UC DAVIS
COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

OUTLOOK

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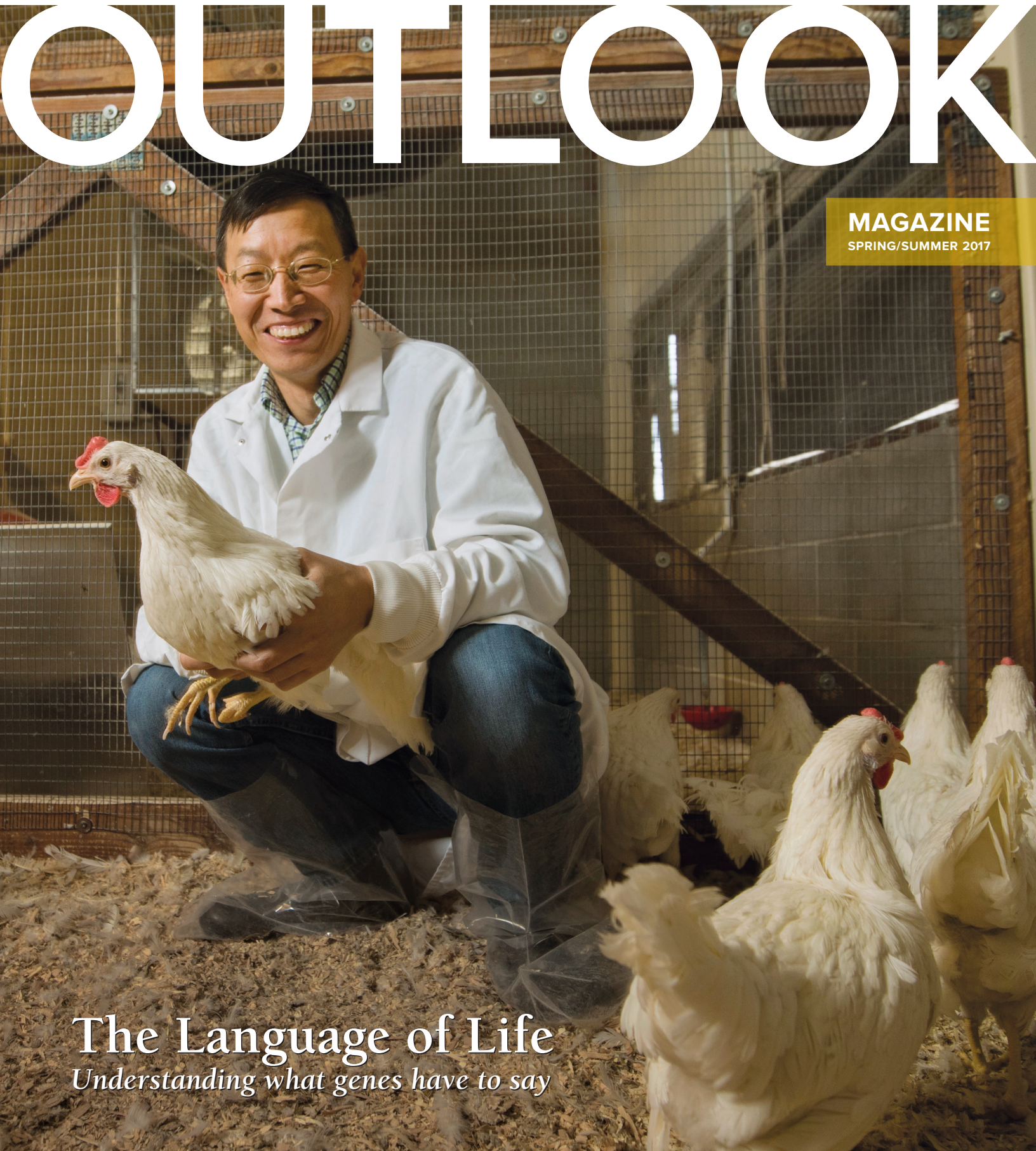
SPRING/SUMMER 2017



The Language of Life

Understanding what genes have to say

GREGORY URQUIAGA/UC Davis

Dean Helene Dillard (center) observes as students taking Biotechnology 161A—Genetics and Biotechnology Lab—learn how the expression of key genes in the tomato genome are regulated by low temperatures. Students wear masks to protect the stability of their samples.

From the Dean

Focus on Breeding, Genetics, and Genomics

HUMANS BEGAN EXPERIMENTING with selective breeding thousands of years ago when plants and animals were first domesticated, but it wasn't until the mid-19th century when Gregor Mendel demonstrated the fundamentals of heredity with scientific experiments on peas that the field of genetics got its start. Today we live in a world where knowledge of the form and function of genes has exploded through many disciplines in the agricultural, environmental, and human sciences.

Our college and UC Davis in general are at the forefront of developing new knowledge about genetics and its many related disciplines like genomics and bioinformatics. We need this knowledge now more than ever. The world population is currently estimated to be 7.5 billion—and growing. Society's challenge is how to sustainably feed this growing world population while maintaining a healthy environment.

Breeders of plants and animals need the information created by geneticists and other scientists to develop resilient species that are more productive and less susceptible to diseases, pests, and the uncertainties of a changing climate. Natural resources professionals use genetic knowledge of biodiversity to maintain a healthy environment. Medical professionals understand much more about human health and wellness today as a result of genetics.

Our ability to understand DNA, gene expression, and how life manifests in the world has improved markedly with the new tools of recent years. Next-generation sequencing technology and the more robust data-crunching power of today's computers enable scientists to look at tens of thousands of genetic markers. This empowers researchers to learn more about population genetics in wildlife, pest resistance in crops, or disease pathways in humans.

We are committed to leading in the discovery and development of new technologies and new knowledge that will benefit our food and agriculture systems, our communities, and our environment. That necessitates a deep understanding of the basic building blocks of life. This issue of *Outlook* provides a glimpse into that world and our contribution to the science of genetics.

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ON THE COVER
UC Davis geneticist Huaijun Zhou leads an international group of researchers seeking advanced genetic and genomic solutions to breeding more robust chickens. Scientists are more than three years into the five-year Feed the Future Innovation Lab for Genomics to Improve Poultry project, funded by USAID.

COVER PHOTO BY:
GREGORY URQUIAGA/UC Davis

The Language of Life

GENETICS IS THE SCIENCE OF HEREDITY. The applications of new discoveries in genetics are as varied as the individuals within a species.

Faculty in the College of Agricultural and Environmental Sciences are using genetic strategies to keep crop varieties robust in the face of changing weather patterns. They are sampling DNA in waterways to help manage invasive species. They are identifying genetic markers to breed livestock that show increased resistance to disease or other favorable traits. They are looking at how genes affect a person's response to stress.

In the pages that follow, we take a closer look at examples of genetics and genomics research being conducted by UC Davis scientists.

FEATURES

DEPARTMENTS

All ABUZZ ABOUT BEES

UC Davis embodies a long tradition of scientists advancing the knowledge of honey bees, and entomology professor Brian Johnson has joined that tradition through his study of honey-bee genetics, evolution, and behavior. Johnson is exploring new areas in honey-bee genetics.

"A major unresolved question is how major changes in traits are specified at the genetic level," Johnson said.

For instance, social insects have many new traits related to their lifestyle that were missing in their solitary ancestors. Most of these traits have to do with communication, which is an intense need in social groups, though less important for solitary animals.

Many glands throughout the body of social species like honey bees produce pheromones—chemicals that stimulate behavioral responses in others. Johnson's work demonstrates that many new traits based on glandular function are associated with the evolution of new genes.

"Our work shows that novel genes are critical for novel functions," Johnson said.

Future research in the Johnson lab will explore the relationship between gene expression in honey bees and other social insects, and perhaps across the tree of life. — *Kathy Keatley Garvey*

#1

Making The World a Greener Place

UC Davis has been declared the "greenest" university in the world.

The seventh annual GreenMetric ranking from the University of Indonesia assessed 516 colleges and universities in 74 countries for environmentally friendly campus operations and policies and research and education on sustainability.

In addition to renewable energy, energy efficiency, water conservation, and green building implementation, UC Davis was also ranked on education and factors such as published research and course offerings related to sustainability. — *Charleen Floyd*

Packing team supporters (left) Rich Underwood and (right) John Raede, with students Erica Falk (holding trophy saddle) and Kayla Wigney (holding plaque).

