grow

Wisconsin's Magazine for the Life Sciences • SUMMER 2019

food systems • health • bioenergy • environment • climate • communities

'APP'-RICULTURE

WITH FREE MOBILE APPS, FARMERS TAP INTO CALS EXPERTISE FROM THE FIELD

College of Agricultural & Life Sciences
UNIVERSITY OF WISCONSIN–MADISON

RESISTANT TOMATOES • NATURE'S EFFECT ON LEARNING • MOSQUITO-REPELLING MICROBES

Volume 12, Issue 3 • Summer 2019

grow

Wisconsin's Magazine for the Life Sciences

FEATURES

DEPARTMENTS

ON THE COVER: The Sporecaster app is displayed on a smartphone resting on a bed of treated soybean seeds at Mike Cerny's farm near Sharon, Wis., in May 2019.

Photo by Michael P. King

"WOULD YOU LIKE EXTRA MEALWORMS?"

This phrase was not out of place at a recent insect and beer pairing at Wisconsin Brewing Company, part of a slate of edible insect tastings, talks, and meals, collectively called "Swarm to Table," that was coordinated by the Departments of Entomology and Food Science. Insect foods, clockwise from far left, are grasshoppers (chapulines), Chirps Chips (made from cricket flour), crickets, and mealworm bread.

Photo by Michael P. King

Dean Kate VandenBosch

Major Modernization

"We're confident that, with the changes to come, our students and stakeholders will be much better served and primed for success."

Last fall, I outlined some of the key goals for the ongoing Organizational Redesign (**orgredesign.cals.wisc.edu**) of the college. At the time, the project was in its early stages, but now we're starting to make things happen.

As a reminder, our primary objective for this critical undertaking is to reconfigure CALS in a way that ensures a bright future for our college, the students we teach, and the people we serve through our research and outreach. A major part of the redesign includes modernizing some of our academic programs to better suit today's students and today's economy. We want to make our majors more broadly integrative in terms of academic fields and more closely tied to the grand, global challenges that our students want to face head-on. By doing so, we can more effectively prepare our students for postgraduation opportunities and grow our enrollment strategically.

We've taken some big steps in this direction. Our poultry major, for example, which had been experiencing very low enrollment (no students were enrolled in the most recent year), has officially closed. However, the option will remain — through summer courses and a partnership with the Midwest Poultry Consortium — for students to pursue a poultry emphasis in conjunction with a different major. Efforts like this allow us to focus on new, in-demand fields, such as global health.

In fact, eight of our departments, along with the UW Global Health Institute, are developing a new global health major to be housed in CALS. The existing global health certificate, which is administered by CALS, debuted in 2011. About 500 students are currently enrolled, which comes as no surprise given how fast jobs related to public health are projected to grow in the coming years.

A global health major will allow our students to dig deeper into the many ways that environmental disruption and social disparities affect human well-being. Students will also gain the necessary quantitative skills and social sciences training to become the future solvers of these problems.

Our college is also undergoing changes beyond academic offerings. The dairy and animal sciences faculty voted in January to develop a proposal for a departmental merger. This move makes good sense for a variety of reasons.

First, the two departments share the goal of advancing livestock-related sciences. They are committed to discovering new ways to improve production and enhance animal (and human) health and well-being. Given their joint mission, the two departments already share some staff and co-teach numerous courses, but a merger would pave the way for more intentional collaboration and planning.

As a single entity, the merged departments could pool resources in developing a critical mass of faculty and staff in key disciplines — genetics, nutrition, meats, physiology — and new fields, such as data science and animal welfare. This helps ensure students and other stakeholders have access to the expertise they need and expect.

Rest assured, whatever changes this merger brings, CALS will maintain its strength in dairy research while supporting excellence in emerging areas, such as biomedical applications from animal byproducts.

I will keep you apprised here of new developments in our Organizational Redesign. We're confident that, with the changes to come, our students and stakeholders will be much better served and primed for success.

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Five things everyone should know about . . .

A2 Milk

By Don Otter and Shelby Anderson

1. **A2 milk comes from cows with a natural genetic variation that gives their milk a slightly different protein ratio than conventional milk.** All milk contains proteins, including whey and casein, and about 80% of the proteins in cow's milk are caseins. There are four types of caseins (αs1, αs2, β, and κ), and each type has different genetic versions. The β-casein protein has two principal genetic variations — A1 β-casein and A2 β-casein — which differ in their structures by a single amino acid. Conventional milk contains a mixture of both genetic variants, while A2 milk comes from cows genetically selected to produce only A2 β-casein.

2. **All cows produce at least some A2 β-casein, but certain breeds have predominantly A2 in their milk.** This includes the Guernsey, Jersey, Charolais, and Limousin breeds. Other animals, such as sheep, goats, buffalo, camels, donkeys, and yaks, also produce milk that mostly contains A2 β-casein. Holstein, Friesian, Ayrshire, and British Shorthorn cows produce milk with roughly equal amounts of A1 and A2 β-casein.

3. **All milk contains an amino acid sequence known as β-casomorphin-7 (BCM-7), which has been implicated in a number of negative health outcomes.** However, digestive enzymes in the small intestine find it harder to derive BCM-7 from the A2 β-casein protein. In other words, drinkers of conventional cow's milk will be exposed to more BCM-7 than drinkers of A2 milk. To suggest that their product is a healthier choice, some A2 milk companies claim that BCM-7 can worsen gastrointestinal motility, absorption, secretion, and immune function in humans.

4. **There is a general lack of definitive human trials that support the various health claims made for A2 milk.** Suppliers of A2 milk products mention that people who experience discomfort when drinking conventional cow's milk may be able to drink A2 milk "without the downsides." However, the existing scientific evidence is inconclusive. Meanwhile, researchers continue to investigate the effects of A2 milk.

5. **"Designer milks" like A2 milk could be the beginning of something big for the dairy industry.** Health debate aside, these new products could be a source of renewed growth and differentiation. Through advanced breeding techniques and other new technologies, farmers could produce milks with express characteristics, such as fewer allergens and specific nutrient profiles. We are already seeing this trend with the rise of milk from grass-fed cows.

Illustration by Danielle Lamberson Philipp

Don Otter is an educational outreach specialist at the UW–Madison Center for Dairy Research (CDR). **Shelby Anderson** is the CDR's communications specialist. The CDR provides education, research, and technical assistance to the dairy industry. More at **cdr.wisc.edu**.

Microbial Repellent

In the fight against mosquitoes, bacteria may come to the rescue

Photo by Jeff Miller

A study from the Department of Entomology shows that a bacterial extract may serve as an effective mosquito repellent in smaller doses than common deterrents DEET and picaridin. Here, a mosquito feeds on the hand of entomology professor Susan Paskewitz during the collection of live specimens for unrelated field research.

When **Que Lan** passed away unexpectedly of complications from gastric cancer in 2014, the UW entomology professor left behind a promising research project. Her work suggested bacteria might offer a new and effective way to repel mosquitoes.

She had started out looking for bacterial compounds that could kill mosquitoes. Before her passing, Lan discovered that, although one particular bacterial extract was not lethal to mosquitoes, when it was put in their food, the insects refused to eat.

Lan's colleague, entomology professor **Susan Paskewitz**, helped secure additional funding to keep the study going and found a scientist, **Mayur Kajla**, interested in carrying the work forward. In January 2019, their findings were published in the journal *Science Advances*. Paskewitz and Kajla, an assistant scientist in the Department of Entomology at the time of publication, describe the first mosquito-repelling compounds to be derived from microbes.

"We didn't come at it thinking we would find a repellent," says Paskewitz, chair of the entomology department and director of the Midwest Center of Excellence for Vector-Borne Disease. "It was a bit of serendipity."

These compounds, purified from extracts from the bacterium *Xenorhabdus budapestensis,* appear to work at lower doses than repellents currently on the market, including DEET and picaridin. The study showed the compounds to be effective against *Aedes aegypti*, *Anopheles gambiae,* and *Culex pipiens* — mosquito species known to transmit diseases such as Zika, West Nile, malaria, and chikungunya, which afflict millions of people worldwide.

Whether these natural chemical compounds, called fabclavines, are suitable for human use remains to be determined. But the study opens up a new area of exploration in the search for insect-repelling and insect-killing compounds, Paskewitz says.

When Kajla joined the project, he designed a set of experiments to test the repellent potential of the bacterial extract and identify the compounds responsible. He modified a commercial mosquito feeding system to more closely mimic a mosquito feeding on a human. For instance, he selected a skin-like membrane to contain a special, red-dyed mosquito diet that simulates human or animal blood. He also tested a variety of cloth coverings to sit atop the membrane, which would be coated with the repellents being screened.

GROW ONLINE EXTRA: VIDEO

See how the bacterial extract affects feeding mosquitoes at grow.cals.wisc.edu/microbial-repellent.

Kajla coated the cloth with water, DEET, or picaridin and allowed mosquitoes to feed for 30 minutes before freezing them and counting the number that were fed (engorged with red liquid) or unfed. The mosquitoes did not feed when the cloth was coated in repellent.

He then tested purified extracts from the bacteria and, with assistance from UW–Madison co-author

Gregory Barrett-Wilt, director of mass spectrometry and proteomics at the UW Biotechnology Center, found that an extract dominated by two fabclavine molecules effectively deterred mosquitoes from feeding.

When compared for effectiveness against picaridin and DEET, which is found in more than 500 insect repellents registered with the U.S. Environmental Protection Agency, the bacterial extract was effective at doses eight times and three times lower than each, respectively.

"If you can use less of an active ingredient in a formulation, it may be less expensive," says Paskewitz, who, with Kajla, has filed for a patent related to this work through the Wisconsin Alumni Research Foundation (WARF).

The scientists are not quite sure how the bacterial extract deters mosquitoes from feeding, but the reason may be simply that it tastes bad.

Paskewitz and Kajla are now collaborating with colleagues at the UW–Madison School of Medicine and Public Health to test the safety of the compounds in human cell culture. Preliminary work suggests the presence of some toxicity, but the investigation continues.

"I am itching to put it on my hand and put it in a cage of mosquitoes, but I can't do it yet," says Paskewitz.

DEET is the most widely used insect repellent in the United States and has repeatedly been shown to be safe and effective, yet the public continues to express concern about its use, especially in young children. This is why some scientists continue to search for alternatives, Paskewitz says. Most research so far has looked to plants. But bacteria are common sources of antibiotics and other pharmaceuticals, and the species *Bacillus thuringiensis* is often used in agriculture to deter insects.

Kajla continues to explore the potential of the compounds extracted from *Xenorhabdus budapestensis* and says they may yet prove useful for other applications.

Paskewitz adds, "These compounds might end up being more effective against a wider array of biting arthropods. DEET works against ticks, but it's not as good as it is with mosquitoes. We will test the bacterial compounds against other kinds of biting insects and their relatives."

—Kelly April Tyrrell

This study was funded by the National Institutes of Health grant no. AI123719.

Awards and Honors

A NUTRITIONAL SCIENTIST TO WATCH

Citing her groundbreaking work on meeting the dietary needs of people living with the rare genetic disorder phenylketonuria, or PKU, *Brava Magazine* named nutritional sciences professor **Denise Ney** to its 2019 list of "Women to Watch." Ney was also selected as a fellow by the American Society of Nutrition, the highest honor the society bestows in recognition of contributions to the field.

NATIONAL ACADEMY INDUCTEES

April 2019 saw the election of two CALS faculty members to national academies. **Jo Handelsman** PhD'84, professor of plant pathology and director of the Wisconsin Institute for Discovery, was elected to the American Academy of Arts and Sciences, and genetics professor emeritus **William Engels** MS'76, PhD'78 was elected to the National Academy of Sciences.

STANDING IN THE HALL OF FAME

Six current and former CALS faculty and staff have recently become hall of famers. They are: the late **Mark Cook**, professor of animal sciences (Poultry Hall of Fame); **Scott Craven** MS'76, PhD'78, professor emeritus of forest and wildlife ecology (Wisconsin Conservation Hall of Fame); **Kathy Glass** PhD'02, associate director of the UW Food Research Institute (Wisconsin Meat Industry Hall of Fame); **Ray Guries**, professor emeritus of forest and wildlife ecology (Wisconsin Forestry Hall of Fame); **Keith Kelling** MS'72, PhD'74, professor emeritus of soil science (Wisconsin Potato and Vegetable Growers Association Hall of Fame); and **Anne Reynolds**, former executive director of the UW Center for Cooperatives (Cooperative Hall of Fame).

Number Crunching

265

THAT'S HOW MANY FARMERS MARKETS WISCONSIN HOSTED IN 2017, according to the Wisconsin Farmers Market Association. The state is part of a nationwide trend in farmers market growth. As of August 2018, there were 8,720 markets listed in the U.S. Department of Agriculture's directory, a more than 7% increase since 2013.

Photo by Bryce Richter

Off to a 'QuickStart'

Summer program helps CALS freshmen connect to college early, save on time and tuition

On a typical morning at Doorco Holsteins in Brussels, Wisconsin, **Austin Vandertie** BSx'22 would be helping his parents milk the 40-cow herd, feed calves, spread manure, or harvest crops on an expanse of land farmed by three generations of his family before him.

"On a small farm like this, you know every cow individually," Vandertie says. "In the local community, you know every person. You make a special connection to the land that not everyone else gets to make."

But now he's heading into his sophomore year at UW–Madison. His interest in agriculture guided his decision to temporarily step away from his role on the farm to pursue a bachelor's degree in dairy science at CALS.

Photos by Michael P. King

CALS QuickStart student Skyler Finucane poses for a portrait with her pet tarantula at her home in Algonquin, Ill., in August 2018. Finucane is interested in entomology.

With the hope of earning his degree on time and on budget, Vandertie enrolled in the inaugural class of QuickStart — a new "early start" program for incoming first-year students at CALS. Over the summer of 2018, after graduating from Southern Door High School, he says he "burned the midnight oil," balancing online coursework for QuickStart with his usual farm chores and duties as a volunteer firefighter with the Brussels-Union-Gardner Fire Department.

QuickStart gave Vandertie the opportunity to earn two credits before the official start of the fall semester, receive tailored academic and career planning, and participate in early networking opportunities to meet his classmates and faculty. The program is designed to help Vandertie and students like him make the most of his college experience and begin his career — quicker.

The online "Foundations" course guides students in examining their strengths, values, social identities, and academic and career interests. They also get a preview of advising, health, and academic resources on campus.

