San Joaquin valleys.

Today, over 90 percent of those wetlands have been replaced by rich agricultural land and ever-expanding cities, and the number of birds that visit has plummeted to the low millions. But they still stop—they *must* stop—twice each year for several weeks to rest and feed during their journey.

Recently, an unlikely alliance of conservationists and farmers have joined forces to help these doughty migrants along by providing water when and where it's needed—a seasonal "pop-up" wetland that benefits the farmers in the region and the shorebirds that visit. The project, BirdReturns, is utterly modern in its scope and approach, marked by such buzzwords as citizen science, big data, market-based incentive, crowdsourcing, and reconciliation ecology. But its goal goes back to our very roots: to sustain life on earth and our connection to it.

Hatched at The Nature Conservancy (TNC), BirdReturns addresses the question, How do you design effective conservation for things that don't stand still? It also takes advantage of natural cycles of the Central Valley rice farmers, who use flooding to manage their fields after the late-summer harvest.

"TNC has a long history of buying lands and restoring them," said TNC ecologist **Mark Reynolds**, PhD '90, Zoology. "That's kind of the gold standard of conservation. But faced with many millions of acres of habitat shortfall, we realized pretty quickly that we're not going to buy our way to a solution. That's only going to result in, optimistically, several thousands of acres, not anywhere close to a million."

But realistically, he pointed out, shorebirds don't need that much land all year long. They really only need it for a few weeks in fall and a few weeks in spring. So if scientists could determine just when the various species were resident, could water be provided "on demand"?

Enter crowdsourcing in the form of the citizen science program eBird. At about 187 million entries currently—and growing by some 30 percent each year—eBird, developed by the nonprofit Cornell Laboratory of Ornithology, is a massive database that uses the power of amateur birdwatchers tracking bird occurrences with their smartphones. Reynolds realized that "we could use these data to predict when and where birds would need habitat in California, and by knowing that, we could be smarter about our engagement with farmers."

TNC economist **Eric Hallstein**, MS '97, Energy and Resources Group (ERG), MCEE '98, Civil and Environmental Engineering, PhD '10, ERG, likens the setup to vacation rentals: Rather than buying a house when you visit a city for a short-term stay, you rent one for only the length of time you need. In this case, what is being rented is fallow agricultural fields and 2–4 inches of standing water—the perfect depth for long-beaked shorebirds, such as dunlins, long-billed dowitchers, greater yellowlegs, black-necked stilts, and sandpipers, to snag their mud-dwelling prey of snails, worms, crayfish, and insects. And, the timing of the rice harvest and clearing of fields coincides perfectly with the birds' visits.

"It's economically efficient to rent," said Hallstein. "And we knew that it was probably going to be cheap because we were only paying for a little bit of habitat just when and where birds needed it most. But how do you actually implement such a program?" His brainchild was a strategy used in the business world for acquiring services at an optimum price. In what's called a reverse auction, the buyer—in this case, TNC—requests a particular good or service—here, land and a farmer's willingness to flood for four, six, or eight weeks—and asks interested service providers to propose a bid. The bid is based on various factors, including the cost of the water, the cost of labor, and the risk that the land will not dry sufficiently in time for the late-spring tilling and planting.

Left: A dunlin flock in rice fields near Colusa, Calif. Above (from left): economist Eric Hallstein, TNC ecologists Greg Golet and Mark Reynolds monitor rice fields near Olivehurst, Calif. PHOTOS: Drew Kelly, courtesy of TNC

Central Valley rice farmers typically flood their fields from mid-November through January to soften rice straw, which is then stomped or turned into the soil. This practice has long been known to benefit waterfowl—and duck hunters. "But when that water is no longer useful for stubble decomposition or for duck hunting," Reynolds said, "the farmers usually pull their boards out and that water goes away." The innovation of BirdReturns was to extend the flooding period on either end to accommodate the schedule of shorebirds.

After holding workshops in August 2013, TNC invited farmers to bid in November. Some 56 farmers participated, with 80 percent of the bids accepted. (The prices remain confidential, but they covered a wide

How do you design effective conservation for things that don't stand still?

Sandhill cranes in a rice field in Colusa, Calif. PHOTO: Drew Kelly, courtesy of TNC

range, both well below and above what the federal government pays for bird-friendly practices.) "We had about 10,000 acres of functional wetland habitat added to the system, and we had good participation throughout the Sacramento Valley," said Reynolds, excited about the success. "We had big farms and small farms. And it covered 17 water districts as well."