Happy Trails

Students win mule packing competition

Packing a mule requires skill. Doing it quickly, working with unfamiliar animals, competing in an arena against other collegians, and making sure no equipment falls off before your mule crosses the finish line—that challenge was met by four UC Davis animal science students who took a first-place win in the 2016 Intercollegiate Packing Competition. The packing competition was one of many contests held during Mule Days, an annual Memorial Day Weekend event in Bishop, California.

Students at the Horse Barn, part of the Department of Animal Science, formed the UC Davis packing team only three years ago. They receive support from veterinarian and UC Davis alumnus Craig London of the Rock Creek Pack Station and coaching assistance from Andy Assereto of the Backcountry Horsemen of California Mother Lode Unit.

"In the arena, the competition was so fierce, yet come dinnertime, all the competitors would come together and have a great time around the fire," said senior Kayla Wigney. "We look forward to packing together or against each other in the future."

—*Robin DeRieux*

by Robin DeRieux

BREAKING THE CODE

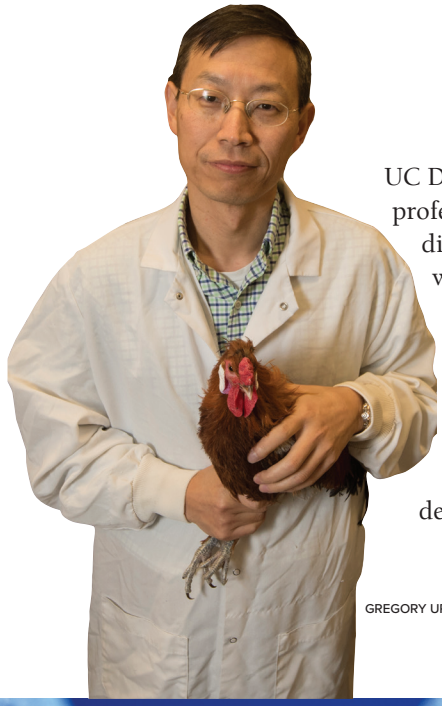
Using discoveries in genetics to make poultry more resistant to disease and heat stress

GREGORY URQUIAGA/UC Davis

IN RURAL AFRICAN VILLAGES, chickens provide families with much more than meat and eggs.

Traditionally, it is women who tend small backyard flocks. Chickens provide high-protein sustenance for families, as well as income that empowers women and improves their quality of life. Raising indigenous chickens is a relatively minor investment compared to cattle, pigs, or other livestock, since the birds scavenge for food and live outdoors without housing.

But rural poultry production in Africa is threatened by the number one avian virus on the continent—Newcastle disease. Newcastle is a highly contagious respiratory illness that can decimate entire flocks in a matter of days. In the United States and other developed countries, the disease is controlled through vaccination. In African countries, various obstacles prevent the Newcastle vaccine from being a feasible means to protect poultry.



GREGORY URQUIAGA/UC Davis

UC Davis geneticist and animal science professor Huaijun Zhou hopes that new discoveries in chicken genome research will help breed a more robust chicken that offers greater food security to poor African households.

Led by Zhou, an international group of multidisciplinary researchers is working on advanced genetic and genomic approaches to develop new strains of chickens with enhanced protection from both Newcastle disease and the heat stress that chickens face in harsh African climates. Scientists are more than three years into the five-year Feed the Future Innovation Lab for Genomics to Improve Poultry project, which has $6 million in USAID funding.

"There is a genetic component to disease and heat resistance," said Zhou, who is a UC Davis Chancellor's Fellow. "We aren't saying the genetic or genomic approach will replace vaccinations—we're taking a complementary

What is a genome?

And what does it mean when scientists say they have sequenced a genome?

THE EXACT ORDER of the four building blocks that make up an individual organism's DNA code—represented by the letters A, T, C, and G—is called a DNA sequence. A genome is the entire DNA sequence for an organism.

For example, an international team of geneticists sequenced the chicken genome in 2004—they determined the exact order of the letters representing the building blocks, or base pairs, of the organism's DNA.

Chickens, like any organism, are likely to share 99.5 percent of the same base pairs in the same sequence.

Because there are approximately 1 billion base pairs in the chicken genome, the 0.5 percent difference translates to nearly half a million genetic variations between any two individuals.

Genes are partial segments of the genome, varied in size, that account for differences in appearance, resilience, and other traits expressed in an organism—collectively called the "phenotype."

In the case of chickens, examples of phenotype include brown feathers, white feathers, good layer, bad layer, muscular chickens, fat chickens.

Once an organism's genome has been sequenced, scientists seek to identify the genes or genetic markers associated with traits of interest.

Some traits are determined by a single gene. More often, many genes work together to specify a trait. Most traits are influenced by both genes and the environment.

Information gleaned from a sequenced genome helps researchers make breeding decisions for crops or livestock that will more reliably and efficiently produce the desired results.

Think of the genome as a book that contains a set of directions to build an organism.

Inside the book are sentences—genes that instruct cells how to make proteins that affect various traits.

But a genome is no easy book to read.

It's like a stream-of-consciousness opus with no capitalization or punctuation, no clear indication where words end or sentences begin. Strings of extra letters are randomly inserted throughout.

Scientists have to discern

approach. We want to identify the genetic markers that are associated with resistance and use the natural variation to breed birds that are more resilient."

Another component of the poultry project is to build capacity—renovating facilities and training scientists at Sokoine University of Agriculture in Tanzania and at the University of Ghana so that the work in these countries can continue beyond the initial involvement of American universities.

One of the most difficult aspects of the project is that disease and heat resistance are complex traits, which means they are controlled by many genes—perhaps hundreds. "Each gene involved tends to contribute a small genetic effect, making them hard to detect," said Zhou. "It's a tremendous challenge." ●

"Each gene involved tends to contribute a small genetic effect, making them hard to detect."

which parts of the book code for genes, what those genes do, and how they interact with other genes to determine individual traits.

Add to that, a book containing the entire genome for a species reads pretty much the same for any two individuals.

The book is so long that the small differences in wording account for significant differences in outcome.

So while sequencing a genome provides scientists with a book of instructions, it's a book that needs to be decoded in order to be understood. Once researchers can read the story, they have to figure out what the story means.

—Robin DeRieux

EXAMPLES OF GENETIC TECHNOLOGIES

GENE EDITING

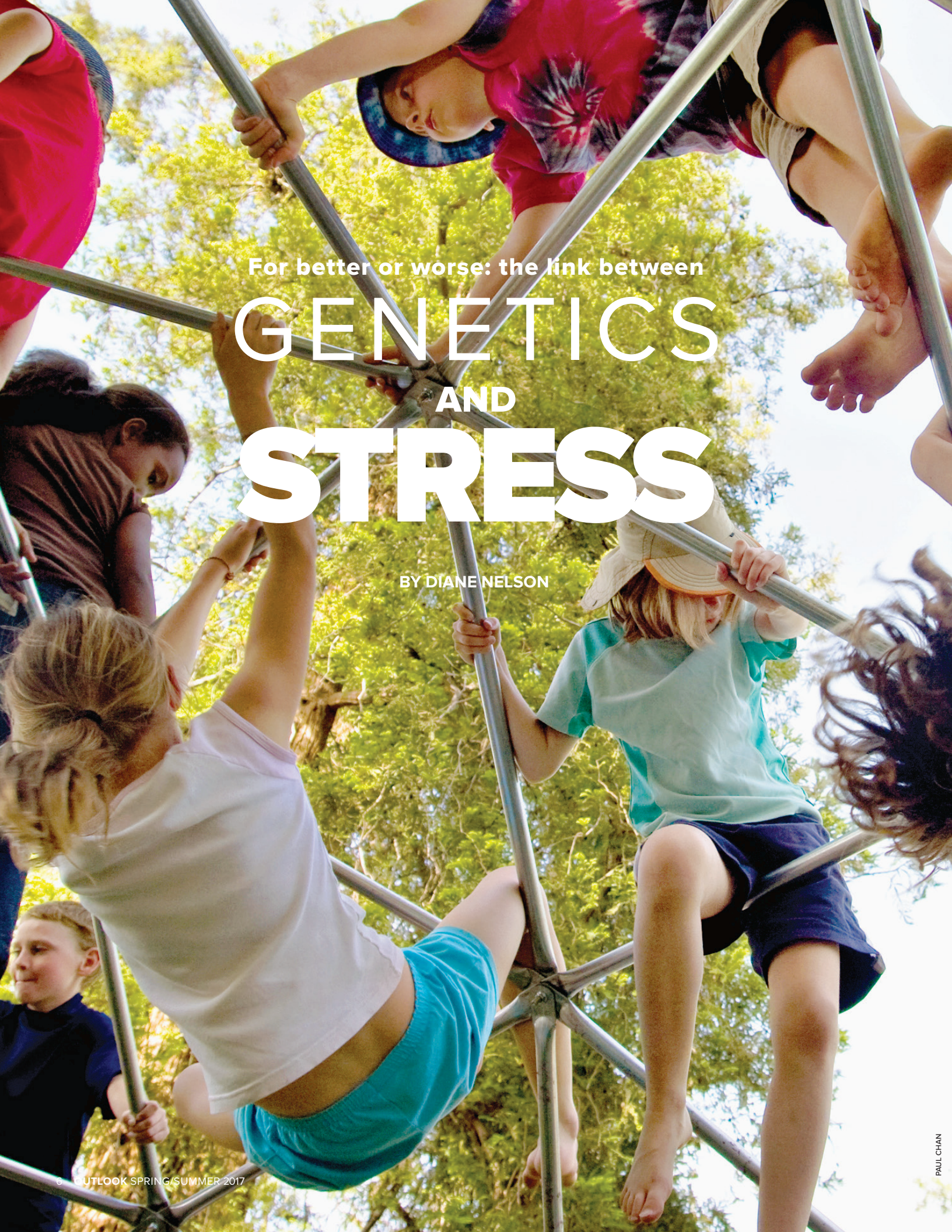
Gene editing uses molecular "scissors" to precisely cut DNA sequences at a particular location in the genome. Think of it as using spellcheck for a gene. By tinkering with the individual letters at a precise location, scientists can introduce a preferred trait, one that already exists as a naturally occurring variation within the species.

