SPRING 2022

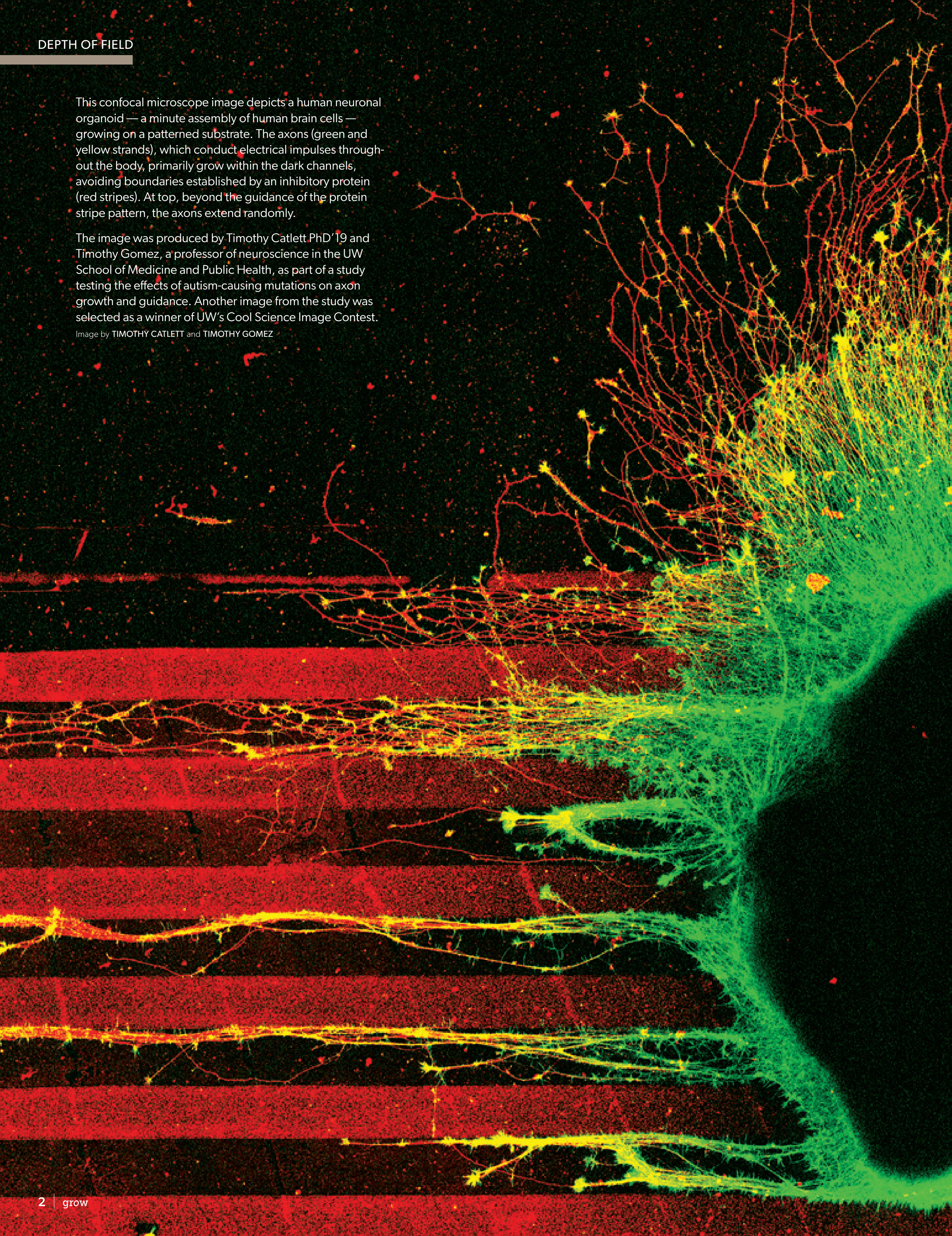
grow

College of Agricultural & Life Sciences
University of Wisconsin–Madison

WHERE GOOD IDEAS ARE **GROWN & SHARED**