The program included unflooded control fields, so the value of the extended flooding could be gauged. "Over the course of February to the middle of April," Reynolds said, "we collected about 2,000 observations—about 220,000 birds of 57 species, 180,000 of which were target water birds. We saw about a fivefold increase in number over February into March of response to the treatment [flooded] fields, and treatment fields averaged 20 times the density of shorebirds compared with control [nonprogram] fields."

The pilot program confirmed the value of extended flooding and provided valuable economic information as well. "We were trying to figure out a couple of things this year, one of which is, is there enough price variation among farmers to justify the auction?" said Hallstein. If prices don't vary, we ought to just send everybody the same contract. But we saw huge amounts of variation—the spread in bids was about fivefold." He attributes the spread to various factors, the biggest being water price. "And I think the other piece is people's environmental attitudes. There are farmers who just want to do the right thing. And some farmers who have been experimenting have realized that there's benefit to having the birds on their fields." The birds turn the soil, leaving the fields in better condition. "The last piece is, there is a real risk for these farmers. We are partnering with the farmers to share the risk."

One rice farmer, Amelia Harter, who contributed 175 acres east of Colusa, summed up the experience like this: "I learned that efforts for nature, environment, and animals can work successfully with our existing agricultural industry. I thought that was amazing."

Reynolds agreed. "It was a real game changer for us, and I think that we've created a new tool in the conservation toolbox. This pilot shows us a couple of things," he continued. "Farmers will participate in a program like this; we can design it to really hit that sweet spot when the birds need the habitat the most; and there are opportunities to take this to a bigger scale." The 2014 effort involves expanding the program into the fall season, essentially creating six months' worth of pop-up wetlands to accommodate shorebirds passing both directions along the Pacific Flyway. "We're also hoping to use this auction mechanism in the future for other kinds of habitats, not just rice," which could expand the program south into the San Joaquin Valley, and eventually, north into Oregon and Washington.

BirdReturns is a good example of what is called reconciliation ecology, Reynolds said, a growing area of ecology that encourages biodiversity in human-dominated ecosystems. "It's important that conservation and agriculture, which haven't always been allied, have projects like this where there is mutual benefit, where we collaborate, and we get to understand each other's perspectives." With BirdReturns, the situation is win-win-win: conservationists and farmers both benefit, but the birds get the biggest win of all.

Q&A: The Next Century of "America's Best Idea"

Big Ideas ISSUE

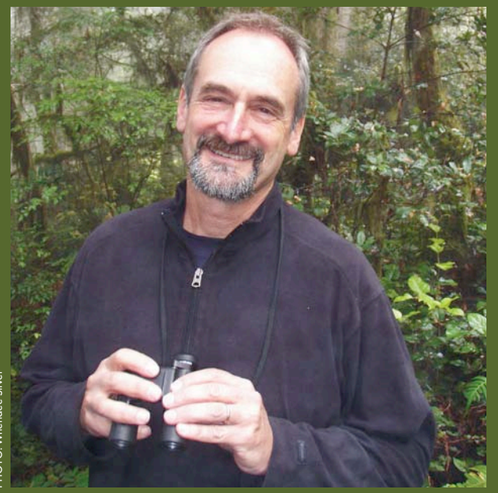

PHOTO: Whendee Silver

In March of 2015, UC Berkeley, in partnership with the National Park Service and the National Geographic Society, will host the summit "Science for Parks, Parks for Science: The Next Century." **Steven Beissinger,** professor of environmental science, policy, and management, chairs the summit steering committee.

Why is UC Berkeley involved with the National Parks centennial?
The establishment of the National Park Service (NPS) was catalyzed by a conference at Berkeley in March 1915, led by alumni **Stephen T. Mather** (1887) and **Horace Albright** (1912). They rallied influential leaders, such as Gilbert Grosvenor, the editor of the National Geographic Society magazine. Together with a dozen companions, they hiked 200 miles through the Sierras later that summer, in what has been called the Mather Mountain Party, as part of a campaign to establish the NPS. The effort came to fruition in 1916. The first cohorts of NPS biologists were trained at Berkeley by professors **Joseph Grinnell** and **Joseph Le Conte,** who led early research on Yosemite's natural history. They and their successors went on to connect generations of students with the parks.