Gene editing has been used to prevent horn formation in cattle, eliminating the need to remove horns from dairy cows.

GENETIC ENGINEERING

Genetic engineering is the process of transferring a specific gene from the genome of one organism into another to pass along a desired trait or function. An organism that has been genetically engineered is called a Genetically Modified Organism, or GMO. This term can be confusing because traditional selective breeding also modifies a species—like domestic dogs and their ancestor, the wolf. Genetically engineered offspring can also be called "transgenic."

Genetic engineering was used to create a papaya variety resistant to ringspot disease by introducing DNA from the virus, which essentially vaccinated the fruit against the virus. Genetic engineering was used because papaya contains no naturally occurring genetic resistance to the virus.



For better or worse: the link between

GENETICS AND STRESS

BY DIANE NELSON

PAUL CHAN

OUR GENES CAN INFLUENCE how we respond to stress. Science shows that some people are more genetically predisposed than others to develop depression and anxiety in response to stressful situations.

What's more, researchers say that chronic exposure to stressful conditions—such as poverty, family discord, and poor nutrition—can alter the way genes behave in children and adolescents, making them more susceptible to depression, anxiety, and other negative effects of stress.

But mounting evidence from scientists with the UC Davis Department of Human Ecology suggests there is also an upside to the link between genetics and environmental exposure. In many cases, the same people who are most adversely affected by negative experiences also benefit the most from supportive and even benign environments.

"It's not just that some individuals are more 'vulnerable' to adversity, but rather that some people are more developmentally malleable for better and for worse," explained Jay Belsky, professor of human development. "Many of the genes long thought to operate as a risk factor for problem behavior when things go poorly may also be an opportunity factor when children are exposed to interventions and when things go well."

Belsky and his colleague, human development professor Johnna Swartz, are uncovering intriguing clues about the connection between genetics, stress, and opportunity that could change the way society views, treats, and prevents depression, anxiety, and other disorders.

FIGHT OR FLIGHT

Swartz and others have discovered that measures of brain function, which are influenced by genetic variation, may predict later psychiatric conditions. Working with Professor Ahmad Hariri at Duke University, Swartz analyzed the brain scans of 340 college students while they were looking at images of angry or fearful faces. Swartz and colleagues measured activity in the students' amygdala—the tiny emotion-processing center of the brain—to see how active it was in response to the threatening stimuli.

After the measurements were taken, the students answered questions assessing stress in their lives, as well as symptoms of depression and anxiety. Students with more reactive amygdalae at the start of the study—more exaggerated fight-or-flight responses to the scared and angry faces—experienced more severe symptoms in response to later stressful situations in their lives.

"By identifying genetic markers that predict these patterns of brain function, we could potentially guide people at higher risk for depression and anxiety to seek preventative treatment before symptoms become chronic and disruptive in their lives," Swartz said.

With further research, genetics could also help doctors identify the imbalance or pathway causing a patient's disorder and more precisely treat the problem.

ENVIRONMENTAL FACTORS

Both nature and nurture seem to play a role in how people process stressful experiences. New research from Swartz and Professor Douglas Williamson at Duke University links poverty to changes in gene expression.

Their study followed 183 children ages 11 to 15 over three years, testing them for symptoms of depression and scanning their brain activity in response to photos of fearful faces. During the course of the study, children from more disadvantaged families had greater methylation—a process that can change the way genes behave—of a gene that controls levels of serotonin, which can affect a person's mood. Children with more methylation also had more active amygdalae, and this predicted greater increases in depression symptoms a year later.

"The small, daily challenges of scraping by can build up and affect children's development," Swartz said. "It shows that our biology is not set in stone, and environments can affect us as deeply as levels of markers on our DNA."

THE BRIGHT SIDE OF SUSCEPTIBILITY

Collaborating with scientists across the globe, Belsky has spent years researching "differential susceptibility"—the concept that some children are more likely to suffer in bad settings and flourish in good ones due to their genetic makeup. He has looked at the effect of quality care at orphanages in Portugal, the link between prenatal stress and attention deficit hyperactivity disorder, and how peer relations influence hyperactivity and impulsivity, just to name a few areas of research. And he has found a genetic connection.

For example, some variations of the serotonin-transporter gene have been linked to depression. And variations of the dopamine-receptor gene have been linked to attention deficit hyperactivity disorder.

But that is not all.

"Intriguingly, these supposed 'risk' genes also turn out to be associated with heightened sensitivity to environmental conditions," Belsky said. "Children who carry either or both of them appear to be most adversely affected by negative experiences, and seem to benefit most from supportive ones."

And children without them seem relatively immune to the effects of both supportive and unsupportive environments.

"Some people are more affected by their developmental experiences than others," Belsky said. "I think of it more as diversity rather than damage. Genetics can inform our understanding of human development and help us find ways for all of us to thrive."

Variable weather is creating extreme challenges for crop breeding in California.

HOW DO YOU DEVELOP CROPS that will thrive under certain conditions when you can no longer predict what those conditions will be?

"It's the question we're all asking," said Charlie Brummer, professor and director of the UC Davis Plant Breeding Center. "Our weather patterns are changing so fast, affecting everything from soil composition to what to expect in terms of weeds, diseases, and pests. It can take 10 years to develop a new crop variety, even more for perennial plants. So we have to extrapolate what the future will bring—very, very quickly."

Changes have already begun, according to Allen Van Deynze, director of research at the UC Davis Seed Biotechnology Center. A spike in insects and the viruses they transmit are threatening vegetable crops in California and beyond.

"An extra four-to-six weeks of heat can produce another generation of aphids and wipe out an entire crop," Van Deynze explained. "The insects are multiplying very fast."

Extreme variations in localized weather pose a bigger challenge to breeders than long-term climate shift. If you know weather will trend hotter, you can plan for that. It is the wild swings—the longer droughts and more intense floodings—that are tricky.

"The insects, weeds, and other pests that thrive in more humid settings are different from those you find during drought," Brummer said. "We're working to breed crops that can adapt to it all."

Breeders and engineers at UC Davis are helping crops keep pace with variable weather by using advanced genetic strategies, developing robotic sensors to measure plant performance, and training the next generation of plant breeders.

Time-lapse evolution

UC Davis breeders help develop new cultivars, or varieties, of the nearly 400 fruits, vegetables, nuts, grains, and ornamentals grown year-round in California's diverse environments. To create a winning variety, breeders cross plants with desired traits and select the best offspring over multiple generations. That is essentially how humans have been improving crops since the dawn of agriculture 10,000 years ago.