Explore the CALS Agricultural Research Stations PAGE 20

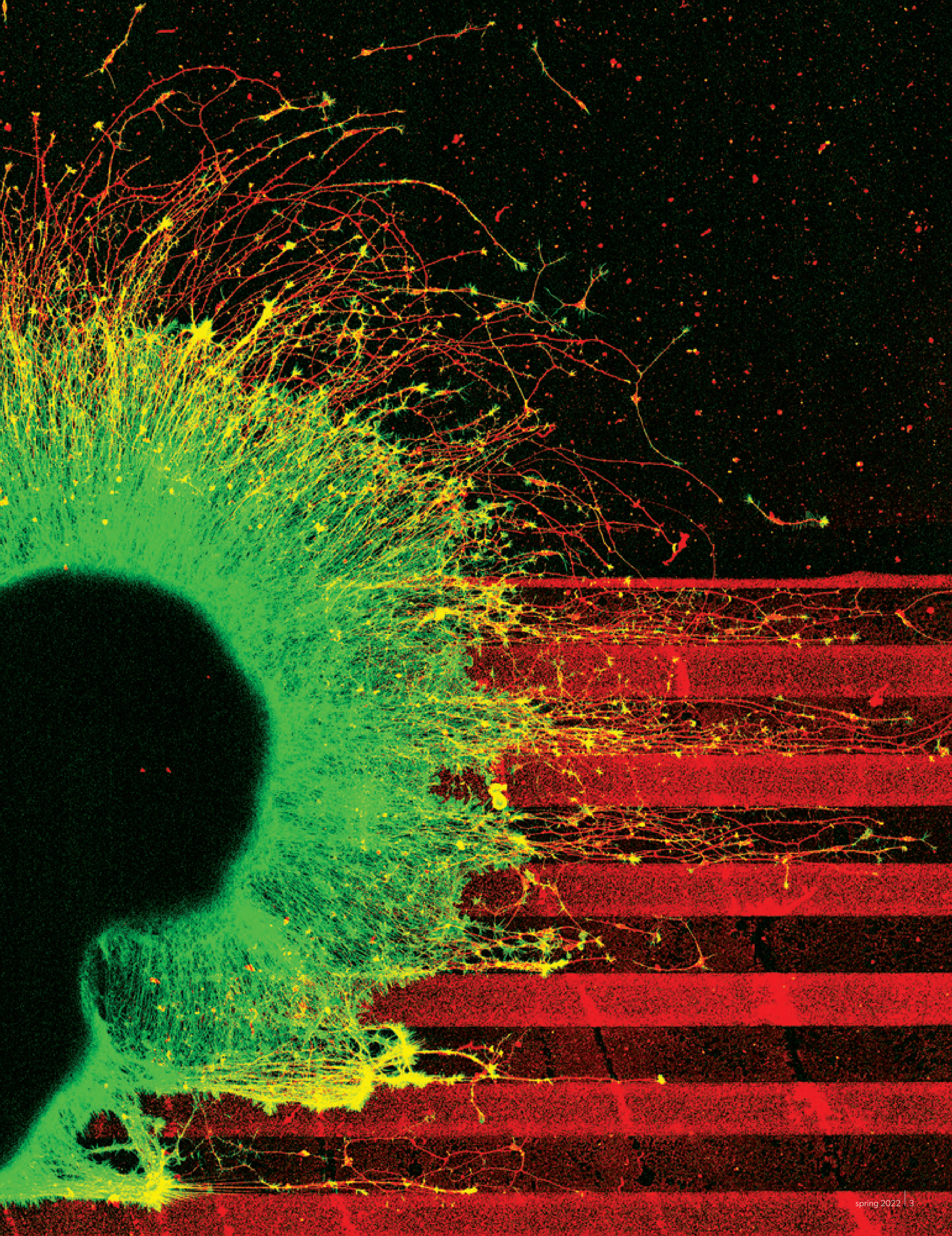
+
CORONAVIRUS RESEARCH AT CALS
PROMISING CARBON CAPTURE TECH
LAB-GROWN MEAT
SIDE-SPLITTING SCIENCE CARTOONS