QuickStarters can also beat the move-in rush by getting into their residence halls early. That's when "Connect2Campus" begins. Students meet CALS researchers face-to-face in their laboratories, visit local businesses tied to agriculture and the life sciences, and learn to navigate the UW–Madison campus.

"Our QuickStart students are highly motivated, but many were nervous about what college would be like," says **Tanya Cutsforth**, CALS QuickStart program manager. "The eight-week online summer course allows them the flexibility to begin their college transition from home. When they arrive for the weeklong on-campus portion of our program, they immediately start making connections — not only with each other but with all of the people, programs, and places they learned about throughout the summer."

Feedback from the inaugural QuickStart class was overwhelmingly positive. In a survey conducted by CALS in the fall, 99% of students reported feeling connected to their peers and the CALS community, and 100% said they understand the advising resources available to them. Several landed on-campus research jobs thanks to the program.

The first QuickStart class in summer 2018 included 103 students, one-fifth of whom are first-generation college students. Forty QuickStarters, including Vandertie, received need-based scholarships to help cover program costs thanks to a $25,000 contribution from the Wisconsin Agricultural and Life Sciences Alumni Association (WALSAA). The summer 2019 class has expanded enrollment numbers, and a spring fundraising effort, Day of the Badger, garnered more than $50,000 for scholarships through donations from alumni and friends of the college and matching dollars from the CALS Board of Visitors and WALSAA.

Skyler Finucane BSx'22 of Algonquin, Illinois, also leveraged one of those scholarships for her own QuickStart experience last year.

CALS QuickStart student Austin Vandertie poses for a portrait at his family's dairy farm in Brussels, Wis., in August 2018.

Finucane is majoring in entomology. It's a topic near and dear to her heart: Back at home is her beloved pet tarantula, Dominick. She's never been afraid of insects or spiders, and the coolest thing she has ever seen is a dragonfly migration.

"My mom has told me stories about when I was a little kid," recalls Finucane, who is also pursuing certificates in environmental studies and global health. "There was this time I was playing out on the back deck, and I told [my mom] to come look at my new friend. I had a wasp on my finger."

A first-generation college student and the oldest of three children, Finucane chose QuickStart because she wants to shorten her time to degree and keep her costs down. After graduating from Dundee-Crown High School, she balanced a job at Marco's Pizza with QuickStart online coursework to earn her two credits before the start of the fall semester.

Finucane is excited to dive headfirst into science studies. She was a frequent participant in science fairs in middle school and high school, and two successful CALS alumni in her extended family inspired her college decision: her aunt **Jacquelyn Riley** BS'99, who has a bachelor's degree in biochemistry and master's degree in medical genetics, and her uncle **Aaron Mertens** BS'99, who has a bachelor's degree in genetics.

"It's just so cool to see what they were able to accomplish from going to Madison and all the opportunities they had," she says. "I just love the town. I love the school, and I like the Big Ten feel. I know there's so much research. You can't always get that at every college."

—Michael P. King

Read profiles of other QuickStart students or learn more about the program at **cals.wisc.edu/QuickStart**.

You can support QuickStart by making a gift at **supportuw.org/giveto/calsquickstart**.

The Nature Effect

Study finds rural upbringing, time spent outdoors in childhood are correlated with academic performance in science courses

If you excelled in your college science classes, chances are you spent much of your youth outside the city limits or exploring nature with grass stains on your knees and soil under your fingernails.

Childhood setting and exposure to nature are strong predictors of academic performance in environmental sciences courses, according to a recent study by soil science professor **Nick Balster**. And this finding, among others from the study published in *Environmental Education*, points toward ways to combat troubling trends in STEM fields at the college level and beyond.

Many estimates suggest that the U.S. will face a deficit of one million students in science, technology, engineering, and math — otherwise known as STEM fields — in the next decade. Meanwhile, according to the Science and Technology Policy Institute, fewer than 40% of students who enter a STEM discipline in higher education actually complete such a degree. Most switch to non-STEM majors following poor performance in introductory coursework.

"Those statistics continue to weigh heavily on me," says Balster, who, when he isn't in the classroom or studying the communications between plants and soil, is immersed in the scholarship of teaching and learning. "And many people are trying to understand the reasons behind these trends and how to reverse them. Because, at the other end, employers are hungry for STEM graduates."

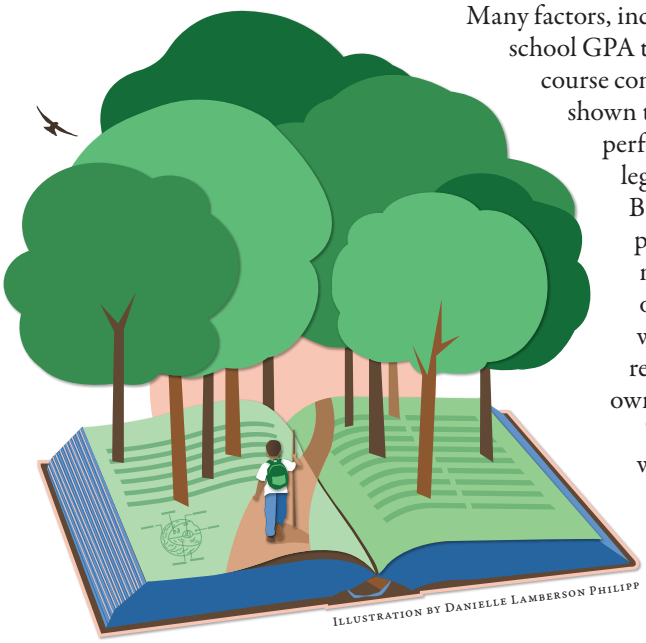


Illustration by Danielle Lamberson Philipp

Many factors, including high school GPA to interest in course content, have been shown to affect student performance in college STEM classes. But Balster suspected there's a bit more to it. Some of his thinking was guided by reflections on his own childhood.

"In fourth grade, we moved from a suburb of Chicago to rural Indiana," says Balster. "It was a mind-blowing experience in every respect because I went from a subdivision that was organized, largely predictable and comfortable — sidewalked blocks with friends only a bicycle ride away — to a hobby farm complete with acres of forests and wetlands to explore. I helped raise a large garden for the first time in my life and was thrust into the wonderful randomness of nature and dealing with things like weather as never before."

So the influence of this urban versus rural upbringing on students' interest and performance in his classes was at the top of Balster's mind. A reading of "Last Child in the Woods" took him further down that path. In this seminal work, Richard Louv introduces the term "nature deficit disorder" to describe the human costs of greater urbanization and immersion in technology.

Louv's ideas crystallized Balster's hunch that where students grow up (urban versus rural settings) and their level of interaction with nature can influence their interest and, therefore, academic achievement in science courses. He further hypothesized that these aspects would be especially relevant in environmental sciences classes, given their close ties to the course content.

With support from the National Science Foundation, Balster recruited **Melanie Spero** PhD'15, who served as lead author, and **Alex Bajcz,** his postdoc at the time, to test these hypotheses via an analysis of nearly 800 students in 11 introductory courses at a major research university. Spero, who was a doctoral student in microbiology at the time, joined the project as part of her internship with UW–Madison's Delta Program, which helps future faculty develop their skills in teaching, advising, and mentorship — a program Balster has engaged with for many years.

The assessed courses were distributed across several environmentally focused fields, including environmental studies, forest and wildlife ecology, botany, atmospheric and oceanic sciences, soil science, and agronomy. In addition to demographics such as academic rank and gender, students were asked about the communities where they grew up, their engagement with nature, and whether they thought their interactions had any bearing on their academics. Other questions delved into areas that might confound the results or suggest cognitive bias,

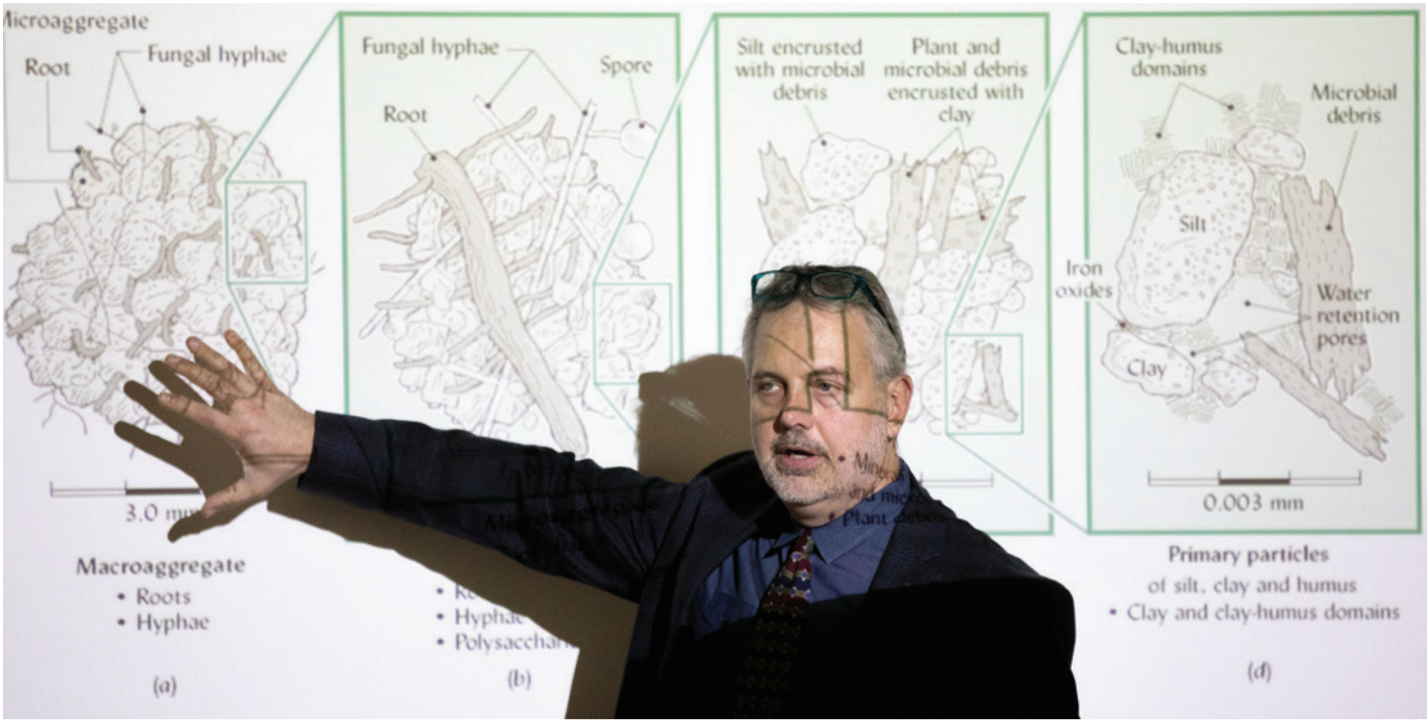


Photo by Michael P. King

Nick Balster, associate professor of soil science, teaches texture and structure in Soil Science 230, a required course in the environmental sciences major. Balster and others recently conducted a study that links childhood setting and exposure to nature with academic performance in environmental sciences courses.

such as career aspirations, level of interest in the course, and previous experience with course content.

The team correlated the students' coded answers with their final grades as an initial measure of "achievement" in the course. To minimize the effects of differing grade distributions and methods of instruction, grades were statistically standardized across courses relative to the median grade in each course. Following a multiple, mixed-effect regression analysis, a few factors stuck out as particularly pertinent to performance in these courses.

"Median-centered grades were significantly correlated with the residence type in which the students spent most of their childhood; a greater proportion of students who came from a more rural setting were earning higher grades, on average, than students who were coming from more urban settings," says Balster. "And students who spent more time interacting with nature before college were earning almost a letter and a half grade higher over the median."

For Balster and his coauthors, the findings highlight several ways teachers might boost performance in STEM courses. This includes promoting more substantive interaction with natural systems and more focus on building interest, taking cues from what appears to work in precollege settings.

"The latest research shows that these interactions are most effective when they're somewhat less formalized and rote," Balster says. "For example, when a child is allowed to explore, to follow their interests and directly interact with the content, when it's more based on authentic problem solving and less on being talked at — a learner-centered approach. This approach can also work in the college classroom; however, it can be a bit scary to implement and assess in that we have to give up a bit of control. And too often it's viewed as a destination and not a practice that changes with student backgrounds, interests, and innovations in teaching and learning, such as flipped classrooms and case-based instruction."

The study also indicates that level of interest in the course content plays a role in academic performance. Not surprisingly, students who reported greater interest did at least modestly better in the class. But perhaps even more revealing, those who reported being uninterested performed profoundly worse. One caveat regarding this finding, Balster says, is that separating the impact of interest from formative childhood experiences is difficult, as they likely build in tandem.

To help address the issue of interest, Balster points to several modifications that can be made to instruction at the college level. For example, departments could assign their most enthusiastic and innovative instructors to intro-level, or "gateway," courses, where studies show most students make the decision to abandon STEM. This might boost their interest and, by extension, their level of success at an earlier stage.

Balster also suggests that taking a "backward-designed learning outcomes approach" can help instructors reframe how they teach. This approach moves beyond broad content coverage to a learner-centered strategy that focuses on "scaffolding" the most enduring concepts.

Through the scaffolding process, Balster says, teachers move students progressively toward deeper understanding and independence in their learning by

Photos by Michael P. King (2)

Students manipulate samples of soil during a texturing exercise in the Soil Science 230 class of Nick Balster, associate professor of soil science (background center).

crafting instruction around successive levels of critical knowledge and skills. The teacher then removes this support, incrementally, to shift more responsibility for the learning to students so they can use the knowledge independently. This is one of many practices that fellows hone at Madison Teaching and Learning Excellence, a campus program Balster co-created in 2011 to support early-career faculty in developing research-based, engaging teaching practices that improve student learning.

"Most important, we need to think deeply about our introductory courses, and we need to focus on threshold concepts that encourage and challenge students to think differently within an authentic context that gets them excited to pursue science," Balster says. "And I believe this begins with a focus on the classroom environment, getting to know our students, being nimble enough to match their context with our instructional design, so we can meet them where they are at and choose the best thresholds to guide them across, rather than a mind-set of 'we're going to get through all of this material.' I don't remember who said it, but I have always loved the quote: 'Education is not just the filling of a pail but the lighting of a fire.'"