But breeding has become faster and smarter, thanks to rapid improvements in DNA sequencing and the computer power to analyze a wealth of genetic data.

Some plant traits, such as flavor and size, are determined by many genes acting together. Other traits, such as resistance to a disease, may be regulated by a single gene. Breeders can now identify genes that influence some traits at the molecular level, so they can select plants at the seed or seedling stage based on their DNA sequence rather than wait for traits to express themselves as the plants mature. That speeds up the process.

"We have the tools to respond quickly to

BREEDING C

for

disease and other threats," Van Deynze said. "We're hoping to reduce the time it takes to breed for disease resistance from eight years to two or three years."

The next frontier: fast phenotyping

To accelerate breeding, genomics are only part of the equation. Breeders also need to phenotype, which is to measure traits as plants grow in the field.

"Molecular tools help us find genes of interest for some traits, but you don't really know what you have for other traits until you make your crosses and grow plants in the field," Brummer explained. "While trying to solve one problem, you can't inadvertently forget about yield or flavor. And for those traits, you have to phenotype to find out which are the best."

Current methods of phenotyping are slow and labor intensive and have not kept pace with genotyping. Breeders use measuring tapes and their own taste buds to assess yield and fruit quality. Phenotyping has become the bottleneck in breeding.

A solution may be at hand. New smart machines and sensor-based technologies can automate the measurement of large numbers of plants and plots. Professor David Slaughter, a biological and agricultural engineer at UC Davis, has developed a rapid, in-field phenotyping system with high-tech cameras that create three-dimensional, virtual models of each plant as it grows in the field.

"It can measure critical components like plant architecture and volume, leaf area and number, and temperature of the leaves, which helps breeders determine growth patterns and whether plants are suffering from heat or water stress," Slaughter explained.

David Slaughter has developed a tractor-pulled phenotyping system (left) that creates virtual models of each plant as it grows in the field. Allen Van Deynze (right) examines new fruit on a wild pepper plant.

Slaughter's tractor-pulled system can currently measure three plants per second, or 10,800 plants per hour.

"That's revolutionary," Brummer said. "Breeding is a numbers game. The more plants you can look at, the better your chances of finding ones that are truly exceptional."

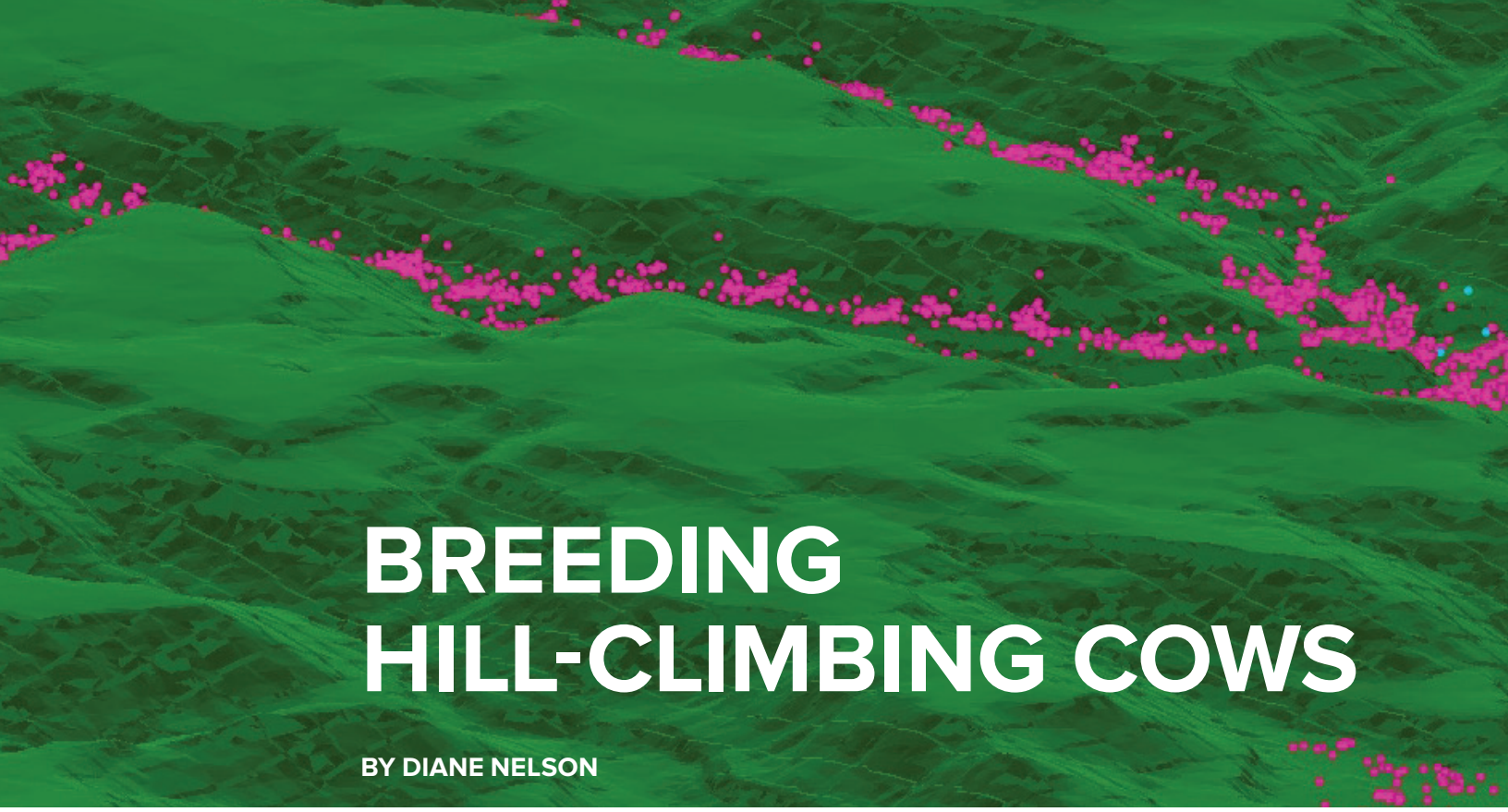
Sensor technology can also provide the big-picture data breeders need to develop crops that can thrive in an uncertain future.

"We need to look at both phenotyping and genotyping, and tie them together with crop-management strategies to optimize performance of new cultivars," Brummer said. "Done correctly, we will be able to breed new cultivars more efficiently and rapidly today so they can perform well in the production environments of tomorrow."

ROPS TODAY

an uncertain tomorrow

BY DIANE NELSON



BREEDING HILL-CLIMBING COWS

BY DIANE NELSON

MOST OF THE 5 MILLION CATTLE THAT GRAZE on California's rangelands like to dine in the valleys and hang out by creeks. This can lead to overgrazing in riparian areas and let perfectly good forage on hillsides go to waste.

But some cows are different. They prefer to climb hills and mountains and eat along the way. If more cattle followed the road less traveled, rangelands would be more productive and sustainable throughout California and the West.

That is why a team of researchers, including UC Davis animal geneticist Juan Medrano, is working to develop an easy, inexpensive genetic test to help ranchers improve cattle distribution by breeding hill-climbing cows.

"It's very exciting research," said Medrano, a professor with the Department of Animal Science who is collaborating with scientists throughout the West. "DNA technology makes it relatively easy to test and breed for production traits like milk yield and growth rate. But it's brand new to identify genetic markers linked to animal behavior. This could have a huge impact on food security and rangeland management."