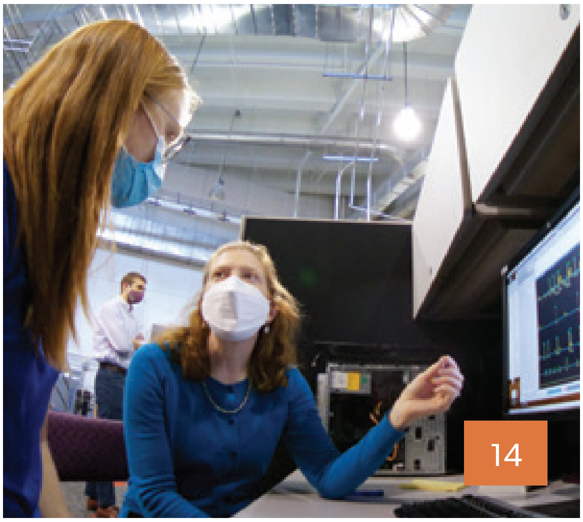


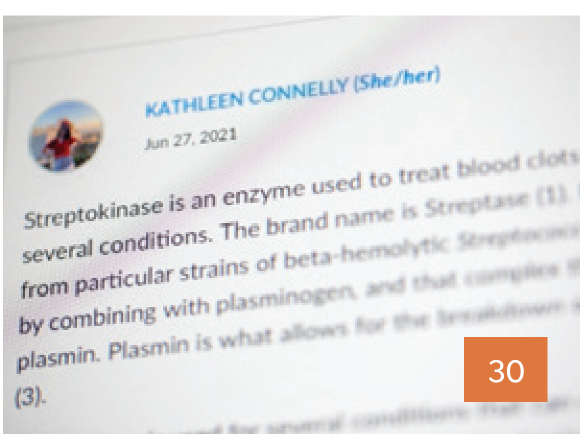
This confocal microscope image depicts a human neuronal organoid — a minute assembly of human brain cells — growing on a patterned substrate. The axons (green and yellow strands), which conduct electrical impulses throughout the body, primarily grow within the dark channels, avoiding boundaries established by an inhibitory protein (red stripes). At top, beyond the guidance of the protein stripe pattern, the axons extend randomly.

The image was produced by Timothy Catlett PhD'19 and Timothy Gomez, a professor of neuroscience in the UW School of Medicine and Public Health, as part of a study testing the effects of autism-causing mutations on axon growth and guidance. Another image from the study was selected as a winner of UW's Cool Science Image Contest.

Image by TIMOTHY CATLETT and TIMOTHY GOMEZ







Wisconsin's Magazine for the Agricultural and Life Sciences

grow

VOLUME 15, ISSUE 2 | SPRING 2022

FEATURES

DEPARTMENTS

ON THE COVER As the sun sets at Rhinelander Agricultural Research Station, potatoes not selected to advance in breeding trials lie in a field after harvest. Explore more of the research stations on page 20. Photo by MICHAEL P. KING

Photos, from top, by ROBIN DAVIES, MICHAEL P. KING (2)

Photo by MICHAEL P. KING

DEAN KATE VANDENBOSCH

A Final Tally for All Ways Forward . . . and a Thank You

In "A Look Back on a Campaign for the Future" (*Grow*, Fall 2021), managing editor **Nik Hawkins** offered a glimpse of what CALS has been able to achieve with gifts garnered during All Ways Forward, the largest comprehensive campaign in UW–Madison's history. We were given a sampling of stories from the perspectives of donors and beneficiaries alike, and we learned what generosity combined with hard work and ingenuity can accomplish.

For those who need a refresher on the campaign, here's a little background. In fall 2015, UW set an ambitious goal to raise $3.2 billion by the end of the decade. Although UW is a public university, fundraising has become more critical than ever to its mission, and to that of CALS. Private funding is one of the largest pieces of the university's fiscal pie — more than state revenue, more than federal financial aid, and just slightly below what the university gathers in both tuition and federal grants. Private financial support lets us do things we otherwise couldn't do, whether that's with facilities or faculty, students or programs.

For a moment or two at the onset of the COVID-19 pandemic, we thought we would have to dial back our expectations, but an extra campaign year put things back on track — and then some. We shared some impressive numbers back in the fall. But, as of December 2021, All Ways Forward officially came to an end, and now we have final figures in hand. You see them for yourself displayed on this page.

Clearly, the campaign was a resounding success. For this spectacular commitment to the future of UW and CALS, we owe our thanks to many, many dedicated alumni, donors, and friends. You have our everlasting gratitude and the promise that we will keep working hard to make the most of your investment.