How do science and parks work together?
Since the late 1860s, when Yosemite was set aside as parkland and UC Berkeley was established as the cornerstone of the University of California, Cal has functioned as a research partner of the national and state park systems. Currently, more than 50 faculty and graduate students from all over campus conduct research in and for parks, from disciplines as varied as biology, engineering, history, architecture, mathematics, ethnic studies, and information science. Some projects use parks as control areas, such as the Grinnell resurvey work I lead to quantify the effects of a century of climate and land-use change on birds and mammals (see Tiny Survivor, page 3). Other projects are focused on producing science for managing parks, such as fire ecology professor Scott Stephens's work on fire management.

What are the priorities in the next century?
Today's parks are part of a rapidly changing world, with a changing climate, invasive species and exotic diseases, ocean acidification, and shifting fire and disturbance regimes affecting their resources. Our culture and society are changing. As a result, people engage with, or disengage from, parks differently than in the past. New knowledge from natural, physical, and social sciences is required to meet these challenges.

What is UC Berkeley's role in the Next 100 Years initiative?
I am leading the two-and-a-half day summit, "**Parks for Science, Science for Parks: The Next Century"** (March 25–27, on campus and open to the public), which seeks to make an impact on the future stewardship of the parks by focusing on scientific research, including work on the relevance of parks to all of America's constituencies. Twenty leading scholars and activists working on park-related issues will speak, led by the renowned biologist E. O. Wilson. In 2016, a group will retrace the footsteps of the Mather Mountain Party through the Sierra Nevada. We are working on assembling a team from science, government, education, and communities—all the stakeholders that we have or want to bring in. Finally, the spring 2015 Albright lecture on Thursday, March 26, will be devoted to the topic, with Secretary of Interior **Sally Jewel** and UC President **Janet Napolitano** discussing the intersection of public lands and public education.

For more information, go to parksnext100.berkeley.edu

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1947 FORESTRY

JOHN H GROSS

For nine years in a row, **John Gross** met his UC Berkeley liaison **Kevin Crilly** for lunch at the same Sherman Oaks restaurant near Gross's home just north of Los Angeles. For nine years in a row, Gross ordered ratatouille and a glass of Cabernet Sauvignon. He always arrived wearing work clothes and driving a beat-up pickup truck, until, at around age 90, he became the proud owner of a new Mini Cooper, which, he insisted, had a mind of its own. "The thing goes too damn fast," he told Crilly, who hand-delivered Gross an annual trust report. "I get in the car and it goes 85 miles an hour!"

By Ann Brody Guy

With his down-to-earth habits and rugged-westerner exterior, Gross wasn't flashy about his wealth or his generosity. Yet his gifts to the University made him the biggest individual donor in the history of College of Natural Resources. Starting with a modest annual gift of $100 in 1995, Gross created a charitable remainder unitrust in 2002, and his giving culminated in a suite of outright gifts, a bequest, and an additional charitable remainder unitrust that together totaled more than $15 million. The only comparable gift to CNR from an individual is banker A. P. Giannini's donation to the College of Agriculture, adjusted for inflation, said Crilly, Berkeley's executive director of gift planning.

"A 'character' is a great way to explain John," said Crilly. Gross was a forestry major but made his career as a builder and developer and bred horses on his ranch, which he raced throughout the state.

He was an avid reader and fiercely independent thinker. Friends describe him as a political moderate who cared deeply about a just and civil society. He supported a woman's right to choose, cared about public education and the public's role in policymaking, and hated big conglomerates, concerned that antitrust law had become diluted.

He enjoyed long talks with **J. Keith Gilless,** CNR's dean and a professor of forest economics. "He was a builder from the start," Gilless said, recalling that at forestry camp—the eight-week field course attended by all forestry majors and minors—Gross spent his spare time building an outhouse.

Still, he remained engaged in the wide-ranging politics of California and nature—concerned with the environment, forestry, fire, earthquakes, and invasive elements like sudden oak death altering landscapes that meant a lot to him.

"The oak savannahs of California were one of the places that he had a deep affinity for," Gilless said. "Where we put his money went beyond the campus, and I know he liked that," added Gilless, referring to Cooperative Extension research in Humboldt County that sought ways to control sudden oak death outbreaks in remote areas, especially landscapes with broad public value, like parks.

As a developer, Gross was interested in how the public should be engaged in the process of issues like fire management in newly developed areas—how equitable policy should be made around building standards, zoning standards, and insurance risk regulation. "How do you make rational decisions on that? Who has a stake in how people, structures, and the environment intersect? He believed the general population, not just the elite, should have informed opinions," Gilless said.

Gross backed this perspective with strong support for public education.