NATURE AND NURTURE

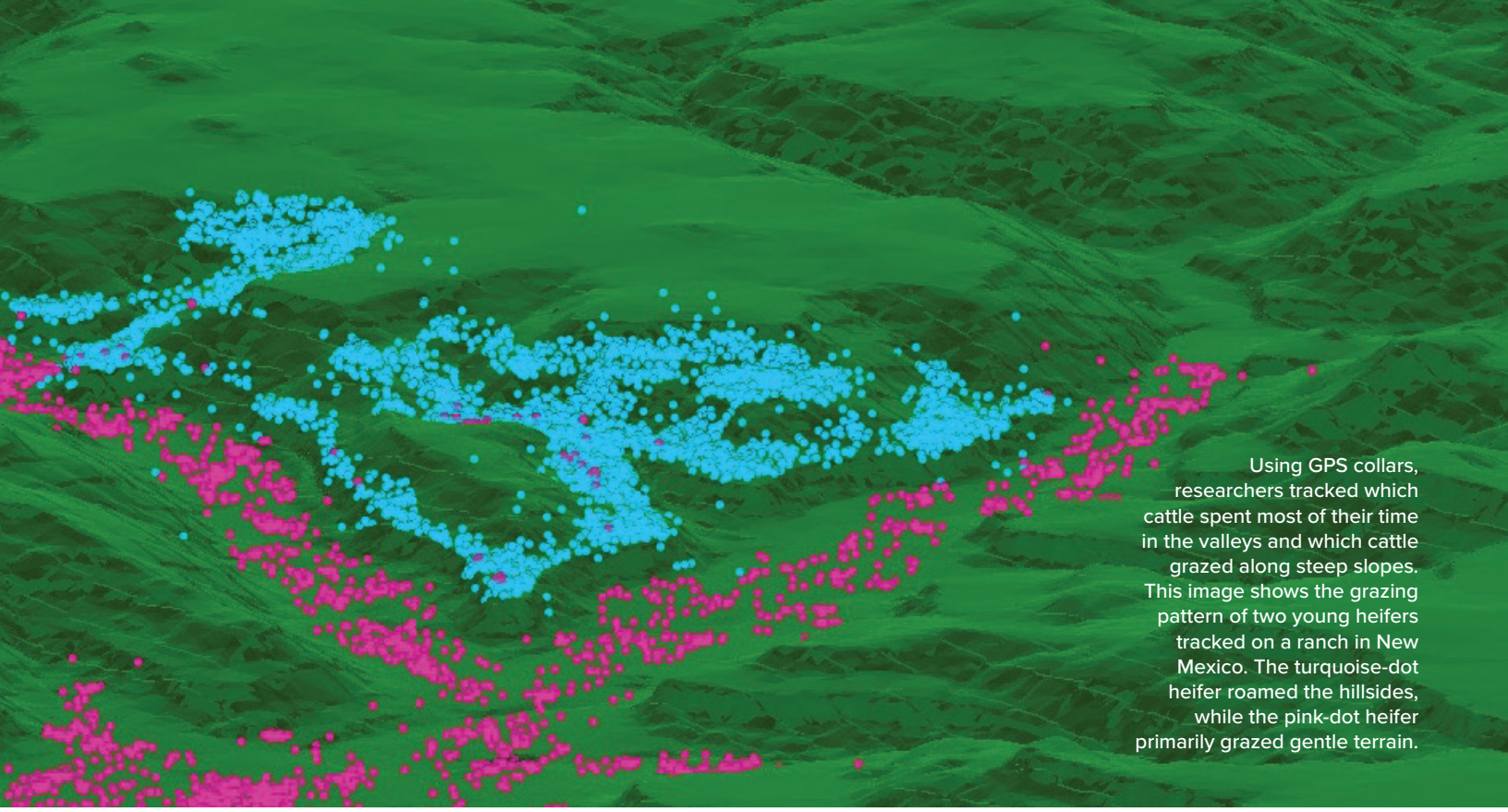
One third of California—38 million acres—is rangeland. Most of it is mountainous or hilly and managed for livestock production. Grazing on rangeland feeds livestock, but also offers many environmental benefits such as keeping weeds and other invasive species in check, providing water storage and carbon sequestration, and supporting habitat for animals and plants found nowhere else in the world.

Problems arise, though, when rangeland is overgrazed and cattle spend too much time near running water, where manure and calving can create water-quality risks for people downstream. That is especially true in California. Some 80 percent of the state's drinking and irrigation water is stored on or passes through rangeland.

Researchers at UC Davis and beyond have been working for decades with ranchers to keep cattle from overgrazing and congregating by creeks. They build strategic fencing, for example, and provide water and salt licks on ridgetops away from running water. Cowhands often herd cattle from low-lying pastures, but that is labor-intensive and only a temporary fix.

A few years ago, Derek Bailey, a professor of range science at New Mexico State University and a colleague of Medrano, had an intriguing thought: What if we combine nature and nurture?

"I've been watching cattle for years, and there are always some cows that just take off for the hills, like they didn't know they weren't elk," Bailey said. "They could be belly-deep in green grass, and just bolt for the hills. They like it up there. We can breed for other traits. Why not



Using GPS collars, researchers tracked which cattle spent most of their time in the valleys and which cattle grazed along steep slopes. This image shows the grazing pattern of two young heifers tracked on a ranch in New Mexico. The turquoise-dot heifer roamed the hillsides, while the pink-dot heifer primarily grazed gentle terrain.

Photo courtesy of Derek Bailey, New Mexico State University

select for hill climbing?"

Bailey joined forces with Medrano and a team of researchers, including animal genetics expert Milton Thomas at Colorado State University. Funded by a grant from Western Sustainable Agriculture Research and Education, the group is close to developing a genetic test for whether a bull is likely to sire daughters who like to climb hills.

LOCOMOTION, MOTIVATION, AND SPATIAL LEARNING

To identify hill-climbing cattle, Bailey and his crew put GPS collars on 180 cows on seven ranches in three western states and took measurements every 10 minutes for months at a time. They tracked the cattle's slope use, elevation gain, and distance traveled from water. They also took blood samples that Medrano and his team analyzed for chromosomal commonalities. Medrano found overlap in genes linked to locomotion, motivation, and spatial learning.

"Results so far are very encouraging," Medrano said. "Soon we will be able to test and breed for hill-climbing behavior."

Breeding for one trait can sometimes produce unintended consequences like predisposition to disease or low calf weight. Researchers are looking closely at that possibility, and have so far found no correlation between hill-climbing behavior and undesired traits.

"We've looked at calf-weaning weights, pregnancy rates, blood pressure, even disposition," Bailey said. "We had one theory that hill-climbing cows tended toward the meaner end of the scale, but that's not the case.

"Some cows just prefer to climb more than other cows," Bailey continued. "And if breeding can move the bell curve in that direction, management tools like fencing and herding will be much more effective."

"I'VE BEEN WATCHING CATTLE FOR YEARS, AND THERE ARE ALWAYS SOME COWS THAT JUST TAKE OFF FOR THE HILLS, LIKE THEY DIDN'T KNOW THEY WEREN'T ELK."

California ranchers are intrigued by the possibility.

"I can see many ecological and economic benefits to breeding for cows who like to travel," said Clayton Koopmann, a rancher and rangeland-management consultant who runs cattle on hilly ground throughout the San Francisco Bay Area. "Forage would be consumed more evenly, and that's good for livestock production and for the environment."

Inside View

During winter break, a dozen students from the College of Agricultural and Environmental Sciences got an insider's view of agriculture while on a three-day tour of farms, nurseries, and related operations in Southern California and Arizona. UC Davis undergraduates joined students majoring in science, technology, engineering, or mathematics (STEM) from other universities on a trip organized by the Western Growers Association. The tour covered automation, irrigation, labor, food safety, and more. While on the tour, students connected with professionals in the agriculture industry and learned about the many career opportunities available in the field. View additional photos at **tinyurl.com/CAESInsideView**.

Photo by THOMAS SHEDD/UC Davis

BRIAN TODD/UC Davis

conservation GENETICS

UC Davis scientists find fresh ways to protect California's native species

by John Stumbos

ALMOST HALF OF CALIFORNIA'S AMPHIBIANS and 80 percent of the state's inland fish are of concern to conservationists. Threats include non-native species such as Southern and common watersnakes that have turned up in recent decades, harming native fish, amphibians, and other species.

Brian Todd, an associate professor in the Department of Wildlife, Fish and Conservation Biology, utilized genetic tools to study these invaders. He and former graduate student Jonathan Rose partnered with state and federal agencies from 2011 through 2015 to identify the extent of infestations near Sacramento.

"Every living thing is constantly shedding its DNA into the environment in some way."

The scientists employed an environmental DNA or "eDNA" technique to get a better sense of where the snakes were located. "Every living thing is constantly shedding its DNA into the environment in some way," Todd explains. "So we compared DNA from water samples with a known genetic standard marking the presence of the watersnakes."

The researchers concluded that the watersnakes were not yet widespread in the Sacramento area. But their models predicted the snakes could potentially spread to many parts of California. The state plans to continue eradication efforts in 2017.

Watersnakes have been illegal to own or possess in California since 2008. Nonetheless, watersnakes still pose a threat to the state's biodiversity. "We know they're already here, and the state's waterways are very interconnected," Todd said.