All Ways Forward Fundraising by the Numbers

UW

$4.2B RAISED

265K DONORS

CALS

$177.3M RAISED (18% beyond $150 million goal)

13.3K DONORS

$33.6M RAISED FOR FACILITIES

$32.8M RAISED FOR PLANNED GIFTS

$109K RAISED FOR QUICKSTART
An early-start program for first-year CALS students

$4.8M RAISED FOR CALS FUND
A versatile pool of resources that helps the college quickly adapt and respond to emerging needs

$23.4M RAISED FOR FACULTY SUPPORT

$18M RAISED FOR RESEARCH SUPPORT

$18.5M RAISED FOR STUDENT SUPPORT

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Six Key Facts about Lab-Grown Meat

Plant-based protein and "meat-alternative" products have streamed into the marketplace in recent years. This trend has been driven in part by world population growth and the quest to meet the increased demand for protein that comes with it. It also stems from the search for options perceived as more sustainable or environmentally friendly than animal-based protein. Another new product on the horizon is lab-grown meat, also known as cell-cultivated or cultured meat. Here are a half dozen facts about cultured meat for the curious consumer.

By JEFF J. SINDELAR

1. Cultured meat is a relatively new idea (about 20 years old) but uses technology that's been around for more than a century.

It involves gathering cells from an animal and raising them in a bioreactor, a typically stainless-steel vessel with the proper environment for growing tissues. The end goal is to produce food that closely mimics meat products traditionally derived from harvesting animals.

2. Cells used for cultured meat can be derived from various kinds of stem or precursor cells. These cells are found in animal embryos, bone marrow, or muscle tissue.

Suitable cell lines are selected from a tissue biopsy and then transferred to a bioreactor. Next, the animal cells are cultured (this involves cell isolation, growth, differentiation, and maintenance) in a bioreactor's controlled environment, which is sterile, warm, and humidified and contains abundant nutrients.

3. After the cells are grown, they can be used as raw food materials in unstructured meat products or used to develop 3D structured tissues.

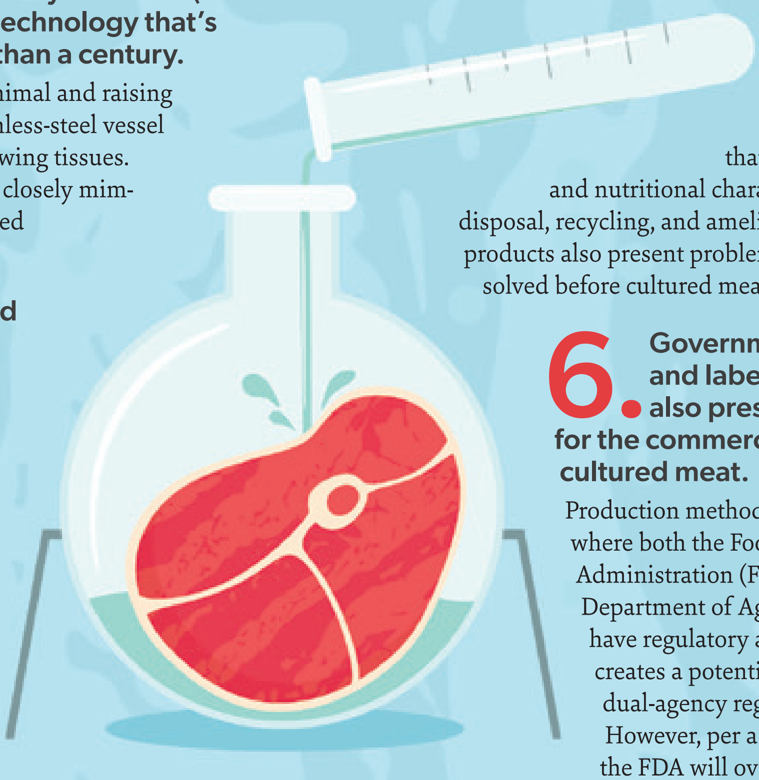
Unstructured meat products include chicken nuggets and hamburgers. Common examples of 3D structured tissues are steak and pork chops. 3D tissue structuring — also called tissue engineering or tissue synthesis — embeds cells within a scaffold that simulates connective tissue. These living tissues are matured in another bioreactor to form simulated meat products.

4. While the concept of producing cultured meat is simple, the implementation has proven to be very challenging.

Cultured meat is not yet available for consumer purchase at retail or food service outlets primarily because the technology is still in the discovery stages. And the industry continues to face several hurdles, technological and otherwise.

5. Scaling up the cell cultivation process is one of the biggest barriers to the production of cultured meat.

Manufacturers are looking for ways to reduce expenses, including the costs of cell-growth media and the operation of large-scale biomanufacturing facilities. They also face difficulties in developing cell lines that can be propagated indefinitely and that have specific taste and nutritional characteristics. The disposal, recycling, and amelioration of waste products also present problems that need to be solved before cultured meat can go to market.