—Nik Hawkins

Photo by Robin O. Davies

ONLINE EXTRA

HELIUM CONSERVATION

A new helium recovery system is helping a high-tech spectroscopy facility reduce costs and preserve this scarce, nonrenewable resource. Read more at **grow.cals.wisc.edu/helium-conservation**.

classAct

Stephanie Hoff

'The Lands We Share' Exhibit Helps Bridge Rural-Urban Divide

Stephanie Hoff BSx'19 grew up in small towns near Thorp, Wisconsin, as part of a rural community where people have a pretty good understanding of how agriculture works. When she moved to Madison to go to college, that was no longer the case.

"In a place like Madison, there's a huge disconnect," says Hoff, who is majoring in life sciences communication with certificates in folklore and entrepreneurship. "People say weird things, like brown eggs are healthier for you than white eggs. And I'm just like, 'What? That's not true.' Egg color is only related to the breed of the hen, not nutrition.'"

Hoff had been an active FFA member growing up, and she internalized the organization's mission to help educate people about agriculture. The misunderstandings she has witnessed in urban Madison have deepened her commitment.

So it felt like she'd landed the perfect student job when she joined the Wisconsin Farms Oral History Project during her freshman year and had the opportunity to help with the project's exhibit called "The Lands We Share." The exhibit tells the story of five distinct types of farms (and farmers) from across the state — including a traditional German-heritage dairy, a Hmong-owned organic produce operation, and an urban farm in Milwaukee — through audio interviews, photos, and articles.

The exhibit toured the state from fall 2018 through spring 2019, with each site hosting a dinner and guided discussion for the local community. These gatherings were Hoff's favorite part of the project, and she attended all of them.

"We asked very open-ended questions [at the gatherings], like what is sustainability to you? Or what is a family farm? And then people discussed it," says Hoff. "It was really cool to see the community members interact and talk with each other. They were from different backgrounds — people who live on farms, people from the town or the city — and it was fascinating to get to listen to the conversations."

Photo by Michael P. King

Stephanie Hoff, a life sciences communication major, is pictured here with "The Lands We Share" exhibit at the village hall in Johnson Creek, Wis., in January 2019.

Hoff was the project's social media coordinator, so her main role was to help promote the exhibit through Twitter, Instagram, and Facebook. She took photos and recorded video at the community gatherings and livestreamed parts of the events via Facebook Live. In the office, she also helped with newsletters, emails, press releases, and reaching out to reporters. All of these tasks took significant coordination because the project was a collaboration of four UW System schools: Madison, Milwaukee, Oshkosh, and Whitewater.

"Stephanie was a natural to work on the [project]," says **Troy Reeves**, head of the oral history program at UW–Madison Archives. "Over the last two and a half years, her contributions have been invaluable. She has done everything we have asked of her — without hesitation and always with a smile."

The job provided an opportunity for Hoff to develop a wide variety of professional skills while devoting her time to something she deeply cares about. And although the exhibit tour concluded in May 2019, she continues to work supporting the Wisconsin Farms Oral History Project.

"I love that the exhibit involved bringing the community together to talk about issues related to food and farming," says Hoff, who plans to graduate in December 2019. "I feel like the project was so much a part of my college career that it's a part of me."

—Nicole Miller MS'06

Learn more about the Wisconsin Farms Oral History Project's "The Lands We Share" exhibit at **landsweshare.org**.

PERU

New Potato Helps Farmers Weather the Frost

In a country with more than 5,000 potato varieties, you might not expect the arrival of another one to be a big deal. But this is Peru, where the potato was first domesticated and still plays a vital role in national identity.

In Spanish you might call it *patrimonio* or *orgullo*; in English it translates to national pride or honor. However it's phrased, for the people of Peru, the concept is forever entwined with the potato, a totemic symbol of the indigenous cultures and heritage of their country and the surrounding Andes.

Now, a trio of CALS scientists has helped extend this rich tradition by introducing a new, frost-resistant variety that can help Peruvian potato farmers contend with difficult growing conditions caused by a changing climate. It's the latest outcome of a decades-long collaboration with Peruvian researchers that is still going strong.

The three UW scientists — **John Bamberg**, **Alfonso Del Rio**, and **Jiwan Palta** — worked closely with researchers from Peru's International Potato Center (CIP) and the Instituto Nacional de Innovación Agraria (INIA), and with Peruvian farmers, to develop the new variety, called Wiñay. The word means "to grow" in Quechua, one of Peru's indigenous languages. The frost-resistant potato is long and thin with brown skin and yellow flesh and is grown for the fresh market. It was developed to be cultivated in Peru's Altiplano at elevations of up to 14,000 feet above sea level.

"Research by definition means you search again and again, and sometimes you hit a winner, and in this case, we have one."

Palta, a professor of horticulture and plant physiologist with the Plant Breeding and Plant Genetics program, says many of the wild potato varieties found in the Altiplano are naturally hardy and can tolerate temperatures down to 14 degrees F. However, these potatoes are small and have a bitter taste due to high levels of chemical compounds called glycoalkaloids.

The need for a hardier, frost-resistant potato in Peru's highlands stems, in part, from climate change, according to both Palta and del Rio, a senior scientist in charge of the U.S. Potato Genebank research lab at UW. They say more frequent late-season killing frosts are causing greater yield losses for Peru's farmers.

But developing a new potato variety to withstand such conditions is a time-consuming project, one that typically spans 10 to 15 years. The devil can be in the genetic details when crossing potato varieties to develop a new one. And an effective frost-resistant potato also needs good commercial qualities, including appropriate size, yield, and taste, and must be suitable for the growing conditions of the Altiplano.

Bamberg, director of the USDA Agricultural Research Service's U.S. Potato Genebank in Sturgeon Bay, Wisconsin, and a professor of horticulture, compares the process to looking for a needle in a haystack.

"Sorting out the offspring, you get just a bewildering number of possibilities to select from," says Bamberg. "Breeders put out thousands and thousands of progeny and select from them over decades to find that one better one."

The project began in 2005 using progeny of a Wisconsin potato clone that had good frost tolerance, yield, tuber size, and eating quality. The clone carried the genes for frost hardiness from a wild potato species called *Solanum commersonii*. The progeny of this clone was selected in Wisconsin, but, when tested in frost-prone areas of the Peruvian high-

Center: A basket of Wiñay potatoes serves as the centerpiece at the main table of a ceremony to introduce the new potato variety in Puno, Peru.

Jiwan Palta reviews data from field trials during the May 2018 harvest at the Instituto Nacional de Innovación Agraria experimental station in Puno, Peru.

Three women harvest Wiñay potatoes from trial plots at the Instituto Nacional de Innovación Agraria experimental station in Puno, Peru.

Photos by William Schaefer

lands, it didn't perform well because the Peruvian summer days are shorter than the Midwest's.

"So Jiwan, John, and I discussed using some of the Peruvian potatoes we have in the collection at Sturgeon Bay," del Rio says.

They chose seven Peruvian varieties. After cross-breeding with the Wisconsin frost-hardy clone, they sent about 20,000 seed potatoes to Peru for field trials at the INIA experimental station in the southern city of Puno. With each passing year, they evaluated new progeny for the preferred qualities and traits and narrowed the pool until arriving at the one potato that came to be Wiñay.

After 10 years of field trials, the culling process, the final variety selection, and the naming of the potato, there came a time to celebrate. In November 2018, near the shoreline of Lake Titicaca in Puno, del Rio, Palta, and Palta's wife, Mari, participated in the public introduction of the Wiñay potato.

More than 200 students, farmers, producers, scientists, and industry and government officials attended the four-hour fete, which concluded with the distribution of Wiñay potatoes in brown paper bags. Both Palta and del Rio found the ceremony to be an enjoyable opportunity to recognize everyone's hard work.

"It's always heartening to see the end result of your labor," says Palta. "Research by definition means you search again and again, and sometimes you hit a winner, and in this case, we have one. Scientists [in Peru] have evaluated it and feel good about it."

Following the celebration, a jovial **Jesús Arcos Pineda**, senior potato researcher at INIA, says he is looking forward to more cooperation and interaction with the CALS research team. Pineda is one of the CALS research team's closest collaborators, along with **Rene Gomez**, senior curator at CIP's gene bank.

In addition to the practical side of the potato ceremony, del Rio says there is a spiritual gratitude for the potato's role in Peruvian villages. "The farmers receiving the potatoes, they appreciate whatever comes from Mother Earth, and potatoes have been such an important part in the life of these communities that they appreciate it very much."

—William Schaefer

The Inner Workings of Microbial Metabolism

Daniel Amador-Noguez is uncovering the secrets of metabolism at a molecular level to the benefit of both biofuels and human health

Interview by Mark Griffin

DANIEL AMADOR-NOGUEZ is learning how living organisms transform nutrients into energy and other useful chemicals. Among a cadre of scientists looking at the biological underpinnings of metabolism, Amador-Noguez knows firsthand the links between the fuel that makes our bodies go and the biofuels that propel our machines. Because he studies both.

When it comes to metabolism, though, there are a lot of unanswered questions. Why are some organisms capable of rapidly breaking down nutrients while others take longer? Why can some creatures consume just about anything, and others have to eat baked chicken every night or their GI tract revolts? And how do we draw maps of the way all this stuff works?

Getting to the bottom of these mysteries could help Amador-Noguez, an assistant professor of bacteriology, improve biofuels, inform us about our guts' determinations of what's friend or foe, and even provide the basic science to individualize medical treatments based on a person's own microbiome.

Amador-Noguez focuses on the series of chemical reactions that occur when tiny living things digest, otherwise known as microbial metabolic networks. He's trying to figure out how to make microbes metabolize differently than the way they're programmed.

Specifically, as a researcher with the Department of Energy (DOE)-funded Great Lakes Bioenergy Research Center (GLBRC), Amador-Noguez is tasked with convincing a broad swath of microbes to metabolize often difficult-to-swallow parts of plants in a way that transforms them into fuels and high-value bioproducts. We spoke to him about the passion behind his vocation and how studying biofuels and the gut microbiome might not be all that different.


Daniel Amador-Noguez

Photo by Michael P. King

WHY STUDY METABOLISM IN BACTERIA?

It's a lot faster than studying metabolism in mice, which is what I used to work with. You can do genetic manipulations much faster, so you can really get at the molecular mechanisms of how metabolism and different parts of the cell are working. Bacteria are a really good system for rapidly testing specific hypotheses and finding answers fast.

Bacteria play such a huge role in human metabolism, too. Not only do they transform the things that we eat into something else, bacteria can also chemically alter the molecules that we make ourselves. This can have a big effect on human physiology because these microbes can potentially modify the hormones or signaling molecules within our bodies that give our cells instructions on how to operate.

THE GLBRC HAS MANY DIFFERENT GOALS ABOUT IMPROVING BIOFUEL AND BIOPRODUCT PRODUCTION. HOW DOES BEING PART OF THIS MISSION BENEFIT YOUR WORK AS A CALS PROFESSOR?

GLBRC has been great for many reasons. We are all working toward a common goal — generating the basic knowledge that we need to be able to efficiently convert plant biomass into biofuels or other high-value chemicals. That's a cohesive goal.

Being part of GLBRC accelerates my research and the amount of progress that I can make because, if I'm trying to solve a particular problem, I don't have to be an expert in every single aspect of it.

For example, in my lab, we are experts at understanding

and investigating regulation of bacterial metabolism using mass spectrometry. We are not plant biologists or enzymologists, but other people on campus and in GLBRC are. And because we don't have to learn how to do that, the research goes a lot faster.

That's part of the reason why the DOE is funding these bioenergy research centers. They realize there's a lot of synergy that takes place when you have a large group of investigators working together toward a common goal.

WITH SUCH A BASIC PROCESS LIKE METABOLISM, HOW DO YOU KNOW WHAT TO STUDY?

We are trying to generate a holistic understanding of how bacterial metabolism is regulated. What that means is that we are not trying to understand just how a single enzyme is regulated. We are trying to understand how complete pathways and metabolic networks work.

In the case of GLBRC, we care about the products, which to the microbe are waste but to us are the biofuels that we are trying to produce.

We have also been developing new tools to increase the number of metabolites — molecules that serve various functions in the process — that we can measure within the cell while broadening our understanding of why metabolism happens at certain rates in the cell.

We apply state-of-the art tools to study microbes that have not been examined before. We know a lot about model organisms, such as *E. coli,* but the microbes that are actually going to be useful for biofuel production could be some other lesser-known microbes that have much better properties for this purpose.

Zymomonas mobilis [a focus of GLBRC research] is a really good example of that. It's extremely fast at converting glucose into ethanol and is also highly resistant to the environmental stressors that are normally present in biomass-derived sugars. Acquiring a deeper understanding of *Zymomonas* metabolism will allow us to engineer its metabolism for improved production of biofuels and other high-value chemicals as well as improve our ability to transfer its more desirable properties to other fuel-producing microbes down the road.

SO HOW DO YOU FIGURE OUT HOW TO MAKE THESE PATHWAYS WORK FASTER?

One way we can potentially improve the production capabilities of a biofuel-producing pathway is by improving the thermodynamics of that pathway. Thermodynamic analysis, a powerful tool for pathway design and metabolic engineering, can help us understand how energy is transferred and transformed within these networks.

Within a particular pathway there can be what we call "thermodynamic bottlenecks." Changes in free energy across the pathway may not be distributed uniformly. There can be big drop after big drop when things are going the way we want them to, but then there may be a very flat part, where things go slow, slow, slow.

LIKE A WATER SLIDE?

Yes, exactly. The steeper the slope, the faster it's going to go. And if the slope is kind of flat, then things are going to move a lot slower. In our laboratory, to measure changes in free energy at each step in a metabolic pathway, we combine mass spectrometry; nonradioactive isotope tracers, which work like different colored paints added to a flowing river, allowing us to determine how fast a particular pathway or reaction is operating; and computational modeling. In other words, these approaches help us measure the slope along the way. That way, we can identify those flat parts and learn how we can modify and make them steeper or, for our purposes, faster.

SPEAKING OF SLOPE, IT SEEMS LIKE A LOT OF THIS RESEARCH IS BEING DONE ON A STEEP LEARNING CURVE.

All these types of studies used to be incredibly tedious. It was a very slow process, and you had to go step by step, analyze metabolite by metabolite. Through the use of mass spectrometry equipment provided by CALS and GLBRC, we can potentially analyze hundreds of metabolites within the cell at once. With tracers and modeling, we can measure the activity of entire pathways and even metabolic networks.