A fungal threat to amphibians

Fungal diseases have become an increasing threat to certain types of animals. Todd and graduate student Evan Eskew looked into the chytrid fungus (*Batrachochytrium dendrobatidis*) that has been implicated in dramatic amphibian population declines in many parts of the world.

They conducted experiments on the wood frog (pictured above) and the American bullfrog —two widely distributed species with very different susceptibility to the chytrid fungus. Observing gene expression would give them a better idea of why the bullfrog is comparatively resistant to the disease, while the wood frog is not.

"What we found was exactly opposite of what we expected," Todd said. "Essentially, the bullfrogs didn't appear to be working as hard to fight off the disease as the wood frogs, yet they fared better. For example, bullfrogs were not activating genes associated with an immune system defense, so we knew there was another mechanism at work."

That something probably lies in the thicker skin of the bullfrogs and may be just enough to protect them from microscopic invaders. A bullfrog's skin-associated microbial community may also hold a key to disease resistance. The scientists believe that greater attention to the nature of pathogenic fungi is needed to preserve vertebrate biodiversity.

"Genetic tools have helped us identify traits that influence

an amphibian species' resistance to disease," Todd said, "and conservationists can use this information in service of captive breeding or other efforts that seek to maintain healthy amphibian populations globally."

Raptor research takes flight

Raptors are birds of prey such as hawks and falcons that provide a number of important environmental benefits. Some raptors—barn owls, for instance—keep rodent populations in check. Raptors can indicate the presence of environmental contaminants. Many years ago, scientists established a connection between DDT and the decline of bald eagles, peregrines, and ospreys. Since that pesticide was banned in 1972, these species have recovered.

"Raptors signal a healthy ecosystem" said Josh Hull, an adjunct professor in the Department of Animal Science. "They are also a good indicator of species diversity."

Hull studies raptors with a team of graduate students and colleagues at UC Davis. They are using genetic tools to understand more about individuals in a population, the relationships among different populations, and the prey species that are important to survival. With the advent of next-generation sequencing technology, more powerful computers, and good old-fashioned field work, Hull's team is gaining new insight into these magnificent birds to assist wildlife managers in conservation efforts.

For instance, Yosemite National Park has a genetically distinct population of great gray owls—a "charismatic" species that is a high priority for park managers. "They're an isolated population that appears to have been on its own for many thousands of years," Hull said. "They appear to be very rare, but we don't have a good sense of how this population is doing."

One of Hull's students, Joe Medley, devoted his graduate work to collecting molted feathers from known nesting areas in the park's high country. From those samples, DNA has been extracted and genetic markers called microsatellites were used to identify individual owls and get a better sense of population status.

The sharp-shinned hawk is the smallest hawk in North America. Working with Golden Gate Raptor Observatory (GGRO) scientists, graduate student Ryan Bourbour has collected DNA samples with a swab from the birds' beaks to learn what these hawks are eating while migrating.

"People are always asking, 'What do hawks eat?'" Hull said. "Beyond that, from a conservation perspective, this is going to help us understand what these birds need."

Work is now underway to sequence DNA that will identify prey species of the sharp-shinned hawks.

Cooper's hawks are a fairly common yet understudied species. Hull's group is interested in finding out which populations are being monitored by GGRO. Graduate student Breanna Martinico is analyzing Cooper's hawk DNA from the Marin Headlands and from other locations around the country.

"Are we monitoring a local population of California birds or are we monitoring a population migrating from someplace else?" Hull asks. "That's important because if we see a decline, where should we look for the problem? We've seen this in red-tailed hawks with two distinct populations that fly through the Marin Headlands—one from California and one from the northern Intermountain West."

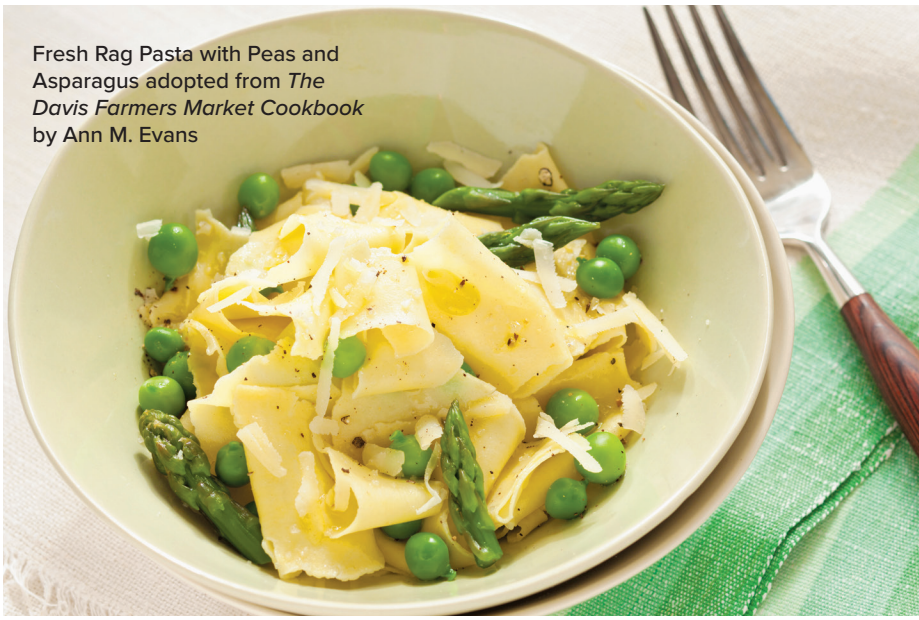
The Harlan's hawk is categorized as a subspecies of red-tailed hawk, but some people believe it is a separate species. "There's a lot of debate about this because there's a lot of variation in the birds' plumage," Hull said. "Each individual looks different from the next to a much greater extent than any other raptor species that we work with."

Genetic analyses by graduate student Megan Mayo have shown, however, that the Harlan's hawk and red-tailed hawk are the same species. "We're confident that they're not a different species and we're confident that they are interbreeding, so that leaves some other ecological factor that is causing this variation to persist," Hull said.

JOSH HULL/UC Davis

Ecology Graduate Group Ph.D. student Megan Mayo has been studying population variation in tundra-breeding, rough-legged hawks, which migrate as far as California in the winter. Scientists are concerned with how rough-legged hawks (pictured with Mayo) will respond to global warming. Knowledge of this species' population structure can help determine areas of importance for conservation management.

What's Cookin' in CA&ES?



Fresh Rag Pasta with Peas and Asparagus adopted from *The Davis Farmers Market Cookbook* by Ann M. Evans

A passion for food and a love of science is apparent in two recent books written by CA&ES alumni—Ali Bouzari's *Ingredient: Unveiling the Essential Elements of Food*, and Ann M. Evans' updated edition of *The Davis Farmers Market Cookbook*.

Ingredient explores eight basic elements found in every culinary creation—water, sugars, carbs, lipids, proteins, minerals, gases, and heat. "It's a book designed for anyone who wants to understand the world of food a little bit better," said Bouzari (Ph.D., '15 food science). "The idea that I could write something applicable to a paleo-nutritionist, a chef in a fine dining restaurant, and my grandmother cooking food for Thanksgiving was really intriguing to me."

The Davis Farmers Market Cookbook features 75 seasonal recipes. "Eating what's in season makes a difference in price and in flavor," said Evans (B.S., '75 consumer food science). "You lose your connection with nature when you don't see and feel the seasons." A portion of the proceeds from her book sales will support the CA&ES Dean's Circle Scholarship Fund, a program that provides essential support to students within the college.

Spice up your library with these two first-rate books from our food science alumni who know a thing or two about good food, how to prepare it, and the science behind it all. Both books are available in regional stores, and online at **ucdavisstores.com**. Evans' book is also available at the Davis Farmers Market. —*Charleen Floyd*

Ann M. Evans '75

Ali Bouzari '15

Locally Sourced

Quality olive oil starts with freshly picked olives rushed to the mill for pressing. In fall, UC Davis students got a taste of the effort involved in harvest by hand-gathering fruit from olive trees at campus research groves.

"I'm amazed at the sheer number of olives it takes to produce a small amount of olive oil," said Lauren Crawford, a food science graduate student who helped with the harvest. Crawford's research at the UC Davis Olive Center lab focuses on developing an enzymatic debittering process for table olives, one that doesn't produce toxic waste water like traditional lye-based methods.