6. Government oversight and labeling regulation also present challenges for the commercialization of cultured meat.

Production methods span areas where both the Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA) have regulatory authority. This creates a potentially complicated dual-agency regulatory approach. However, per a recent agreement, the FDA will oversee cell collection and propagation up to the point of harvesting, and the USDA will be responsible for all aspects of the end product, including food safety and labeling. That said, no decisions have been made on the appropriate labeling terms to be used for cultured meat, poultry, and seafood. So the official names we may see in the marketplace are anybody's guess.

Jeff J. Sindelar is professor and extension meat specialist with the Department of Animal and Dairy Sciences and an affiliate faculty member of the Food Research Institute.

Illustration by JANELLE JORDAN NAAB, iSTOCKPHOTO.COM/EKATERINA VAKHRAMEEVA

HANNAH VANDERSCHEUREN

Fertilizer's Fungal Effects

A biology major probes an underappreciated kingdom for insight into how nitrogen pollution harms forests.

By JORI SKALITZKY BSx'22

When excess fertilizer leaches out from croplands and urban lawns, nitrogen and other elements pollute the environment. Extensive research shows the damage that nitrogen pollution causes to soils, forests, and waterways. But a lesser-known victim — fungi — remains understudied despite its importance to healthy forest ecosystems. Undergraduate researcher **Hannah Vanderscheuren** BSx'22 is determined to change that.

Vanderscheuren's fascination with fungi can be traced back to when she first opened a basic biology textbook and laid eyes on a nutrient cycling diagram. She was captivated by the complexity of carbon and nitrogen cycles — the paths these elements follow through ecosystems. "But I wondered: What does that mean on the ground?" says Vanderscheuren. "It turns out that fungi are the way to study that." At CALS, Vanderscheuren learned that the organisms in this large kingdom, which includes yeasts, molds, and mildews, are important components in the cycles that captivated her.

Now a senior pursuing a bachelor's degree in biology, she is exploring fungi and nutrient cycling in the laboratory of UW botany and bacteriology professor **Anne Pringle**. Vanderscheuren has contributed to multiple projects in the lab, but thanks to funding from a Holstrom Environmental Research Fellowship, she's now leading her own fully funded study (with mentorship from Pringle).

Vanderscheuren's research is inspired by an ongoing project on the East Coast, the Chronic Nitrogen Amendment Study (CNAS), where scientists are looking at the effects of excess nitrogen in forest ecosystems through the lens of fungi.

"Fungi are a part of the global carbon cycle, but in ways that are less appreciated," says Pringle. "They underpin a lot of ecosystem processes."

One of these processes is decomposition. Fungi are responsible for breaking down organic matter, which releases nutrients into the environment. Plants then use these nutrients to grow.

But in nitrogen-polluted systems, such as the CNAS forests, fungi composition is changing, and organic matter is building up. Species that specialize in breaking down lignin are decreasing in abundance, while species that specialize in breaking down cellulose are increasing. (Lignin and cellulose are both important structural molecules found in plants.) As a result, the compositions of both forest plants and fungi are changing, which depletes the productivity and functionality of forest ecosystems.

To complement research from CNAS, Vanderscheuren is looking at one species of Ascomycete fungi and how it physically responds to elevated nitrogen levels. In particular, she focuses on hyphae — long, branching, filamentous structures that serve as the main mode of growth for fungi — and compares the growth rates of nitrogen-exposed hyphae and nitrogen-free hyphae.

By studying fungal growth, Vanderscheuren hopes to fill gaps in the current CNAS research. CNAS researchers have shown that fungi compositions in forests are changing, but they are unsure of the mechanisms behind it. If Vanderscheuren's work reveals that nitrogen-exposed fungi grow differently than her control group, this could provide a new direction for CNAS.

Vanderscheuren plans to present her research at the 2022 Mycological Society of America annual meeting. She'll also share her work with the campus community through the CALS Undergraduate Research Symposium.

As she continues to spend long hours in the lab tending her fungi, Vanderscheuren looks hopefully to a future with greater appreciation for the impact of these little organisms. "There is so much to learn about fungi and the human-induced changes to nutrient cycling," she says. "The more people interested these subjects, the better."