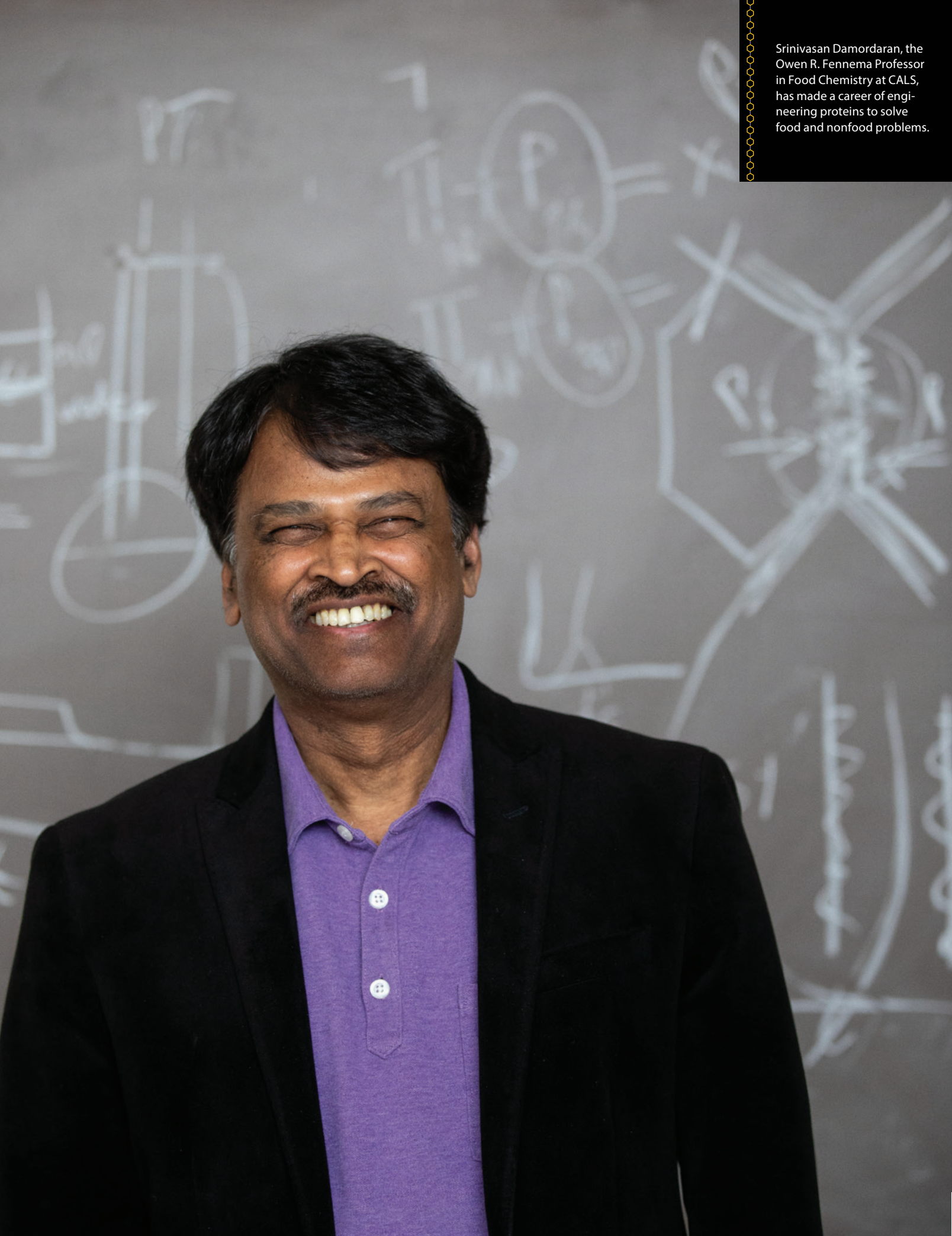
YOU ALSO STUDY THE HUMAN GUT MICROBIOME — HOW MICROBES HELP US DIGEST THINGS. WHAT'S THE DIFFERENCE BETWEEN STUDYING WHAT HAPPENS WHEN I EAT A CHEESEBURGER AND YOUR RESEARCH INTO BIOFUELS?

Actually, it's fundamentally the same. When you eat a cheeseburger, you are essentially using the same metabolic pathways that the bacteria is using. The glycolytic pathway, which converts sugar into energy and biosynthetic precursors that we can, in turn, convert into fuels and bioproducts, for example, is essentially identical in *E. coli* and in human cells. So whatever we can learn about the regulation of this pathway in bacteria can potentially be applied to human systems, too.

GROW ONLINE EXTRA: VIDEO

For an inside look at the lab and research of Daniel Amador-Noguez, visit grow.cals.wisc.edu/microbial-metabolism.

I'm very curious as to how things work, but I'm also very curious as to how we can make them work for ourselves. Microbes can be used as factories for the production of almost any imaginable compound, whether its biofuels, high-value chemicals, or pharmaceuticals. The goal of my laboratory is to generate the fundamental knowledge required to be able to do this quickly and efficiently. The understanding of bacterial metabolism requires a tinkering type of approach about how different pieces of cellular machinery fit together — that makes me keep asking, "How can we make something useful out of this knowledge?"



Srinivasan Damordaran, the Owen R. Fennema Professor in Food Chemistry at CALS, has made a career of engineering proteins to solve food and nonfood problems.

Food chemist Srinivasan Damodaran has lent his expertise to innovations in food and nonfood products alike

The Protein Professor

BY DAVID TENENBAUM ● PHOTOS BY MICHAEL P. KING

Srinivasan Damodaran came to the United States in 1976 from South India, where the green revolution was fueling an explosion of wheat and rice production — a welcome development in a country with a long history of hunger problems. He will never forget the long food lines of his childhood in the 60s and 70s.

"You could not buy rice in the markets, or the price was exorbitant," says Damodaran, now the Owen R. Fennema Professor in Food Chemistry at CALS. "I'd go to the public distribution system in the morning and stand and wait my turn. They would give out only five kilograms of rice at a time. This left an impression."

India was chronically short of food during much of the 20th century. Outright famines were headline material in neighboring Bangladesh in 1972–73 and later in West Africa, Ethiopia, and Sudan, among many other nations.

Although India was becoming self-sufficient in food production with the help of superior seeds, fertilizer, and pesticides, Damodaran still felt there was plenty he could do to help. He decided to enter a Ph.D. program in food chemistry at Cornell University. To introduce himself, he wrote a long proposal for easing malnutrition by growing yeast for protein.

After Cornell, he came to UW–Madison to join the Department of Food Science. "This is my first job," he says. "I came here in 1984 and stayed forever."

Among his four siblings, Damodaran says he is "the loner" who came to the United States. "They asked why I was going, and I said there was no scope to do the kind of research I wanted in India." Every couple of years, he returns to his home country and marvels that it now exports rice. He's also astonished by its ongoing "white revolution" — a surge in dairy production that is part of a broad range of technological progress in the world's largest and most astonishingly diverse democracy.

Quick to smile and unhurried in conversation, Damodaran (who usually goes by Damo) is married to Meera, an architect recently retired from UW–Madison's Division of Facilities Planning and Management. The couple have two daughters, both physicians. For entertainment, he says, "I like to do handyman jobs. Building out the basement, all sorts of work — electrical, plumbing, everything but drywall. Fixing things is my real hobby."

Suitably, Damodaran has made his name in fixing proteins. If you have a protein that needs a bit of engineering, he just may be your man. His various inventions include a process for the efficient removal of phospholipids (the chemicals that oxidize into an off-flavor in soy foods) and plant-based superabsorbents for industrial cleanups and diapers. He has also patented a technique (along with fellow food science professor **John Lucey** and research associate **Dani Zhu**) for making protein-polysaccharide complexes that allow all the protein to stay absorbed in solution — a surprisingly difficult task.

According to Lucey, Damodaran's productivity rests on "an amazing depth to his understanding of the basic nature of the interactions that govern protein structures, and he has combined that ability with an intellectual curiosity that allows him to derive innovative approaches to test these ideas.

"He is considered one of the world's leading food chemists," Lucey continues. "He is versatile and can apply his basic skills to a wide range of topics, which has allowed him to move into different areas over the course of his long career."

He is considered one of the world's leading food chemists. He is versatile and can apply his basic skills to a wide range of topics, which has allowed him to move into different areas over the course of his long career."

Damodaran's skills prove invaluable in the study of proteins because, as Lucey explains, they are a vitally important component in most foods and also highly varied. "They impact the nutrition and texture of many food products, such as yogurt, meat, bread, and cheese," Lucey says. "Knowledge of the chemistry of the amino acids and how they interact to create protein structures are the keys to unlocking the complex behavior of protein in food products."

MILKING MILK'S POTENTIAL

Proteins can cause trouble, too. They're one of the components that make milk such a desirable food, but they can also spark allergies in up to 5% of children ages 6 months to 5 years. The bad news can arrive when the first bottle of cow's milk triggers symptoms ranging from a skin rash to life-threatening shock. Infant formula manufacturers have countered the threat by taking milk protein apart through a process known as hydrolysis. This leaves a bitter concoction of isolated amino acids — the building blocks of proteins — whose taste must be masked with sugars and flavoring.

In 2018, Damodaran disclosed his solution to milk allergy (not to be confused with lactose intolerance) to the Wisconsin Alumni Research Foundation (WARF). He avoids the conventional practice — dicing the long strings of amino acids — and instead cuts them into medium-size pieces using an enzyme. He then cross-links them back into a large polymer. This neopolymer is not recognized by the immune system, so it does not trigger an allergic reaction.

The disassembly relies on an enzyme used to make the artificial sweetener aspartame, and reassembly is done by an enzyme used in making surimi, a crab meat substitute made from minced fish. Based on these products' long record of use, Damodaran's neopolymer can be labeled "generally recognized as safe," or "GRAS." GRAS is a Holy Grail for food and industrial products because products with this classification are assumed to be nontoxic without expensive testing.

Milk protein contains every amino acid that people need, and Damodaran's engineered proteins, just like regular milk protein, are broken down in the small intestine into individual amino acids. After these amino acids move through the bloodstream and into cells, they combine to build human proteins.

That's classic food science and technology — taking something good and making it better, Damodaran says. The same process can also defuse soy protein allergies.

'GREEN' GLUE

Damodaran's expertise on soy protein led him beyond edible territory when, in 2016, he received a request to help develop a replacement for the urea formaldehyde glues that bond plywood, particle board, cabinets, and furniture. Over the years, the multiple health impacts of airborne formaldehyde prompted first California, and then the U.S. Environmental Protection Agency, to restrict this widely used adhesive.

The formaldehyde glues are cheap and effective, so the restrictions naturally increased the demand for an affordable replacement that is just as good at bonding wood sheets and fragments — but without toxic "off-gassing." The U.S. Forest Products Laboratory in Madison was interested in improving existing soy-based adhesives that, although strong, were not as strong as their formaldehyde counterparts and failed after absorbing moisture from the air.

To meet California's standards and improve the glue's environmental

The plies in these two samples of laminated wood are held together by a nontoxic, soy-based glue that food science professor Srinivasan Damodaran and research associate Dani Zhu designed as a replacement for urea formaldehyde glues. On the right, separated plies show how an earlier iteration of the glue failed over time.

profile, Damodaran chose to avoid petrochemicals, focusing instead on inorganic chemistry. He settled on a chemical process called phosphorylation, which improves attachment to the cellulose in wood. "The solution was almost too easy," Damodaran says. "It took us two or three months to demonstrate, though the optimization took much longer."

The patented, soy-based "green glue" has now been licensed by California-based Specialty Organics, Inc.

Photo courtesy of Specialty Organics, Inc.

In 2016, Damodaran and Zhu were awarded a WARF patent for a soy-based glue that has now been licensed by California-based Specialty Organics, Inc., as part of an effort to commercialize a new soy protein–based adhesive. According to vice president and chemical engineer **James Seruto**, the company is working to obtain manufacturing approval from the EPA, and he expects to start sampling the "green" adhesive with the copyrighted name BreezeBond to wood panel manufacturers this year.

PROTEIN MATRIMONY

To Damodaran, green glue is good, but it's a detour from his passion: sculpting proteins for human consumption. His memories from growing up in a hungry country feed directly into his latest — and likely last —project in his Babcock Hall lab. He's attempting to "marry" proteins to each other, or to various food polymers, to create new food ingredients and take advantage of the vast wealth of plant protein in soybeans.

One promising approach is tying soy protein to milk protein, which can be whipped into appealing, frothy confections — think whipped cream, eggnog, or ice cream. Someday — and there has already been progress in this regard — he hopes to make hybrid proteins that bring the best of both worlds.

In these efforts, Damodaran is aided by postdoctoral researcher **Nilushni Sivapragasm**. She is working on a USDA-funded project to develop new protein combinations for beverages. The research, she says, is the perfect preparation for her plan to pursue a career in food industry research and development. And Damodaran is just the kind of mentor she was looking for.

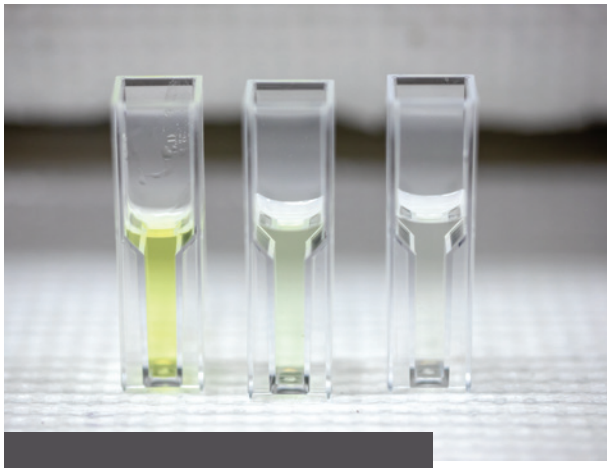
"I used a book he co-authored as my Bible for my master's thesis," Sivapragasm says. "And I've always wanted to work with the writers."

Damodaran says his and Sivapragasm's attempt to improve what scientists call the "function" of protein rests on how molecular structure affects taste, cooking, and storage. "Structure and function — that's always been my career," he says.

"Soy is very cheap," he adds, "and we're aiming at new ingredients that will be less expensive than milk protein. If we succeed, it will open a lot of possibilities for using improved plant proteins safely."

A second possibility is bonding non-milk protein molecules to soy protein. "If you give a poor man, even if he's very hungry, soy protein powder, he is not going to eat it, even though we know that it's good enough for survival," Damodaran says. "But we all want tasty, appealing food, and one of the simplest, most effective tactics is to attach molecules, like polysaccharides or hydrocolloids, to soy protein to transform it to a better protein ingredient."