The fruits of the harvest are available at UC Davis Stores, and online at **ucdavisstores.com**. You can purchase UC Davis Olive Oil or try the Olive Center's newest product, Premium Dipping Oil (shown left), which is a blend of extra virgin olive oil from campus groves with balsamic vinegar from Modena, Italy, along with garlic, herbs, and spices. — *Robin DeRieux*

Andrew Fulks, assistant director of the UC Davis Arboretum and Public Gardens, provides an update on the Arboretum Waterway project to students who are helping with restoration efforts.

KARIN HIGGINS/UC Davis

Homegrown experts help restore the Arboretum Waterway

UC DAVIS HAS A SECRET WEAPON in its mission to clean and beautify the Arboretum Waterway: homegrown expertise.

An expanding group of undergraduate students—led by Randy Dahlgren, a professor and world leader in water-quality biogeochemistry—will sample the water and provide important analysis throughout the university's multiyear effort to enhance the waterway. The students are part of a new group internship Dahlgren designed to provide undergraduates hands-on experience in water-quality and aquatic-ecosystem restoration.

"It's good for everyone," Dahlgren said. "The students are playing a critical role in solving real-world problems, which gives restoration efforts a better chance to succeed and benefits all of us who enjoy the centerpiece of the Arboretum."

Visitors love walking the 3.5-mile loop around the Arboretum Waterway—except when the water is covered with unsightly duckweed and algae, a natural byproduct of what is essentially a stagnant pond.

The waterway sits in the channel that used to be the North Fork of Putah Creek, but long ago the creek was diverted due to frequent flooding. Now, the waterway is dammed at both ends and serves as a holding pond for storm runoff and a receptacle for clean, recycled wastewater.

UC Davis recently launched a four-year project to reduce algae growth and sedimentation by increasing water flow, deepening and narrowing the channel, and planting more native wetland vegetation on the banks.

"We're introducing small elevation gains and a pump to recirculate the water," said Andrew Fulks, assistant director of the UC Davis Arboretum and Public Gardens. "Picture a series of large, natural steps with water cascading down."

HOW MONITORING WATER QUALITY HELPS

Water quality is not a toggle switch, not something you switch on and off.

"It's like cholesterol in our blood," Dahlgren explained. "When your cholesterol is too high, you take progressive steps to lower it. Maybe first you increase exercise, then change your diet, then turn to statin drugs if the other two steps aren't effective."

But you don't know whether interventions are working if you don't monitor the blood or, in this case, the water. Throughout the restoration project, Dahlgren and his students will measure water-quality indicators such as levels of nitrogen, phosphorous, dissolved oxygen, and algae.

The group internship got underway last fall with 10 undergraduates majoring in Environmental Science and Management.

"It was a lot of fun," said Samuel Moose, a member of the inaugural group. "I really enjoyed the fieldwork and the opportunity to solve problems."

"And we got to see the big picture," added Anna Britzman, who plans to pursue a career in wildlife conservation. "We worked with so many experts, and it helped me see how important water quality is to restoring wildlife habitat."

—Diane Nelson

Professor Diane Beckles of the Department of Plant Sciences (center) interacts with students during a biotechnology lab class.

GREGORY URQUIAGA/UC Davis

FACULTY GROWS IN NUMBERS AND DIVERSITY

THE UC DAVIS COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES welcomes 25 new faculty members who reflect the college's multicultural student body and bring a wealth of knowledge in a broad range of fields.

"We value faculty who, regardless of their race and ethnicity, are committed to mentoring and educating students from the broadest cross section of their communities and countries," said College of Agricultural and Environmental Sciences Dean Helene Dillard. Additional recruitments for 2017 are underway.

Here is a quick look at our new recruits. Visit **caes.ucdavis.edu** and click on New Faculty Profiles to learn more.

BRIAN BAILEY

Assistant Professor
Department of Plant Sciences

Develops the next generation of plant and crop computer simulation models, which provide a realistic virtual environment in which to study plant communities

BARBARA BLANCO-ULATE

Assistant Professor
Department of Plant Sciences

Studies fruit biology and the regulation of ripening in order to improve fruit quality and reduce susceptibility to fungal pathogens

CATHERINE BRINKLEY

Assistant Professor
Department of Human Ecology

Examines the connections between farms and homes to inform policies that improve sustainable land use and equitable access to health

ANNA C. DENICOL

Assistant Professor
Department of Animal Science

Specializes in reproductive and developmental biology using cattle and other domestic species as models to improve female fertility, increase animal longevity, and enhance animal welfare

ERIN DICAPRIO

Assistant Cooperative Extension Specialist
Department of Food Science and Technology

Focuses on microbial food safety with an emphasis on foodborne viruses, which are the leading cause of foodborne diseases

IRWIN DONIS-GONZALES

Assistant Cooperative Extension Specialist
Department of Biological and Agricultural Engineering

Develops engineering–systems strategies to reduce energy consumption while ensuring the quality and safety of postharvest agricultural produce

REINA ENGLE-STONE

Assistant Professor
Department of Nutrition

Seeks solutions to different forms of malnutrition across the globe, focusing on micronutrient nutrition among women and young children in low-income settings

REBECCA HERNANDEZ

Assistant Professor
Department of Land, Air and Water Resources

Studies the ecology of arid landscapes—how they are affected by the changing climate and their potential for producing renewable solar energy

JENS HILSCHER

Associate Professor
Department of Agricultural and Resource Economics

Investigates the risks of corporate and sovereign default, the need to design governance structures that mitigate risk, and inefficiencies in financial markets

KRISTINA HORBACK

Assistant Professor
Department of Animal Science

Studies how personality traits develop within animals, how these traits are related to biological fitness, and whether they impact an animal's psychological well-being

ADELE IGEL
Assistant Professor
Department of Land, Air and Water Resources
Studies cloud physics, including how clouds form precipitation, interact with aerosol pollution, and impact weather and climate

DANIEL KARP
Assistant Professor
Department of Wildlife, Fish and Conservation Biology
Develops holistic management strategies to safeguard wildlife while maintaining robust agricultural production in order to harmonize farming and conservation

BWALYA LUNGU
Lecturer, Potential Security of Employment
Department of Food Science and Technology
Explores emerging technologies in food safety, as well as the use of technology for more effective teaching strategies in the lecture hall

GERARDO MACKENZIE
Assistant Professor
Department of Nutrition
Focuses on the role diet and other lifestyle factors play in cancer development and prevention

"We value faculty who, regardless of their race and ethnicity, are committed to mentoring and educating students from the broadest cross section of their communities and countries."

—Dean Helene Dillard

STEVEN SADRO
Assistant Professor
Department of Environmental Science and Policy
Examines how biological, physical, and chemical factors interact to regulate aquatic ecosystems

TINA SAITONE
Cooperative Extension Specialist and Lecturer
Department of Agricultural and Resource Economics
Specializes in economic and management issues for California livestock and rangeland, including prices and marketing strategies for cattle and sheep and sustainable grazing practices

ASHISH SHENOY
Assistant Professor
Department of Agricultural and Resource Economics
Studies development and labor economics, how workers use migration to increase their income and manage risks, and how those choices affect broader economic growth

BEN MONTPETIT

Assistant Professor
Department of Viticulture and Enology

Specializes in yeast biology and genetics, investigating how changes in gene expression impact cell function and how these changes impact wine fermentation and human health

FRANCES MOORE

Assistant Professor
Department of Environmental Science and Policy

Works to quantify how climate change will impact people and societies, particularly in regard to crop yields, food prices, and food security

L. ALLEN PETTEY

Lecturer, Potential Security of Employment
Department of Animal Science

Focuses on undergraduate curriculum development and assessment in animal sciences, livestock management and evaluation, and applied animal nutrition

ERIC POST

Professor
Department of Wildlife, Fish and Conservation Biology

Seeks to understand the ecological consequences of a changing climate in high-latitude regions such as the Arctic, as well as the impact on wildlife conservation

RAHEL SOLLMANN

Assistant Professor
Department of Wildlife, Fish and Conservation Biology

Develops and applies statistical models to examine how wildlife populations are affected by habitat, climate, and other factors such as the impact of humans

EDWARD SPANG

Assistant Professor
Department of Food Science and Technology

Focuses on character-izing and optimizing the efficiency of food, water, and energy systems across multiple scales, both geographic and temporal

JOHNNA SWARTZ

Assistant Professor
Department of Human Ecology

Studies how neurobiological and environmental factors influence the risk of anxiety and depression in adolescents in order to better treat and prevent these disorders

XIANG (CRYSTAL) YANG

Assistant Professor
Department of Animal Science

Investigates pre-and post-harvest management practices for livestock and poultry production, such as feeding systems and antimicrobial interventions, to enhance meat safety and quality

Scholarship Support

Alumna Destinee Cooper contributes to programs that helped her

DESTINEE COOPER ('04 ENVIRONMENTAL TOXICOLOGY) is paying it forward by paying it back.