Biology major Hannah Vanderscheuren displays petri dishes containing *Trichoderma koningiopsis*, a fungus she studies, in Anne Pringle's lab at the Microbial Sciences Building. Photo by MICHAEL P. KING

Innovative Tech Captures Carbon — and a Big Prize

A UW team developing a method to pull carbon dioxide from the air and turn it into a cement alternative is among the winners of a Musk Foundation competition.

By JOCELYN CAO BS'21

Cut greenhouse gas emissions and stave off the harmful effects of climate change. It's one of the most important challenges we face today. And it's no small feat. On our current trajectory, many fear the planet faces an imminent "too little, too late" scenario. A new approach is needed.

Fortunately, there's hope, and it comes in the form of an innovative technology created by a team of UW students and professors. They've been working on a way to take carbon dioxide, the most common greenhouse gas, out of the air and seal it away where it can't contribute to rising global temperatures.

In November 2021, the team was selected as one of the top winners of the XPRIZE Carbon Removal Student Competition. The contest aims to kickstart projects that could mitigate the impacts of climate change by removing carbon dioxide from the air, ground, and oceans. The UW team, which includes members from CALS, received $250,000 — the largest available award in the student competition — to fund their continued work.

"We are really excited about our technology, and it's cool to be working on something that has the potential of scaling up in a big way and actually have an impact," says team leader **Keerthana Sreenivasan**, a graduate student in civil and environmental engineering.

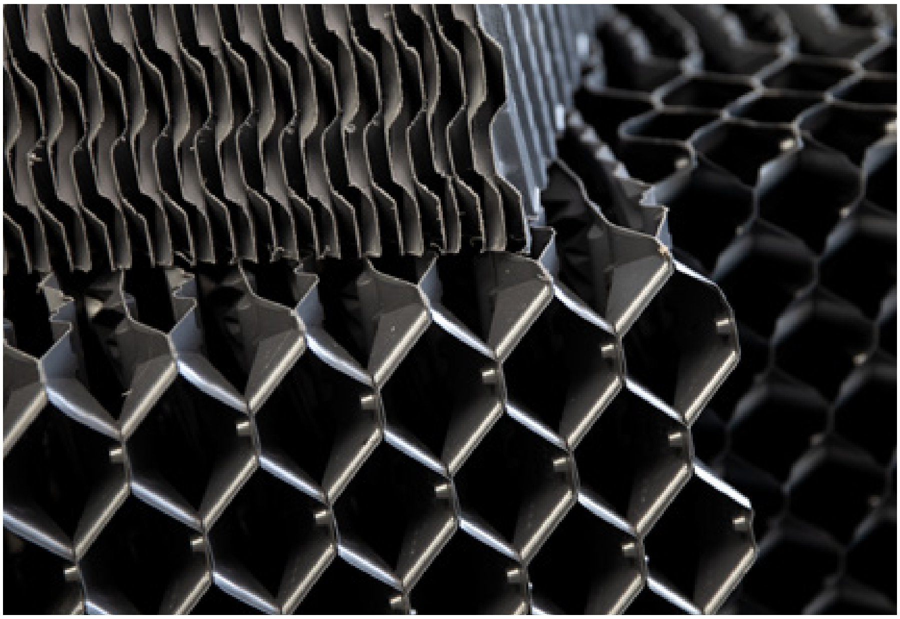
The student challenge is part of the larger $100 million XPRIZE Carbon Removal competition supported by the Musk Foundation, a nonprofit research foundation established by entrepreneur **Elon Musk**. The multiyear global competition is designed to fund early-stage carbon removal concepts, and Musk encourages teams to "build real systems that can make a measurable impact and scale to a gigaton level."

With the new funding, the UW group can develop its project as the competition advances to subsequent rounds.

"This is just the first step. We have great hopes for the next phase of the XPRIZE Carbon Removal competition," says **Rob Anex**, a professor of biological systems engineering in CALS who advises the team with **Bu Wang**, an assistant professor of civil and environmental engineering.

Seunghyeon Jung PhD'21, at the time a biological systems engineering graduate student, left, and Evan Schmid, a biological systems engineering undergraduate student, work on a direct air capture unit in a lab at the Wisconsin Energy Institute at UW–Madison in November 2021. The two are part of a team that is one of the top winners of the XPRIZE Carbon Removal Student Competition.

Photo by MICHAEL P. KING



Detail of the packing materials used in a direct air capture unit being developed by a UW–Madison team. The system aims to remove carbon dioxide from the air to mitigate the impacts of climate change.
Photo by MICHAEL P. KING

The team is developing a two-part system that consists of a direct air capture (DAC) unit that traps carbon dioxide from the air plus a carbonization component that converts the captured CO2 into limestone particles. It's an idea Anex and Wang have long discussed.