"As he considered his legacy, he looked at the impact of the College's work and decided it felt like home."
– Kevin Crilly

"John felt the value of public universities to the state was enormous—in scientific research, job creation, innovation, technology, business, and health," said **Kathryn Moriarty Baldwin,** CNR's assistant dean of development and public information, who worked with Gross through his 14 years as a donor. "He believed that the citizens of California got more from the University than they gave, and that UC was something rare and wonderful that was worthy of investment. He was a joy to work with, and giving gave him great pleasure."

Despite his wide-ranging interests and generosity to multiple campus units, including creating an endowed political science chair in the College of Letters and Science, Gross's experience as a forester remained a seminal part of his life. "When he got near the end, as he considered his legacy, he looked at the impact of the College's work and decided it felt like home," Crilly said.

"The scope of what the College does resonated with him—a systems approach to dealing with the natural environment, including people as part of that system," Gilless said.

John Gross died on August 25, 2013, at the age of 93. With the endowment given to the College as a whole and not restricted to any one area, Gross's legacy is far-reaching, giving CNR's dean discretion to spend money where and when it's needed the most.

"The environment and society are rapidly evolving," Gilless said. "This extraordinary gift gives CNR the ability to be highly responsive to change. I can support research to find the answers to the questions we have right now, but none of us can say what the questions will be 100 years from now. Well managed, this endowment will help CNR address the most compelling questions of the day for generations to come."

Left: Raising and racing horses was a passion of Gross's.

Right: The CNR Dean's Office in Giannini Hall will administer Gross's $15M gift, comparable only to the gifts of A. P. Giannini himself.
PHOTO: Adam Parker

Digitizing Ecological History

By Zac Unger, MS '00

Big Ideas ISSUE

"The world is changing. It always has, it always will. But the current rate of change is unprecedented."

–Rosemary Gillespie

Joseph Grinnell was good at a great many things, but sitting still was not one of them. The famed field biologist journeyed to Alaska to collect birds as a 19-year-old, conducted zoology surveys at hundreds of sites throughout California, published an authoritative guide to western birds, and, in 1908, was chosen as the first director of Berkeley's Museum of Vertebrate Zoology (MVZ).

Grinnell—like any modern field scientist—would probably tell you that the best part of his job was, well, the *field*. Long days in the forest, moonrise over the desert, chasing butterflies with a net. "We must confess that we have gotten more complete satisfaction, in other words *happiness*, out of one vacation trip into the mountains after rare birds and eggs than out of our two years of university work in embryology!" he once wrote in an editorial on the ethics of egg collection. Thanks in part to Grinnell, the UC system now manages nearly 60 field stations like Sagehen, Hastings, and Blodgett.

The problem, of course, is what to do with all those eggs (or fossils, or eagle feathers, or little baggies filled with vole feces) when you get back to campus. After you've used the samples for your own research, what then? If you've ever walked through the back rooms of the MVZ or the Essig Museum of Entomology, you've probably gotten the feeling that you're in the presence of a whole lot of history. In fact, across all UC Berkeley's natural history museums—MVZ, Essig, UC Paleontology Museum, and the University and Jepson Herbaria—over 16 million specimens are sitting in limbo, many of them untouched and all but forgotten since Joseph Grinnell and his colleagues put them there.

Of course, an earthworm in amber isn't just an earthworm. It's *data*. Every sample tells a story about what our world was like at a specific time and place. Some bee specimens even include the pollen they carried, preserving a detailed narrative about their environment.

"The world is changing. It always has, it always will," **Rosemary Gillespie**, professor of environmental science, policy, and management and Essig director, said at the launch event for the Berkeley Data Science Institute. "But the current rate of change is unprecedented." Because of this, knowledge about the past is more vital than ever as we try to understand what the future holds. But all of that critical historical data is almost impossible to access—you can't exactly Google 10,000 dried Depression-era acorns.

And yet that's exactly what an ambitious new initiative is attempting to make possible. The Berkeley Ecoinformatics Engine—Holos for short, from the Greek word for "whole"—will eventually allow researchers to search, sort, and analyze all of the invaluable data collected by industrious UC scientists over the past 100-plus years. The idea, if not the execution, is simple: Digitize the data from every single item in the massive collection and then make the data available to researchers.

"We need to look at the broadest context of how organisms have changed in the past," says Gillespie, who is the principal investigator for Holos. "If we use information about how change has happened in the past, we may then be able to build a trajectory to predict what will happen in the future." While climate change is the most commonly discussed shift, the data from UC's collections will be valuable for assessing the effects of all manner of transformative forces, such as agriculture, development, invasive species colonization, and genetic shifts.