It's a difficult puzzle, but one that Damodaran is poised to solve, according to his former graduate



Different concentrations of protein-based conjugates are prepared before they are measured in a UV-visible spectrophotometer as part of food science professor Srinivasan Damodaran's ongoing USDA-funded research related to protein-based beverages.

student, **Akshay Arora** PhD'08. "Dr. Damodaran was working on proteins long before they became popular in the mainstream," says Arora, who leads the development of plant protein ingredients and technologies at Igredion, a New Jersey–based ingredient manufacturer. "What distinguishes him as a researcher in this field is his ability to think deeply and connect the dots from fundamental sciences to solve complex problems. His research has shed light on how proteins behave and how this knowledge can be harnessed in food and biological systems."

As a food chemist, Damodaran sees his job as framing the building and inviting others in to install the plumbing, wiring, and countertops. "If you demonstrate something, get the proof of principle, then you can move on," he says. "With soy glue, for example, I wanted to demonstrate a chemistry with very desirable functions and walk away. Others can apply it to various proteins from different sources, based on this particular technique. But at that point, when it becomes mundane, I've done my job."

'APP'-RICULTURE

CALS experts develop mobile apps to bring science to farmers anytime, anywhere

BY JIM MASSEY

Mike Cerny has been farming long enough to have a reliable intuition when it comes to decisions about applying chemical protection to his crops.

So it came as a surprise to the Wisconsin farmer when he downloaded a smartphone app — developed by UW–Madison field crops pathologist **Damon Smith** — and it told him he should hold off on spraying a fungicide to prevent an infestation of white mold on his soybean plants.

"I thought the conditions were favorable for the development of white mold," Cerny says of the disease that can drastically reduce soybean yields. "But when I looked at Damon's Sporecaster app, it said there was no need to spray. By not applying, it saved me more than $10,000."

Smith is one of a growing number of experts at CALS who are developing mobile apps as a way to get applied research into the hands of farmers quickly and efficiently — and in an easy-to-use form. An app (short for software application) is a computer program, accessible through a smartphone or other mobile device, that is designed to perform a specific function for the user. With a few clicks of a button, certain apps can help farmers determine whether they should replant a crop, calculate how much fertilizer they should use, or decide if they should change what they are feeding their cows.

Sporecaster in particular helps farmers determine if and when they should apply fungicide during their soybean crop's flowering stage — when it's most susceptible to an influx of white mold fungus spores. The program accesses GPS weather data, does some mathematical analysis, and spits out a probability of risk for infection by the white mold fungus that day.

"It helps farmers determine the best time to apply [fungicide] based on the highest risk," says Smith, an associate professor in the Department of Plant Pathology. "It has saved folks some money. During the 2018 season, we had about 250 active users a day."

Apps have been developed in several UW–Madison departments to help disseminate new knowledge beyond campus borders. While CALS researchers continue to publish their research in peer-reviewed journals, present findings at conferences, and share results with the public in many ways, they have come to the logical conclusion that sometimes the best way to get information to users is through mobile devices.

"If [the apps] are handy and useful, they spread like wildfire, and everybody uses them," says **Eric Birschbach**, a crop consultant with Ag Site Crop Consulting in Verona, Wisconsin.

Several apps developed at CALS have certainly taken off. This new generation of tools for agricultural education is helping the college fulfill its mission of sharing knowledge with Wisconsin farmers and beyond.

BETTER CROP MANAGEMENT ON THE GO

The concept of apps as a research delivery method was pretty new when **Carrie Laboski**, a professor in the Department of Soil Science, developed her first one in 2012. Her Corn N Rate Calculator was the first university-based agronomic app introduced to the Apple iTunes Store.

Mike Cerny is shown in a recently planted soybean field on his farm near Sharon, Wis., in early May 2019.

Photo by Michael P. King

The calculator is designed to help farmers determine how much nitrogen fertilizer to use based on the price they expect to pay and how much income they expect to receive for their crop. For many plants, nitrogen is a key nutrient that often limits growth. The app's goal is to maximize the return on investment in nitrogen fertilizer.

"We decided that, since our nitrogen recommendations were already available in a table, we should try to make them into an app," Laboski says. "We figured we could use this as a new platform to deliver tools to growers."

The groundbreaking app won an award from the American Society of Agronomy. And since 2012, it has been downloaded on nearly 25,000 devices on every continent except Antarctica.

"It surprised me when I heard people are downloading it in Africa because the app is built on Wisconsin data and is not necessarily applicable everywhere," she says. "But it just speaks to the fact that some countries may lack resources and are starving for information."

A second app Laboski developed, the N Price Calculator, allows farmers to quickly compare nitrogen fertilizer prices from multiple sources to find the least expensive option. And her third app, NPK Credits — which helps farmers compute the "credit" they should take for the fertilizer value of having manure and legume crops on their arable land —can save money and protect the environment at the same time. The value of these credits is subtracted from the base fertilizer recommendations for the fields.

All these apps are steeped in soil science, a field that has captivated Laboski since her first introductory course as an undergraduate. She then knew that she had found what she was looking for in a career.

"Soil is our most important resource; it sustains life," she says. "If we don't have soil, we're not eating."

She eventually gravitated toward a specialty in soil fertility and nutrient management when she was a graduate student. She has been conducting research on Wisconsin soils since she started her position at CALS nearly 15 years ago.

"We know if we want to have good production of crops, we need to apply some plant nutrients," she says. "Two of our major plant nutrients, nitrogen and phosphorus, are also environmental contaminants. I like the challenge of developing nutrient application guidelines that balance profitable crop production with environmental sustainability."

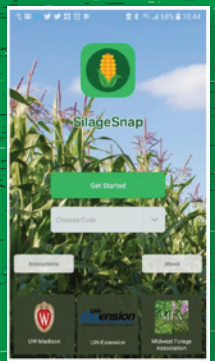
The recommendations in Laboski's apps are based on many decades of research by CALS scientists. The college's first fertilizer recommendation bulletin was distributed in 1962. About that same time, UW soil scientists were among the first in the nation to develop a computer program to easily make field-specific fertilizer recommendations that account for the influence of soil type and crop rotation on nutrient need.

The apps are designed to be farm-size neutral and dependent only on the interest level and technological savvy of the farmer or crop consultant. Laboski believes more people will use them as they become more comfortable with the technology. And the apps will continue to prove useful in the field, where connections can be spotty, because they do not depend on the internet after being downloaded.

In addition to producing new resources for farmers, some of the app development at CALS provides educational opportunities. All eight apps managed by the UW Nutrient and Pest Management Program were created in-house with the help of students. This can extend the amount of time it takes to move an app from concept to finished product, says **Roger Schmidt**, the program's information technology specialist, but it saves a considerable amount of money and provides students with a hands-on learning experience.

Schmidt, who has been with the program for 27 years, says apps are a relatively new way for researchers to reach farmers, so he and his colleagues need to change the way they operate — just like farmers have to adapt their practices in the field.

"It's different than doing outreach through a website or a publication or a journal," he says. "You have to take your research or the model you might be using, and it has to work in the real world on the fly."



SILAGESNAP APP

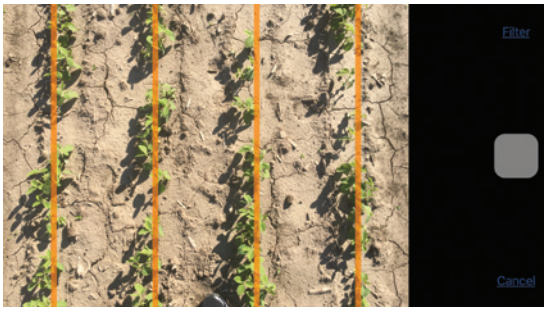
Another smartphone app developed by CALS faculty, SilageSnap, can save farmers time and money during the fall feed-corn harvest and make for more content, productive cows year-round.

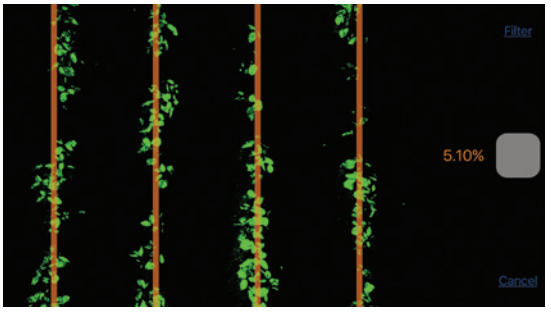
With just a handful of harvested corn, the app allows farmers to gauge — without leaving the field — the effectiveness of their harvesting machinery so that they can achieve the highest-quality cracked corn, which is easier for cows to digest. Learn more at **go.wisc.edu/silagesnap**.

TO SPRAY, TO SEED, TO START AGAIN

One major decision many soybean farmers face each year is whether to replant if their initial crop stand appears to be coming in thin or sparse. It's a complicated choice, and a big chunk of profit can sometimes be on the line.

The modern context in which farmers operate confounds the issue further, says **Shawn Conley** BS'96, MS'99, PhD'01, a professor in the





Photos courtesy of Roger Schmidt (4)

Top left: Marian Lund, a graduate student in the Plant Breeding and Plant Genetics program at CALS, tests out the Soybean Replant Calculator app. The app uses photos taken in soybean fields to calculate plant stand (i.e., population) at early growth stages and then estimates the expected yield with and without spring replanting.

Top and bottom right: Rows of soybean plants as seen through the camera of the Soybean Replant Calculator app and the same image as seen when the app uses a filter to remove the background to help make an accurate count of the plants.

Bottom left: The Sporecaster app, shown here displaying the characteristics of a soybean field on a smartphone, helps farmers calculate the risk of white mold infection in their soybean crop and determine the best timing for treating or not treating for the disease.

Department of Agronomy and soybean and wheat specialist with the Division of Extension. Many producers today are running larger operations and have less time on a per-acre basis to manage their crops, he says. Recognizing this, CALS delivers apps that offer farmers instantaneous data for making rapid yet informed decisions. Conley's Soybean Replant app is a prime example.

The replant app calculates plant populations by averaging five plant-count samples taken randomly within a soybean field during various growth stages. The app then provides expected yield percentage at harvest, with or without replanting. It performs these tasks by consolidating and drawing on years of data collection and multiple research papers. To apply this knowledge to the field, all you need is a smartphone with a camera.

"You simply snap five photos, and the app does the rest," Conley says. "It's as easy as it sounds."

The recommendation will rarely be to rip up a field and start over because, even if a stand comes in poorly, the crops in the field typically have a better yield potential than a totally replanted crop, he says. But sometimes it makes sense to add more seeds on top of what is growing.

Cerny, who plants about 2,000 acres between the villages of Walworth and Sharon, says a friend asked him for a recommendation on replanting his soybean field based on what he perceived as a poor stand. After analyzing the field using Conley's replant app, Cerny advised against it.

"An agronomist was there with me, and he recommended replanting," Cerny recalls. "I said I wasn't so sure that was great advice. I suggested that if he was going to replant, he should leave five acres of the stand so he could compare."

The yield turned out about the same where he replanted and where he didn't. But the replanting added extra seed and fuel costs, so the app's advice was sound.

As weather patterns have migrated to less frequent, more intense rainfall events, pounding rains sometimes seal the soil and hinder soybean emergence, Conley says. This intensifies the need to make quick decisions in the field, and for this purpose, apps backed by CALS research can deliver.

"I've been giving farmers these replant recommendations for years, and they didn't believe me. But now that I

put it into a phone it's got to be right," he jokes.

Conley, who grew up on a dairy farm near Browntown in Green County, had several sales internships in college but felt odd making recommendations when he knew the product he was selling wasn't necessarily the best option. That led him into the research arena and, eventually, into academia.

"This is where academic freedom is so important," he says. "If I have a strong data set, I can make recommendations that, 'Yes, this product or practice works,' or, just as importantly, 'No, this product or practice does not work or doesn't have a positive return on investment for Wisconsin farmers.' That ability to deliver unbiased recommendations to Wisconsin farmers is vital and at the core of the Wisconsin Idea."

Schmidt, the IT specialist, says apps like Conley's get downloaded all year round as farmers and crop consultants analyze them for their usefulness. He estimates that a couple hundred Wisconsin soybean growers will use the Soybean Replant app during the growing season.

Seeding and replanting are two aspects of soybean management; disease prevention is another. In addition to Sporecaster, Smith, with the help of agricultural and applied economics professor **Paul Mitchell**, has developed one other app that helps farmers deal with white mold infestations in their fields.

While Sporecaster helps farmers determine when or if they should be applying a fungicide to prevent white mold, Sporebuster can help determine which fungicide program would be the most profitable. Farmers enter their expected soybean price, expected yield, and treatment cost, and the app instantly compares 10 different treatment plans to determine the average net gain and break-even probability of each.

After the 2015, 2016, and 2017 growing seasons saw significant outbreaks of white mold, farmers were quite interested in getting the white mold apps developed, Smith says. This includes **Jonathan Gibbs**, a crop farmer from Beaver Dam, who is convinced that the white mold apps could help improve his profitability.

"One nice thing about the Sporecaster app is it's a really good prediction tool for when you might have all the [white mold] factors coming together," Gibbs says. "You don't want to spend more money [on a fungicide] than you need to, but you don't want to give up any more production, either. You've got a margin that's awfully thin, if it's even there. This is one way to keep money in farmers' pockets."

Gibbs says some older farmers might shy away from apps because they don't think they have enough technological savvy, but from his experience, they aren't that difficult to use. "If you can find your pictures on a smartphone, you can work your way through a Sporecaster or replant app," he says. "They've made it fairly user-friendly."

Both Conley and Smith say their apps can be used by farmers beyond the borders of Wisconsin. In fact, Conley asserts that the replant app is applicable to farmers who grow 82% of the soybeans in the U.S. And both soybean apps are offered free to the public, paid for by farmers through a checkoff to the Wisconsin Soybean Marketing Board, which uses the funds for soybean research and marketing projects.

WHERE ARE THE APPS AT?

The UW Integrated Pest and Crop Management program delivers research-based information to Wisconsin farmers and landowners. One way the program shares knowledge is through free mobile apps.

Learn about the apps highlighted here, and others, at **ipcm.wisc.edu/apps**.

NEXT UP: DAIRY

Managing a dairy farm requires keeping tabs on the operation's multitude of facets, from livestock breeding and diet to housing and medicinal treatments. Somewhere within the data pouring from these sources is the information to make the best choices for production and profitability. But tracking and making sense of it all is a massive undertaking.