"Bu and I had been working on the basic concept for a while, and then XPRIZE for Carbon Removal came around, which is really about taking an idea and being able to turn it into an engineering system that works and scale that up," says Anex. "Then we talked to some of our students, and they decided that they should come up with a team."

Team member **Seunghyeon Jung** PhD'21, recently a CALS graduate student in biological systems engineering, has been focusing on building the team's lab-scale DAC unit, which relies on specialized materials and a simple chemical reaction to capture CO2 from the atmosphere.

"We flow a hydroxide solution over the packing material while blowing air over the surface," says Jung, now a research associate in the UW College of Engineering. "The chemical reaction on the surface captures carbon in the form of carbonate ions."

From there, the carbonate solution goes into the carbonization component, where it is combined with ash or slag, byproducts of industrial furnaces like those in coal-fired power plants or steel mills. What comes out is a carbonated powder that includes fine limestone and activated silica particles, which can be used in construction in place of cement. A hydroxide byproduct of the limestone-forming step is recycled back into the DAC unit to capture more carbon dioxide.

"In essence, we're converting carbon dioxide from the air into carbonate minerals that can be upcycled into construction materials, all under ambient conditions," says Wang, who holds a patent related to the carbonization part of the system.

The team includes six graduate students and two undergraduates from across the UW campus. As it moves forward in the XPRIZE contest, which runs through Earth Day 2025, members will further refine the system, figure out how to scale it up, and develop a plan for its implementation. For those involved, notes Anex, there's value beyond competing and succeeding in the XPRIZE competition.

"Students learn a lot about building things, running experiments, working in teams, and making presentations. And they gain a lot of experience and maturity," he says. "Some of these students might make a career out of this. It's an important problem, and I'd love to see a bunch of them work on solving some of the big environmental problems that face the world."

For sophomore **Evan Schmid**, being a part of the project has a dual appeal. He feels good about working toward a solution for one of the world's most difficult challenges; and while he's at it, he accumulates practical experience and skills.

"Whenever you're in a hands-on engineering environment, you get to learn about the process so much — just seeing it play out in front of you," says Schmid, a biological systems engineering major. "There are things about engineering that you can't learn from a book or that sometimes you just have to do. You see how things happen in the real world."

EXPLORE ONLINE

Read more about XPRIZE Carbon Removal at **xprize.org/prizes/elonmusk**.

NUMBER CRUNCHING

In 2019, global emissions reached the equivalent of **59 gigatons of carbon dioxide**, according to the United Nations. A gigaton is 1 billion tons. The Musk Foundation's multiyear XPRIZE Carbon Removal competition incentivizes participants to submit carbon-removal systems and concepts that can scale to this level.

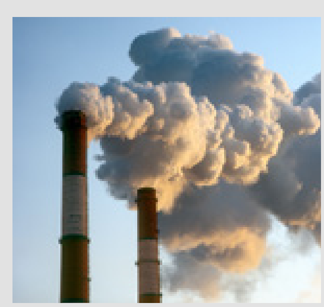


Photo by SHUTTERSTOCK

Illustration by ISTOCK; modified by JANELLE JORDAN NAAB

Was 'Flatten the Curve' Effective?

The catchy phrase and infographic may not have changed pandemic attitudes, but the message still yielded benefits.

By ERIC HAMILTON

Early in the COVID-19 pandemic, one message became ubiquitous: "Flatten the curve."

Tied to a simple yet compelling chart of infections over time, with and without interventions, the message encouraged people to socially distance to delay and reduce the peak of infections. The idea was to prevent hospitals from becoming overwhelmed.

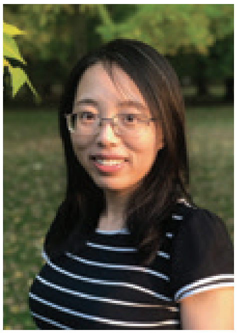
The message spread far, reaching nearly three-quarters of Americans by August 2020, according to a recent study by assistant professor of life sciences communication **Nan Li** MS'11, PhD'15 and doctoral student **Amanda Molder**. But the study also shows that awareness of the flatten-the-curve graphic did not predict people's willingness to engage in social distancing. Nor did it forecast their belief in society's ability to control the course of the pandemic.