As a youth, she knew she wanted to help others. Bright and ambitious, she had her sights set on college—the first in her family to dream that big. She applied to and was accepted at four UC campuses. She chose UC Davis.

"I knew I would be going through a huge transition because my family was moving to Montana," the Modesto native said. "Davis reminded me of home. It was a place I felt comfortable with, and I felt like I'd be supported. Right from the get-go, it was a good fit."

Her instincts were right. She discovered an interest in environmental toxicology and found department faculty and staff who readily offered their support—academically and through an especially challenging time. During her senior year, Destinee experienced fainting spells and feared she would have to drop out of college. Fortunately, that didn't happen.

"My doctors found something that was relatively minor," she said. "It was a huge relief."

"I never forgot the fact that I was helped in this manner."

Destinee worked hard at her studies and always held several jobs—as a math and chemistry tutor and as an undergraduate research assistant in a molecular biology lab studying yeast, a Superfund lab investigating arsenic, and for the Department of Viticulture and Enology working with grapes.

Destinee and her family did not have the resources to pay for her education at UC Davis. "Once I got in, I wondered, 'How am I going to finance this? How do I support myself through this process? Scholarships were the number one thing.'"

Destinee was the recipient of the Henry Jastro Scholarship and the Henry W. Seale Scholarship. These scholarships were established in the early years of the college by the families of California ranchers, Jastro and Seale, to support students. "Those programs not only supported my academic career, they also gave me the money to do research and to support me financially."

A Native American of Crow descent, Destinee is now in a satisfying career helping Native American tribes in California and Arizona build the capacity to address environmental needs. And she is making regular contributions to the very scholarships that made her education possible.

"I never forgot the fact that I was helped in this manner," she said. "I can make the sacrifices to give back financially and to fulfill a promise I made when I signed my scholarship agreements. I had an awesome time at UC Davis, and I am definitely grateful for everything I was able to do while I was there. I want others to have the same opportunity."

—John Stumbos

Courtesy photo

ON TAP

The first Sierra Nevada Brewing Company Endowed Brewer will be Joe Williams (left) who brings considerable hands-on knowledge to the UC Davis brewing program, where he is a staff researcher. In addition to fulfilling his teaching and brewery management duties, Williams will be involved as a liaison to the brewing industry for UC Davis and a host for visitors to the campus brewery.

GREGORY URQUIAGA/UC Davis

Sierra Nevada Brewing owners establish endowment for UC Davis brewing program

IN LATE 2016, KEN GROSSMAN OF SIERRA NEVADA BREWING CO. and his wife, Katie Gonser, presented UC Davis with a $2 million gift to support our renowned brewing science program.

The gift establishes an endowment to fund a full-time staff brewing position in the Department of Food Science and Technology. The new Sierra Nevada Brewing Company Endowed Brewer position is dedicated to mentoring and managing students and teaching assistants, maintaining and operating the campus brewery and its equipment, and assisting in teaching brewing classes.

"This Endowed Brewer position allows us to provide outstanding practical brewing experiences for our students as we continue to align hands-on training with the best theoretical education," said Charlie Bamforth, the Anheuser-Busch Endowed Professor of Malting and Brewing Sciences. "Students don't get that combination in most other brewing programs."

Teaching and research in brewing science has been an integral part of UC Davis since 1958. Undergraduate and graduate programs provide students with a solid scientific grounding and afford opportunities to learn core brewing and business skills.

"My family and I have supported the brewing program at UC Davis for nearly two decades," said Grossman, Sierra Nevada's founder. "Charlie Bamforth is not only an expert in brewing science, technology, and engineering, but a frequent guest speaker at our brewery and a close, personal friend. The ideals that he and the rest of the staff instill in the students are the very same principles that have guided our success in craft brewing for the past 36 years."

Founded in 1980, Sierra Nevada Brewing Co. is one of America's premier brewing companies, highly regarded for using only the finest quality ingredients. The company is widely known for its brewhouse innovations and commitment to sustainability.

"Over the years, Ken has been incredibly good to UC Davis," said Bamforth, noting that Grossman generously shares his expertise in commercial brewing with students. For many years he lectured every quarter in the Introduction to Beer and Brewing course and often hosts Bamforth and his students for tours of the Sierra Nevada brewery in Chico.

"Our students have learned from Ken the true meaning of quality," Bamforth said. "Everything at Sierra Nevada speaks quality, from the brewing itself to the company's insistence on sustainable approaches to the process. Sierra Nevada is the ultimate in brewing excellence, and it is marvelous that Ken and Katie have demonstrated their commitment to UC Davis, where our mantra also is about doing things the right way."

—Patricia Bailey, UC Davis News and Media Relations

Mussel Dogs muscle in to protect California waterways

POPEYE LIKES TO PLAY hide-and-seek, and that is good news for aquatic environments, municipal water supplies, and people who enjoy California's lakes and reservoirs.

GREGORY URQUIAGA/UC Davis

Debi DeShon visits her alma mater with two of her dogs, Popeye and Shelby.

Popeye is a chocolate lab working with UC Davis alumna Debi DeShon ('87, agricultural science and management) to sniff out invasive quagga and zebra mussels that destroy any waterway they infest. DeShon and her "Mussel Dogs" contract with several lakes and reservoirs in California to inspect incoming boats to make sure no tiny, invasive mussels have hitchhiked a ride.

"Mussel Dogs have given us a significant technological breakthrough in the difficult fight against zebra and quagga mussels," said Scott Cameron, president of the national Reduce Risks from Invasive Species Coalition, which recently honored DeShon for her work. "They do it by tapping into one of the most sensitive detection instruments known to man, a dog's sense of smell."

Native to parts of Europe, quagga and zebra mussels wreak havoc in Western waterways, where they first appeared in 2007. They eat native species' food and create an environment that kills fish eggs and attracts toxic algae.

"The best detection dogs are ball crazy, because it's really just a huge game of hide-and-seek. "

Invasive-mussel inspections are not mandatory at most lakes and reservoirs in California. But more waterway managers are investing in preventative inspections because the Department of Motor Vehicles has made funding available, and the cost of coping with a mussel invasion is so high.

Humans can protect against mussels by taking about 20 minutes per boat to hose the hull with scalding, hot water. It takes dogs about two minutes to check for mussels.

"Popeye and our other Mussel Dogs—Noah, Nemo, Captain, and Sinbad—can inspect about 110 boats a day," DeShon said from her home outside Turlock.

DeShon trains dogs for a variety of missions, such as sniffing out a form of yeast in wineries that can taint the flavor of wine, detecting bed bugs, and providing companionship to veterans coping with post-traumatic stress disorder. She works with the Green Dog Rescue Project based in Windsor, California, where she helps dogs find their true calling in life.

"We got Nemo from someone who couldn't keep him anymore," DeShon said. "He was barking and driving the neighbors crazy. He was just bored."

The best detection dogs, DeShon said, are "ball crazy, because it's really just a huge game of hide-and-seek."

—Diane Nelson

GREGORY URQUIAGA/UC Davis

Cute Kid

Genetic engineering makes it possible to improve agriculture in ways that traditional breeding cannot. Animal science professors Jim Murray (above) and Elizabeth Maga have spent many years working on a line of genetically engineered dairy goats that produce higher levels of a protein called lysozyme in their milk. Lysozyme is an enzyme naturally found in human breast milk. The enzyme has antibacterial properties that help protect babies against diarrhea and promotes growth of a healthy gastrointestinal tract.

The researchers introduced the human gene into the goat genome to produce higher levels of lysozyme in goats' milk. The hope is that milk produced by these transgenic goats could one day be used to help prevent deadly diarrhea in weaned children of the developing world.

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We are working hard to address critical issues with food, water, energy, conservation, climate change, and human health to improve our quality of life and to support the needs of the public good.

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