CALS dairy science professor **Victor Cabrera** knows this, and it's the very reason he launched the Virtual Dairy Brain Project. It's designed to integrate all of a dairy farm's various data streams in real time and then use artificial intelligence to perform a sophisticated analysis. His hope is that, someday soon, dairy farmers will be able to access this rich reservoir of knowledge through mobile apps.

"Farmers may not be realizing the full extent of the information they have available to them because it is not all connected," Cabrera says.

The "brain" is a conglomeration of computers installed on multiple dairy farms. At the moment, data from six Wisconsin farms stream continually into servers at the Wisconsin Institute for Discovery, where they are securely stored and analyzed. Eventually, more farms will be added to the project. These efforts are guided by a 35-member advisory committee that includes farmers, academics, and industry representatives.

After the data are analyzed and researchers determine how they can best help farmers, Cabrera says the project team plans to develop several apps to disseminate the information to a broad base of farmers in user-friendly forms.

"Farmers are inundated with data," he says, "but nobody has taken the effort to connect all the information together with the events that are happening with the cow. We have all the data; the technology is improving fast. It's an exciting time to be working to bring it all together."

Photo by Ted Halbach

Victor Cabrera, associate professor of dairy science, and a team of UW scientists have created a "virtual dairy farm brain" that will help farmers make better management decisions. They plan to develop mobile apps that farmers can use to access this reservoir of knowledge.

Other CALS faculty working on the project include **Kent Weigel** MS'92, PhD'92, chair of the Department of Dairy Science, and **Heather White**, an assistant professor of dairy science. They are collaborating with **Miron Livny**, **Michael Ferris**, and **Jignesh Patel** from UW–Madison's Department of Computer Sciences.

The first app to launch will likely be one that helps farmers predict occurrences of ketosis in their dairy animals, Cabrera says. Ketosis, or acetonaemia, is a metabolic disorder that afflicts cattle when energy demands from producing large amounts of milk exceed energy intake. A costly condition for dairy farms, it usually shows up in cows during the first several weeks of lactation and is accompanied by weight and appetite loss, fever, and lower milk yield, among other signs. The ketosis app should give farmers a better tool for predicting the disorder so they can treat their animals in a timelier fashion.

Yet another future app will connect feed data with other management information, which will be invaluable in setting the best nutritional requirements for animals.

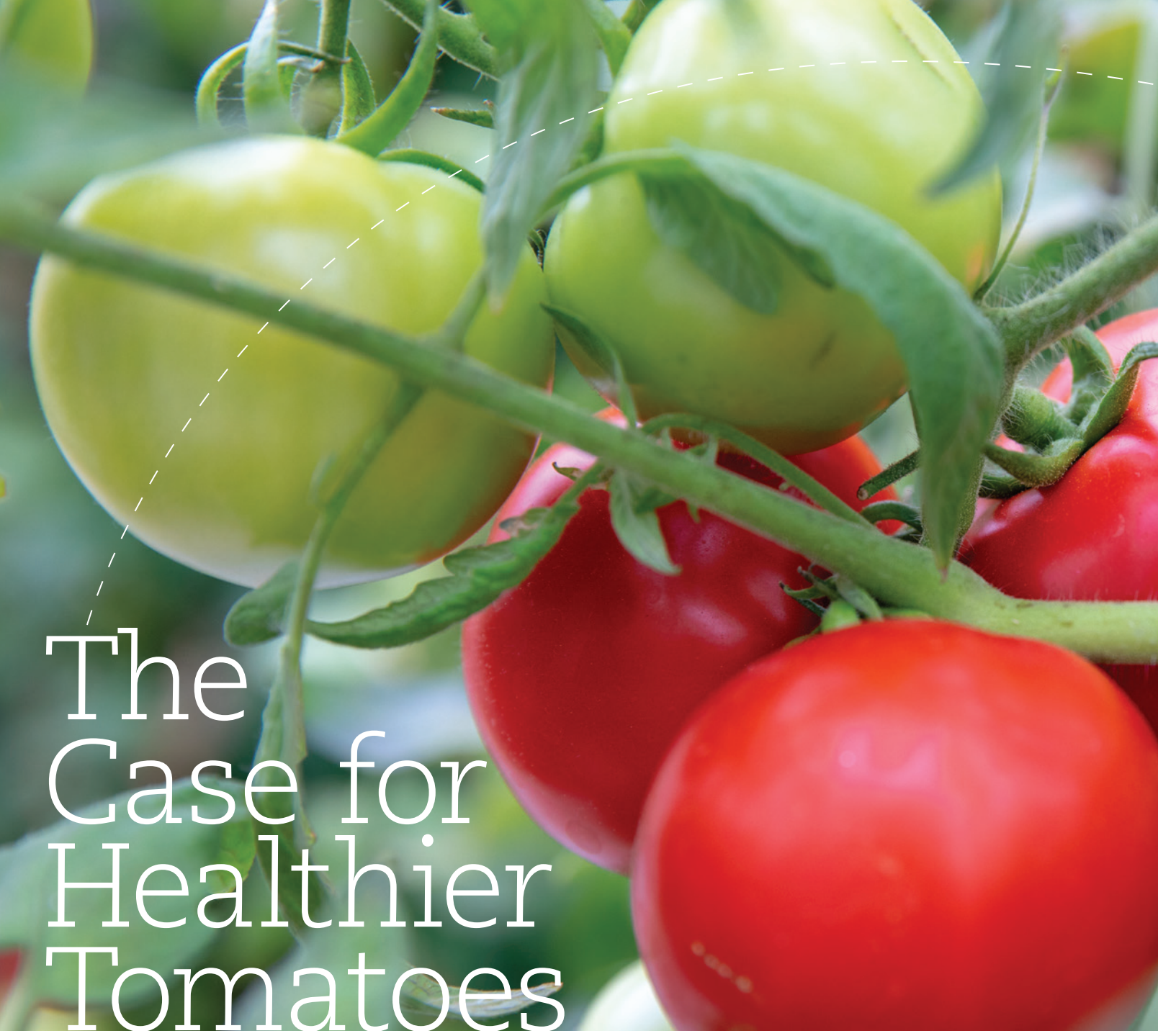
"Farmers will be able to access the data in a very easy and direct way," he says. "There will be layers, and depending on their level of interest and knowledge, some farmers will want to go further than others. It will provide them information about day-to-day management but will also predict what will happen six months from now if they change their feed composition today."

Some of the companies participating in the project have competitive interests when it comes to the data they collect for farmers, so collaborators are still working on ironing out the potential conflicts. There are many players in the dairy industry, Cabrera says, and each one fills a role as best it can.

But no company can cover everything, so researchers hope to aggregate the decision-support tools to provide farmers with the most complete information possible. The dairy brain team recently submitted a $1 million grant proposal to the U.S. Department of Agriculture that Cabrera says could help pull loose ends together in a hurry.

Cabrera took his position at UW–Madison in 2008 after working in a similar role at New Mexico State University. His ultimate goal as a researcher has always been to help dairy farmers improve their bottom line, and he thought he could make more of an impact in Wisconsin, where dairy represents a larger part of the state agricultural sector. Providing high-quality apps that create more efficient access to the university's knowledge banks can only help him achieve this aim.

"The great thing here is there is a lot of research going on at the university all the time," he says. "The latest discoveries are happening here, or we are on top of that information from somewhere else. What I have done is connect the latest discoveries with the economics, trying to help producers make the best decisions they can using that scientific information. We think we can make a huge difference."



The Case for Healthier Tomatoes

By Caroline Schneider MS'11

AT SOME POINT IN YOUR LIFE, YOU'VE probably gone to class knowing you left an assignment unfinished. The knot in your stomach grew as homework was collected. And, as you practically crawled under your desk to avoid the teacher's gaze, a ridiculous, clichéd excuse may have flitted through your mind: "The dog ate my homework."

For a team of researchers in the Department of Plant Pathology, the destroyed assignment was a plot of test tomatoes in northern Florida. But they didn't need to devise a hungry canine. For them, the villain was a swarm of voracious whiteflies. And then came not one, but two howling hurricanes.

Could boosting resistance to plant pathogens in our crops help prevent the spread of foodborne illnesses to people?

Photo by Michael P. King

Tomatoes grow in the King Hall greenhouse as part of a plant pathology study. They will be used to harvest seeds for additional experiments.

These scientists aren't making any excuses, though. Instead, they're treating the unfortunate events as opportunities to better understand how, in real-world settings, tomato genetics influence the microbes that live on them, even under the pressure of ravenous insects and 80-mile-per-hour winds.

"If we've learned anything in the project yet, it's that fieldwork is very challenging," says professor of plant pathology **Jeri Barak** with a smile. "It's important to us that we are doing the work in the real environment in the field."

In this real environment, Barak is working with plant pathology colleagues **Caitilyn Allen** and **Rick Lankau** to study the microbiomes of tomato plants. They're exploring how a plant's genetics influence its microbiome and, in turn, how microbiomes may alter the behavior of pathogens. And they're finding that the ability of plants to ward off diseases may also be a key component in protecting human health.

Where Outbreaks Start

Raw eggs or undercooked chicken typically get the bad rap as food poisoning sources, but over the last 10 years, fresh produce has been the more likely culprit in cases of salmonellosis. And the romaine lettuce episode of Thanksgiving 2018 showed that fresh produce can also harbor a toxic form of *E. coli* (as opposed to the mostly harmless strains of the bacteria that humans need to live). It's a risky pathogen. Of those who get infected with the toxic strain of *E. coli*, 1% will die and another 3%–6% will develop hemolytic uremic syndrome, an illness that shuts down kidneys and requires dialysis for the life of the patient. Those percentages increase in children and immunocompromised people.

Although these pathogens prove dangerous for humans on the consumer side of the food system, epidemiology studies show that contamination of fresh produce happens in the fields, not during processing or transportation. Animals and water both bring pathogens to areas where crops grow. So Barak and her colleagues went to the field to study the microbes and the circumstances around them.

"We're having outbreaks annually with these organisms now," says Barak. "So we're looking at the agricultural system, trying to figure out the factors that come together to create a perfect storm that results in outbreaks in humans."

Inside Microbial Communities

Although their investigation is system-wide, much of the researchers' focus is on the many microbiomes found in plants. Microbiomes, or communities of microbes that live in a particular environment, are often thought of in humans as part of a healthy gut. We take probiotics to build up healthy microbes and read about how our diets can affect our microbiomes. Plants, too, have microbiomes, where human pathogens, such as *Salmonella* and the toxic strain of *E. coli*, although rare, are sometimes present.

"There are different groups of microbes in plants, though there's not rigid, distinct separations," explains Lankau, an assistant professor of plant pathology. "We talk about endophytic microbes, those that live inside the plant — for

Photo by Michael P. King

From left, members of the plant pathology department — assistant professor Rick Lankau, professor Caitilyn Allen, and associate professor Jeri Barak — gather in the King Hall greenhouse where tomato plants grow as part of their study.

instance, in the vascular system — and epipthytic ones, those that live on the surface, such as on the leaves. There are also microbes associated with the rhizosphere, the zone of soil around a root that's under the influence of that root."

The different environments where microbes live on a plant vary greatly, and they each pose their own challenges. The roots are leaky and buried under soil, and microbes that live on or near them have to contend with antimicrobials that the roots exude. These microbes also may have to partake in intermicrobial warfare to defend their place in a crowded community.

The leaves, on the other hand, are bombarded by sunlight for much of the day and act as tiny fortresses set up to defend the plant against invaders. There are some cracks in the walls, though, in the form of small holes called stomata, which open and close to allow the plant to "breathe" or exchange gases. Plant pathogens sneak through these stomata to infect the leaf and live more comfortably in small chambers, where they can avoid drying out in harsh UV rays.

With so many niches for microbiomes in the plant, researchers want to better understand which microbes live where and how they might affect the presence of human pathogens in these environments. In 2017, with funding from the Wisconsin Alumni Research Foundation, UW–Madison launched the Microbiome Initiative, a strategic effort to fund research that galvanizes the research community and allows UW faculty to be more competitive when applying for federal grants. Barak, Lankau, and Allen saw the initiative as an ideal opportunity and came together with Barak's colleagues in the Sunshine State, including **Gary Vallad** PhD'03, associate professor of plant pathology at the University of Florida, to propose a winning project using tomatoes as their research model.

What Tomatoes Teach •

Why tomatoes? For the past 15 years or so, this widely cultivated fruit, which is often enjoyed raw, has been a common source of salmonellosis. Each year, tomatoes, usually in the form of salsa, take the blame for foodborne illnesses. They are a cash crop in many developing countries, and they grow almost everywhere in the tropics, clear signs of their worldwide importance. All these factors, combined with Barak's standing collaboration with researchers in Florida who study tomato diseases, made the plant an ideal fit for the project.

To address the question of how microbiomes and human pathogens interact, Barak and her colleagues are starting with plant diseases. Specifically, they are using a variety of tomatoes that has been engineered to resist certain types of plant pathogens. One plant cultivar, Bs2, is named after a resistance gene borrowed from peppers. Bs2 plants have resistance specifically to *Xanthomonas*, a microbe that causes bacterial spot. The other cultivar, EFR, is named after the elongation factor receptor gene that was cloned and put into the

tomato. EFR plants have resistance to a number of pathogens, including *Xanthomonas* and another bacterium called *Ralstonia solanacearum*, which causes bacterial wilt.

"We have plants with two different types of defenses," says Lankau. "We have plants that basically always have their defenses on, their shield up all the time. And then we've got another version that has this narrow defense against just the *Xanthomonas* pathogen."

With these two models of tomato plants growing in the sun-kissed Florida fields alongside "normal," unmodified tomatoes, the researchers challenged each with either *Ralstonia* or *Xanthomonas* to put them on alert and kick-start their defense mechanisms. How would the microbiomes of the unmodified tomatoes versus those with either the broad or narrow resistance change in response to a plant pathogen? And what would those changes mean for human pathogens?

Barak already had some clues from previous work. "What we've found, starting in about 2014 in greenhouse experiments, is that when tomato plants are infected with *Xanthomonas*, *Salmonella* does really well," she says. "And if it's doing well in the plant, that means the fruit gets contaminated."

The researchers started growing both tomato models in fields in the same area of Florida. But an invasion of whiteflies, which carry a devastating pathogenic plant virus, decimated their plots. Luckily, their collaborators were growing the same plants in a field unaffected by whiteflies and were able to supply leaf samples that season. To avoid losing all their research in the event of another catastrophe, the UW scientists decided to split the research into two places. The group studying the EFR tomatoes stayed in the north, where *Ralstonia* is a common problem, and the group studying Bs2 tomatoes and *Xanthomonas* moved south.