Take the connection between climate and elevation, for example. When an area warms, it's intuitive to hypothesize that plants and animals will move uphill to find cooler temperatures that better suit them. "But through all these studies that use historical surveys, it's becoming apparent that it's actually not as clear as that," says **Giovanni Rapacciuolo**, a postdoc with the Berkeley Initiative in Global Change Biology who is helping to guide the early days of Holos.

"Many plants end up moving downhill to find wetter climates rather than cooler ones," he says. "As the plants move downhill, so do the birds that depend on them, and the mammals that live within them, and so on." So making predictions about future plant and animal migration requires a good analysis of the past. And it's the past that Holos

PHOTO: Jim Block

Alpine chipmunk specimens housed at UC Berkeley's Museum of Vertebrate Zoology. Many of these were collected by the founding director of the Museum, Joseph Grinnell, and his associates. Recent studies have found that the species' move to higher altitudes and reduction in genetic diversity are connected to climate change. PHOTO: kdedquest/Flickr

hopes to make available with the click of a button.

Cleaning Up Dirty Data

That's the theory, at any rate. The practical realities of digitizing so much data are daunting. The available information is staggeringly varied in form, content, and quality. And just what does it mean to digitize a dragonfly? Historically, when scientists placed a specimen in storage, they would fill out a paper card to go along with it. The vast majority of specimens were cataloged before easy access to computers, so the card itself is often the only record.

And despite Grinnell's attempts to standardize protocols for field observations, people have persisted in doing things their own way. "Back in the day, people didn't have GPS readers," says Rapacciuolo. "So a lot of these labels might only have a county or just say something like 'Found 2 miles south of West Sacramento.'"

Of the four major collection types at Berkeley—insects, fossils, vertebrates, and plants—only the MVZ is completely digitized. But it also has the smallest collection—a mere 677,000 items—whereas the Museum of Paleontology has 6.5 million samples, over 95 percent of which still need digitization.

And it's not just the museums. Historical records include archival soils, data from climate sensors, fossil pollen extracted from lakebeds, and even old photographs showing vegetation types in specific locations. Researchers will be able to overlay this unique data on top of publicly available base-layer records such as topo maps, fire records, and maps of political boundaries. Eventually, says Gillespie, scientists will be able to easily determine that "we found beetle X at point Y on date Z. And then with 100 years of data about location and abundance, you'll really be able to paint a picture of how everything has changed."

Crowdsourcing and Collaboration

Even working quickly, there's not enough time, money, or bleary-eyed undergrad research assistants to enter all the data in-house. So Holos has turned to the Internet, crowdsourcing the project at notesfromnature.org, with users earning badges based on how much data entry they do. It's not exactly as addictive as Tetris, but the number of people willing to donate a few minutes a day to science is surprisingly large.

UC data is idiosyncratic to wherever UC researchers have gone—especially the Sierras and the Richard B. Gump South Pacific Research Station in French Polynesia. Fortunately, other universities and governments have embarked on their own massive digitization processes from their unique corners of the globe. Holos exists not only to digitize UC's data, but might also be able to serve as a computerized framework, integrating data from institutions far and wide.

Holos is already live, with more data and capabilities being added all the time. Access comes not a moment too soon. "We know we're causing change very rapidly right now," says Gillespie. "But we don't know when we'll reach the tipping point that prevents communities from responding at a rate that will allow them to continue to exist." Understanding the specifics of how ecosystems have responded to change in the past might help us avoid ecological calamity in the very near future, she says.

Joseph Grinnell might not have had GPS on his wristwatch or an Excel spreadsheet to catalog his specimens, but he seems to have had something a lot like Holos in mind. "The greatest value of our museum," he wrote in 1910, "will not . . . be realized until the lapse of many years, possibly a century, assuming that our material is safely preserved [so] the student of the future will have access to the original record of faunal conditions in California and the West, wherever we now work."

Holos tools and information are live at globalchange.berkeley.edu/ecoinformatics-engine

Photo by Matthew Luskin

A tiger in Gunung Leuser National Park, a UNESCO World Heritage Site in North Sumatra, Indonesia. **Matthew Luskin,** a PhD candidate in the Department of Environmental Science, Policy, and Management living in Indonesia last year as a National Geographic Society "Explorer" and Fulbright scholar, used 80 motion-activated cameras throughout Sumatra's three remaining large jungles to understand how tigers are coping with their rapidly shrinking habitat. Luskin and his team are finding that altered prey availability and human poachers strongly affect where the remaining 450 critically endangered tigers now persist—information that can be used to develop effective conservation plans.