Then, more proverbial homework-eating dogs showed up. In 2017, Hurricane Maria hit. The researchers were astonished to find that some of the plants survived the natural disaster, but they couldn't sort out which were inoculated and which should have been disease-free. And in 2018, the northern group suffered a direct hit from Hurricane Michael. Luckily, amid the upheaval, some samples and data were salvageable.

Plant Disease and Food Safety

Adam Bigott, a plant pathology graduate student in Barak's lab, works on the ground gathering plants and data for the Bs2 model system. "I travel to Florida twice a year to collect leaf samples," he says. "It's imperative to process the samples and extract DNA quickly so it doesn't degrade. Then I prepare the samples for DNA sequencing so we can find out which microbes are in the sample. My end product is a very large spreadsheet that I spend a lot of my time processing."

> "Our greenhouse data has shown over and over again that with plant diseases like bacterial spot, *Salmonella* does better. But we could show in the field that, with resistance like the Bs2 model, you can decrease the human pathogens. If that's true, then we need to increase our investment in reducing plant disease to increase food safety."

Even with all that data to decipher and hurricanes and insects to face, researchers are starting to uncover answers to some of their burning questions. Bigott and Lankau, for example, have discovered fascinating distinctions between how plants with the Bs2 narrow resistance and those without react to *Xanthomonas*.

"On the leaf surface, the different plants weren't that different in terms of their microbe communities," says Lankau. "But when the pathogen came in, the whole microbial community shifted and became less diverse. We saw that the two most common members of a healthy community decreased. The Bs2 gene did a very good job of preventing the infection, and the microbial communities on those leaves did not shift like those on the plants vulnerable to the pathogen."

The number of changes in the microbial communities that seem to occur when a plant gets infected suggests that the entire microbial state could become more vulnerable to harmful microbes and, possibly, human pathogens.

"Again, our greenhouse data has shown over and over again that with plant diseases like bacterial spot, *Salmonella* does better," Barak says. "But we could show in the field that, with resistance like the Bs2 model, you can decrease the human pathogens. If that's true, then we need to increase our

Photo courtesy of Adam Bigott

Tomato plants in a field plot in Florida display signs of bacterial spot, which is caused by the pathogen *Xanthomonas euvesicatoria*.

Plant pathology research assistant Adam Bigott poses with tomato plants in a grow room at Russell Labs.

Photo by Michael P. King

investment in reducing plant disease to increase food safety."

Results with the EFR tomato model are proving to be a bit more complex. The researchers did not see any effect of the EFR gene on microbes living on the leaves, but the microbe communities in the roots of EFR plants were different than those found on the normal tomato plants. Specifically, there were more Actinobacteria, a group of bacteria that play an important role in decomposing organic material and in producing antibiotics, and fewer Proteobacteria, which include a wide variety of pathogens, such as *Salmonella*, and many of the bacteria responsible for nitrogen fixation. And this was true even when the plants weren't challenged by a pathogen.

The team is still teasing apart what these changes mean. Although it is by no means a conclusive result, a pattern in their data prompts speculation that an abundance of Proteobacteria is linked with greater yield. It seems that the EFR genetic resistance reduces the infection by pathogens when they're present. But it may come at a cost: The resistance shifts the communities in the roots to a state that harbors fewer microbes that support or promote growth.

"In the end, the effects sort of cancel out in the field," explains Lankau. "This broad spectrum resistance is a useful disease control tool, and I think it is protecting plants from pathogens. But it also is potentially affecting the nonpathogenic, beneficial microbes in a way that's dragging yield down."

Lankau finds the results associated with the EFR broad resistance tomato plants especially intriguing. It may answer a long-standing question of his: If plant pathogens are such a nuisance and detriment to plants generally, why don't we have plants that always guard against all diseases? It would make targeting defenses at specific diseases unnecessary.

"Yet in all of evolutionary history, we don't have plants that are defended against every pathogen," says Lankau. "So we're interested in what might be the trade-off behind putting this broad spectrum resistance out there."

Plant-Soil Feedback

One way in which those trade-offs may be felt is if farmers start to dial back on the water and nutrients, or inputs, they put on their fields. Over the years, breeders have selected for plants that give higher yields. But they've been selecting for those plants in well-irrigated and fertilized fields

— comfy places for crops to grow. In other words, they may have been selecting for wimpy plants that no longer need the help of beneficial microbes. They've become poor hosts.

But if farmers want to save money and energy and decrease their environmental impact, they will have to move toward agricultural systems with fewer inputs and more variabilities. In response, breeders may need to make the plants resilient again by "teaching" them how to be proper hosts for the helpful microbes they've taken for granted.

"Relying on a microbe comes at a cost to a plant," explains Lankau. "So if the plant can get that thing directly from the field, why pay a microbe? In fact, the plants that do pay microbes are probably smaller, since it's a yield drag. We may have selected against plants that host beneficial microbes. We have to go backward now and figure out what we bred away. It's possible we bred past a plant that could have been extremely useful when we were only worried about yield in irrigated, fertilized conditions."

Researchers can get insights into useful plants that may have been overlooked in the breeding process in what Lankau calls plant-soil feedback experiments. Lankau and his team take soil from various fields, grow plants in the different soils, and expose the plants to a stressor, such as disease or drought.

"Our agriculture is outside, and so we have to go where our agriculture is to really understand it. That is where we will see how defense mechanisms and genetics can affect microbial communities and human health."

Since researchers can sequence the genome of microbe communities found in the soil in each pot, they can figure out which microbes in particular are best for surviving drought or fighting off a disease. In this way, they could define the best "probiotics" for plants under different circumstances. Perhaps in the future, we can have the equivalent of a probiotic supplement for crops to keep them healthy.

"I don't think of these plants as individual organisms anymore," says Bigott. "I've come to see them as a much more complex assemblage. There is interplay between plants and the pathogens and microbes that associate with them."

Understanding that interplay and the balance between inhibiting plant pathogens while supporting beneficial microbes and making plants as strong as possible will be extremely useful as foodborne illnesses continue to cause problems.

Photo courtesy of Jeri Barak

Rows of tomato plants stand in a commercial grower's field not far from the CALS–University of Florida team's test site in northern Florida in 2017.

"On the human gut side, people are really interested in what a healthy microbiome is and what we can do to promote that," says Barak. "I'd like to know that on the plant side too. When you see a decrease in human pathogens, do you see an increase in something else? Can we decrease the chance of foodborne illness by increasing the amount of other particular microbes [on plants]?"

All these experiments could lead to a range of healthier and more robust crops, not just tomatoes. Studies on the leaf microbiomes of soybeans, rice, and clover have found that all three crops have the same three most abundant microbes. It's possible that a healthy prescription for one plant could help researchers write healthy prescriptions for others. They are, after all, faced with many of the same challenges in the field.

For Barak, this is the power of their tomato microbiome project — not just that they're posing questions about healthy plant microbiomes but that they're digging up answers in the field, where plants grow and where crops encounter environmental challenges, diseases, and pests.

"Our agriculture is outside, and so we have to go where our agriculture is to really understand it," she explains. "That is where we will see how defense mechanisms and genetics can affect microbial communities and human health. We have to do it outside, insects or no insects, hurricanes or no hurricanes."

in the field

by Stephanie Hoff BSx'19

JUSTIN MARGOLIES MA'16

"My experience with REDA served as the doorway into possibility," says **Justin Margolies**. "I greatly appreciated the college's commitment to train the next generation of energy and resource professionals — and to do so quickly with a one-year accelerated program." He says the program honed his critical thinking, analysis, and statistical skills and prepared him to be confident with almost any industry topic. "I graduated and was able to hit the ground running," he says. Today, Margolies is an analyst in the research and innovation group at Slipstream, a nonprofit that designs energy efficiency programs to achieve a clean energy economy. It partners with utility companies, governments, and other agencies to find solutions to energy challenges. Margolies designs pilot programs for electric and gas utilities focused on energy efficiency. "I also focus my research on beneficial electrification — replacing direct fossil fuels to reduce carbon emissions — which is gaining attention across the energy industry quite quickly but still faces significant policy and market barriers," says Margolies. "I chose my field because, as I began learning about our energy system, I realized the tremendous potential of emerging technologies coinciding with the urgent need to address climate change — what I believe to be the largest and most complex challenge of humanity."

KATHLEEN WARD MS'16

Kathleen Ward always intended to get a master's degree in the economics field. She chose CALS and the REDA program after working with **Bill Provencher**, professor of agricultural and applied economics and part-time director at Navigant, a consulting firm that collaborates with companies, investors, and the government to help them adapt to the changing energy environment. "He made the hard sell and convinced me REDA would be a good fit," says Ward. "I really liked the idea of finishing a masters in one year instead of two, and that the degree was tailored to the energy field. Without REDA, I would not be where I am today. The econometric training that I received in the program was top-notch, but I also walked away with some lifelong friendships." After six years with Navigant, Ward is happily located at its Boulder, Colorado, location. "The energy field keeps evolving, and I keep learning, which makes it an exciting field for me to be in," says Ward. She specializes in evaluating programs that incentivize energy demand reduction during peak periods. She's also worked with the Nest Learning Thermostat in estimating the impact and annual energy savings for thermostat-enabled events, when the devices self-adjust to save energy during periods of peak use. "I like knowing we're pushing for a more efficient and dynamic energy future," Ward says.

ABBY MAYER MS'16

"I knew I wanted to work in a field where I could contribute to addressing environmental issues," says **Abby Mayer**. "Energy is vital to our society, but with the increasing concerns about climate change, it's an industry that needs to adapt to our changing needs." Mayer's position at Seminole Electric Cooperative in Tampa, Florida, allows her to do just that. She applies the critical thinking and analytical skills she learned in the REDA program to help Seminole's nine cooperative members make decisions about their future energy needs. "The energy industry is changing with the rise of new technologies and the push for cleaner energy," she says. "So it's vital to have the skills to adapt to changing standards." As a load forecasting analyst, Mayer makes predictions using historical data to assist with long-term planning (30 years and more ahead) for future energy and demand needs. For example, her estimates may be used to determine when Seminole will need a new power plant to meet consumer demand. She prepares, interprets, and monitors the forecasts for Seminole's members. Mayer says she is grateful to REDA for giving her the foundation to start a career. "Being a part of REDA has also allowed me to make contacts within the energy industry at consulting firms, utilities, and nonprofits," says Mayer. "Past classmates and professors have been a great resource for discussions and are a great asset for different analytical approaches."

The Resource and Energy Demand Analysis (REDA) program at CALS offers an accelerated path to a master's degree with a focus on "economics and data analytics for a smart, green world." These alumni from REDA's first three cohorts of graduate students have found success in their energy management careers. More at **reda.aae.wisc.edu**.

About *In the Field* | *The CALS graduates highlighted here represent the depth and breadth of alumni accomplishments. Selections are made by* Grow *staff and are intended to reflect a sample of alumni stories. It is not a ranking or a comprehensive list. For more about CALS alumni, visit* ***cals.wisc.edu/alumni****.*

Alumni making a difference through ENERGY MANAGEMENT

DREW BLUMENTHAL MA'17

Drew Blumenthal was already interested in the energy industry before enrolling in the REDA program. But there were so many paths to choose from, he couldn't decide on just one. "Thankfully, the program nudged me in a single direction," says Blumenthal. REDA taught him coding, including importing and cleaning data, and statistical knowledge, such as the pros and cons of different program designs and how to validate energy savings results. "With this knowledge, I felt the most comfortable working for an energy evaluation consulting firm than anywhere else." Blumenthal is now a senior consultant working in the data science field at Opinion Dynamics in Oakland, California, his home state. He helps utility companies understand how their programs are performing and makes recommendations on how they can generate additional energy savings. "My favorite part of my work is comparing energy savings results from customers' behaviors for various energy saving devices, like smart thermostats, with designated savings values that assume customers are using these devices efficiently," says Blumenthal. This information is used to provide recommendations for utility companies on how to improve their programs. "CALS taught me that even if you're not making it large in the energy industry, such as working for Tesla or another company that's transforming the industry, any contributions will make a difference," he says.

MICKEY FRANCIS MS'16

Mickey Francis is an analyst at the U.S. Energy Information Administration (EIA), the U.S. Department of Energy's independent statistical and analytical agency. The EIA collects, analyzes, and publishes energy information to promote sound policymaking as well as public understanding of energy, including its interaction with the economy and the environment. "EIA is policy neutral," Francis says. "The bottom line is no other governmental entity — including Congress, the secretary of energy, or the president — may alter EIA data. I like our independent work, especially in today's political climate." Francis spends most of his time estimating state-level consumption, production, and prices for all energy types. At the national level, he works on estimating noncombustion (nonenergy) applications for fossil fuels, such as the use of petroleum products to make plastics or coal for skin care products. "Yes, there could be coal in your anti-dandruff shampoo," Francis says. Those consumption estimates are important for carbon dioxide emissions estimates because less carbon dioxide is emitted through nonenergy consumption than when fossil fuels are burned for energy. "I saw a need in our world to be more efficient in how we use resources, and after graduating from REDA, I thought EIA would be a great fit as well as a great way to serve our country," says Francis. "I wouldn't have this job if I hadn't gotten a master's degree, and I was first introduced to EIA during the program, so REDA has been essential to my career success."

MARY VAN LEUVEN MS'18

Mary Van Leuven is passionate about using renewable energy to address climate change, so working in the solar industry was a natural choice. "My work at The Solar Foundation allows me to enhance my lifelong commitment to sustainability by promoting a clean, reliable energy source to support a prosperous future for communities across the world," she says. The Solar Foundation is a nonprofit organization dedicated to advancing the use of solar and solar-compatible technologies worldwide. As project manager, Van Leuven supports data and research needs for the foundation's projects, such as the *National Solar Jobs Census* and the *U.S. Solar Industry Diversity Study*. She also works on a program called SolSmart, which recognizes communities across the country for removing barriers to solar energy development. "My favorite part of my work is evaluating the results from interviews and surveys to see the growth and impact the solar industry is having in the U.S.," says Van Leuven. "A lot of my work is focused on solar policy as well as the solar workforce and how to ensure it remains strong and equitable." As renewable energy sources continue to become more financially accessible, Van Leuven is committed to promoting them by helping others understand the research underlying the industry. "My experience at CALS provided me with the education to prosper in a research role in the renewable energy industry," says Van Leuven. "My classes covered policy practices and issues, qualitative analysis tools, and, most importantly, the quantitative tools to analyze data in the energy industry and effectively communicate this data to the public."

Catch up with…

Lucas Rapisarda BS'15

Community and Environmental Sociology and Wildlife Ecology

Lucas Rapisarda spent his early years in Illinois before his family moved to Bristol, Wisconsin, a village in Kenosha County. Along the way, he went to great schools and received a well-rounded education. It wasn't until he came to the UW–Madison campus that he had his first in-depth conversations about poverty and social justice in the United States.

These conversations, which took place in classrooms led by community and environmental sociology professors **Gary Green**, **Leanne Tigges**, **Monica White**, and others, inspired Rapisarda to join Teach for America after graduation. He was placed in Rosedale, Mississippi, as a science teacher in the local public schools.

Photo courtesy of Lucas Rapisarda

The experience brought educational lessons to life for Rapisarda, who had never been to the South before. Rosedale, located in the Mississippi Delta region, is small, rural, and poor, with a majority African American population. The school where he taught didn't have a lot of resources to support learning, and he felt his students deserved so much more.

Toward the end of his Teach for America service in 2017, Rapisarda joined the Rosedale Freedom Project, a nonprofit founded in 2015 to provide summer education and enrichment programs for Rosedale youth. As director of operations, he is part of a small team that helped the organization expand to offer year-round programming with a much wider focus on academic, artistic, economic, experiential, and leadership opportunities. The project has served more than 150 area youths.

HOW DID YOU END UP JOINING THE ROSEDALE FREEDOM PROJECT?

When I first started teaching in Rosedale, I was shocked by the conditions of the public schools and the ways students were marginalized. There was this sense among the students that nothing would ever change.

My students were some of the most intelligent, bright, wonderful, funny, caring people that this world has ever seen, and I kept thinking there's no reason they shouldn't have the same opportunities as anybody else in the country. I joined the Rosedale Freedom Project because I believe it provides a needed space for students to learn and grow.

WHAT KIND OF PROGRAMMING DOES THE ROSEDALE FREEDOM PROJECT PROVIDE?

We are a nonprofit youth empowerment organization. We serve students, whom we call Freedom Fellows, in grades seven through 12, and provide support for graduates of the program when they are in college. During the school year, we have after-school tutoring as well as special programs, such as filmmaking, creative writing, and a social justice reading group. In the summer, we hire amazing undergraduate students to work as teaching assistants (TAs). They help lead classes in reading, math, art, and fitness, as well as the other programs that we offer throughout the day.

All of our programming has a civil rights focus. We expose Fellows to the history of social injustice in our country by talking about the civil rights movement and openly discussing racism in the state, both in the past and today.

WHAT DOES SUCCESS LOOK LIKE?

This year, we will have our first graduating cohort, which is very exciting. We plan to hire our graduates as TAs each summer during their collegiate years, and then, once they graduate from college, we can snatch them up and give them a job. That's the model. The ultimate goal of our programming is to empower our Fellows to expand their critical consciousness and challenge the status quo that our country sets for them based on their race and their gender.

One of the ironies of our organization that I always like to point out is that we are an all-white staff from outside of Mississippi. One of the big pushes for our organization right now is figuring out how to phase out the founding staff in favor of local people of color. I may be leaving sooner than I would otherwise, and I think that's actually really important and healthy for the organization.

—Nicole Miller MS'06

Deibel Family Gift Cultivates Grad Student Discoveries

Scientists-in-training at the UW Food Research Institute (FRI) are identifying better probiotics and improving food safety with the help of a generous gift from retired bacteriology professor **Robert H. Deibel** and his wife, **Carol**.

The Deibels, longtime proponents of food safety and probiotics, recently established a pair of endowed fellowships to support graduate student research in the two fields. Their $1 million gift was doubled thanks to a match established by UW–Madison alumni **Albert** and **Nancy Nicholas**. With the support of these vital funds, the inaugural fellows have already made scientific strides.

Dianiris Luciano-Rosario, a doctoral student in plant pathology, is the first recipient of the Robert H. and Carol L. Deibel Distinguished Graduate Fellowship in Food Safety Research. She studies a troublesome blue mold called *Penicillium expansum*, which can be devastating to fruit crops and human health.

"This fungus grows on apples and other fruit, contaminating them with a mycotoxin called patulin," says Luciano-Rosario, who works on the project with her mentor, bacteriology and genetics professor **Nancy Keller**. "Patulin is very toxic and is difficult to remove from fruit. By better understanding at the molecular level how the fungus infects apples, we hope to find ways to reduce patulin contamination and prevent the health problems and food waste it causes."

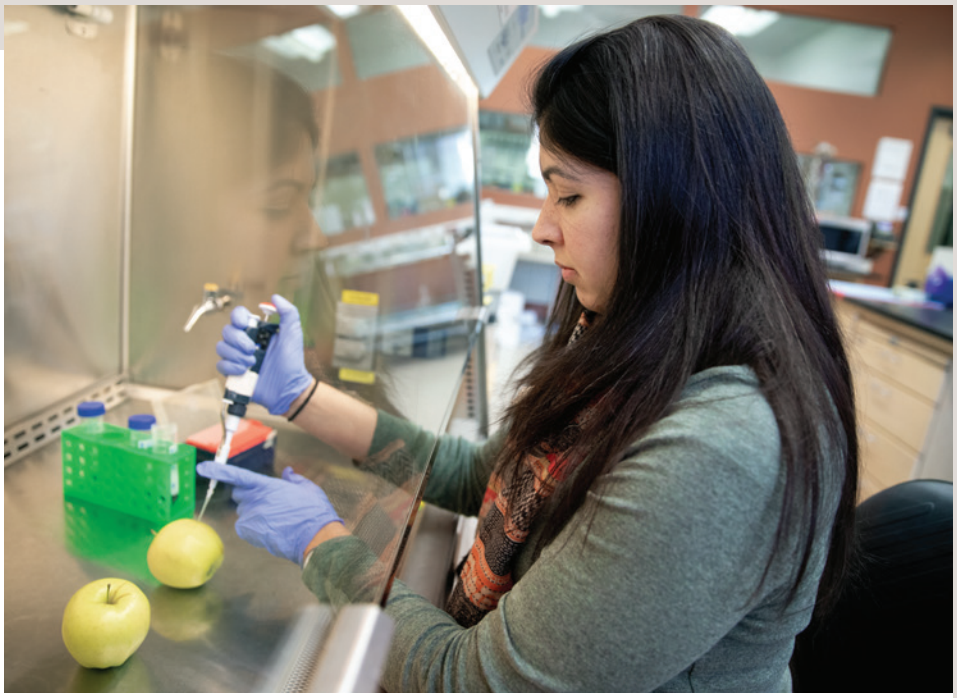


Photo by Michael P. King

Plant pathology graduate student Dianiris Luciano-Rosario inoculates apples in Professor Nancy Keller's lab at the Microbial Sciences Building.

Mustafa Özçam PhD'18, who completed his degree in food science under the mentorship of assistant professor **Jan Peter "JP" van Pijkeren**, is the inaugural recipient of the Robert H. and Carol L. Deibel Distinguished Graduate Fellowship in Probiotic Research. While at CALS, he investigated interactions between probiotic bacteria and their human hosts.

"We identified a novel pathway by which certain probiotics activate the aryl hydrocarbon receptor, which mediates intestinal inflammation," says Özçam, who is continuing his probiotics research as a bioprocess development scientist at DuPont Nutrition and Health. "We can use this discovery to design probiotics with improved benefits for people."

Robert Deibel, a former chair of the Department of Bacteriology and member of FRI, led an influential career as an educator and researcher. Among his many notable accomplishments, he is one of the early developers of the globally utilized food safety system known as HACCP (hazard analysis and critical control points), which he expanded and taught through a first-of-its kind short course for industry. After 22 years at UW–Madison, he launched Deibel Laboratories, Inc. Under his leadership, and later that of his son, Charles, the lab has become an internationally recognized provider of food safety testing, scientific consulting, and training for leading North American food manufacturers.

Deibel's legacy as an educator continues with these fellowships. Luciano-Rosario credits the fellowship for giving her time to build a critical foundation for her doctoral work. For Özçam, the financial support played a major role in the start of his successful career.

"Having secure funding allowed me to fully focus on my main Ph.D. project and motivated me to keep working in the field of probiotics," he says.

—Wendy Bedale

If you'd like to help CALS graduate students succeed by supporting fellowships and other awards, please contact Brandi Funk at brandi.funk@supportuw.org or 608-308-5204.

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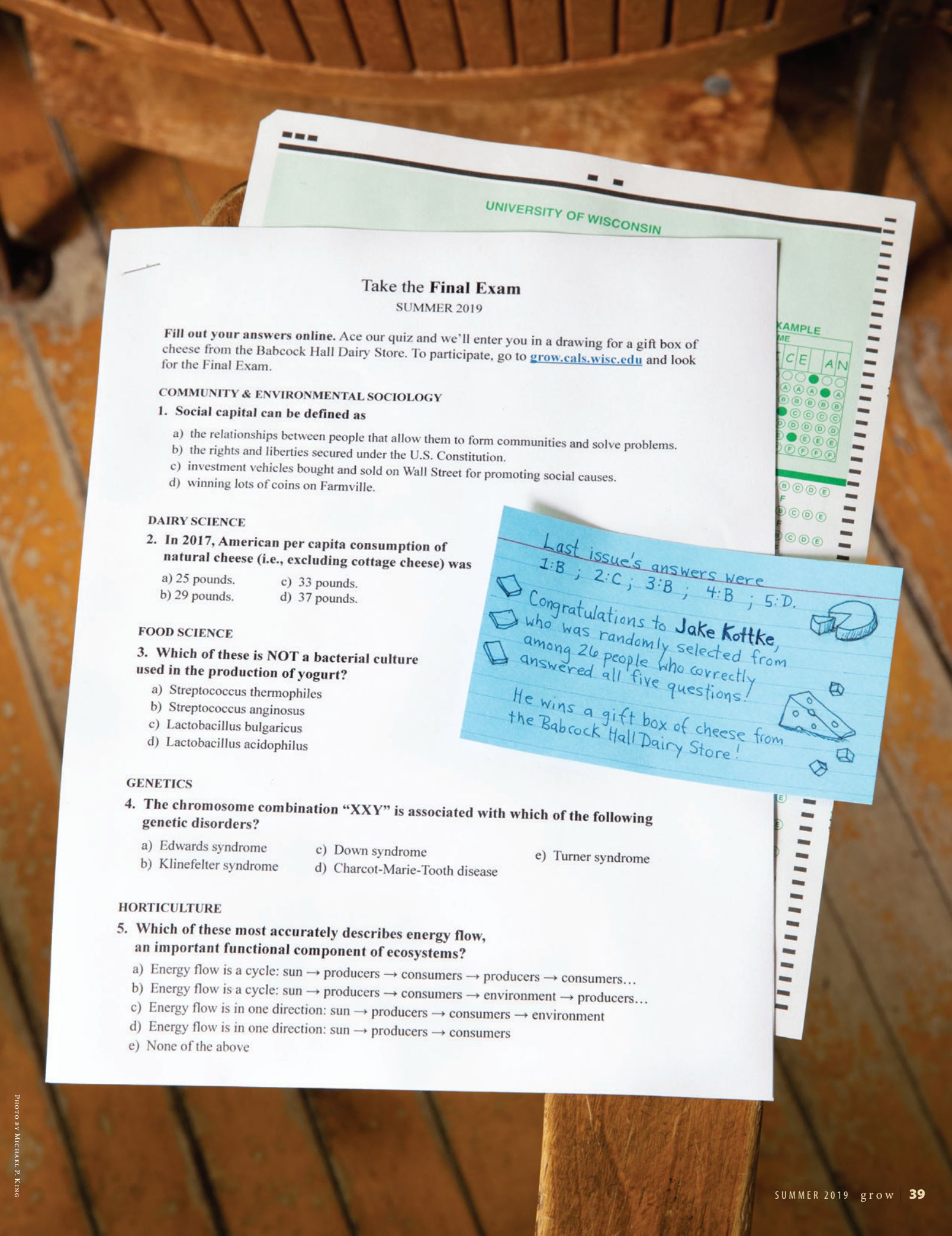

Take the **Final Exam**

SUMMER 2019

Fill out your answers online. Ace our quiz and we'll enter you in a drawing for a gift box of cheese from the Babcock Hall Dairy Store. To participate, go to grow.cals.wisc.edu and look for the Final Exam.

COMMUNITY & ENVIRONMENTAL SOCIOLOGY

1. Social capital can be defined as

a) the relationships between people that allow them to form communities and solve problems.
b) the rights and liberties secured under the U.S. Constitution.
c) investment vehicles bought and sold on Wall Street for promoting social causes.
d) winning lots of coins on Farmville.

DAIRY SCIENCE

2. In 2017, American per capita consumption of natural cheese (i.e., excluding cottage cheese) was

a) 25 pounds.
b) 29 pounds.
c) 33 pounds.
d) 37 pounds.

FOOD SCIENCE

3. Which of these is NOT a bacterial culture used in the production of yogurt?

a) Streptococcus thermophiles
b) Streptococcus anginosus
c) Lactobacillus bulgaricus
d) Lactobacillus acidophilus

GENETICS

4. The chromosome combination "XXY" is associated with which of the following genetic disorders?

a) Edwards syndrome
b) Klinefelter syndrome
c) Down syndrome
d) Charcot-Marie-Tooth disease
e) Turner syndrome

HORTICULTURE

5. Which of these most accurately describes energy flow, an important functional component of ecosystems?

a) Energy flow is a cycle: sun → producers → consumers → producers → consumers…
b) Energy flow is a cycle: sun → producers → consumers → environment → producers…
c) Energy flow is in one direction: sun → producers → consumers → environment
d) Energy flow is in one direction: sun → producers → consumers
e) None of the above

Photo by Michael P. King

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HEMP HELP

A flowering female industrial hemp plant grows at the Wisconsin Crop Innovation Center in Middleton, Wis. The plants are being used for research as part of a collaboration between CALS and the Division of Extension that aims to help hemp growers in Wisconsin. Industrial hemp is harvested for fiber, seed, and oil. It is a member of the cannabis family but with low levels of the psychoactive compound tetrahydrocannabinol (THC).

Photo by Michael P. King