FINDINGS

HEALTHIER PRISONERS, SAFER COMMUNITY

The presence of a state prison in a county was associated with 11% more COVID-19 cases during the spring and early summer of 2020, according to a nationwide study by researchers in the Department of Agricultural and Applied Economics. The findings suggest that prisons can acquire, incubate, and amplify outside diseases and then spread them to surrounding communities. The key takeaway is that **prioritizing the health of prison populations and surrounding communities ensures better protection for all**.

Photo by SHUTTERSTOCK



Nan Li

The message, however, may have had another effect. According to the study, people who had seen the widespread chart relied less on their trust in scientists when determining how controllable the pandemic was. This suggests that the "flatten the curve" message might have armed them with the knowledge they needed to draw their own conclusions about social distancing measures without needing to rely as strongly on trusting experts.

"This chart became the visual mantra that defined the initial pandemic response in the U.S.," says Li. "Although we didn't see a difference in people's ideas or behavioral intentions based on their awareness of the chart, the message is still beneficial because there's some evidence that it allowed people to form a more informed decision without relying on trust."

The first version of the chart and the phrase "flatten the curve" appeared in a 2007 report from the Centers for Disease Control and Prevention (CDC) about ways to control the spread of a pandemic. With interventions such as social distancing and mask wearing, the CDC said, the peak of infections could be delayed and lowered, and the total number of infections could be reduced.

In February 2020, *The Economist* printed a modified version of the chart showing the delay and lowering of peak infections. However, the magazine removed the CDC's message that preventative measures could also reduce the total number of infections, instead focusing on not overwhelming hospital capacity.

Population health educator **Drew Harris** adapted *The Economist*'s chart to share on Twitter. He added a dotted line representing the capacity of the health care system, further emphasizing this capacity-based goal.

The message took off. The Instagram hashtag #FlattenTheCurve was shared more than a million times, and Google searches for the phrase soared.

Li and Molder predicted that the chart's simplicity would help people understand the benefits of interventions such as social distancing. To test this idea, they surveyed a representative sample of 500 American adults in July and August 2020 and asked them whether they had ever seen the chart. The survey also asked respondents to rate the effectiveness of social distancing measures, how controllable they thought the pandemic was, and their trust in the CDC and other scientists.

More than 70% of respondents said they were very likely to engage in social distancing, while about 40% thought that the pandemic could be brought under control with these interventions. When asked who they trusted, people ranked medical professionals ahead of other scientists and the CDC.

While 74% of adults said they were aware of the chart, this awareness did not correlate with their intention to engage in social distancing or their belief in whether interventions could control the pandemic.

Li says that the timing of the survey, which was during a summer surge in cases, combined with the ubiquity of both the "flatten the curve" message and social distancing measures, make it difficult to determine the true effect of the infographic.

"I would suggest that people not underestimate how effective the chart was based on this finding alone, because the popularity of this chart itself is strong evidence of how important the message was and how critical it is for scientists to send the right message out about something like this," she says.

That the "flatten the curve" graphic reached so many people shows the power of simple, strong, visual messages, says Li. Although the most popular versions of the chart removed messages about reducing the overall case numbers of COVID-19, the graphics' focus on protecting hospital capacity seemed to connect strongly with people who could envision their local hospitals filling up.

"I think scientists should definitely do more of this kind of visual messaging," says Li. "Who knows, maybe it will save a lot of lives."

This study was published in August 2021 in the journal *Public Understanding of Science*.

PANDEMIC UNEMPLOYMENT DISPARITY

An analysis of counties in Michigan, Minnesota, and Wisconsin revealed that **those more reliant on dairy and animal agriculture experienced higher unemployment rates during the COVID-19 pandemic than counties more reliant on crops**. The study, co-authored by assistant professor Andrew Stevens and professor emeritus Daniel Bromley in the Department of Agricultural and Applied Economics, suggests that rural communities that rely heavily on hired agricultural or food processing labor will require more robust public safety nets to deal with future crises.

MONEY-SAVING INNOVATION FOR MEAT INDUSTRY

In 2017, in an effort to better control *Salmonella*, the federal government issued new guidance on minimum humidity levels during meat and poultry cooking. The change presented problems for processors using certain dry-heat ovens. In response, **a team at the Food Research Institute worked with meat industry advisors to design, test, and validate a new steam injection method called hydrated surface lethality (HSL)**. HSL meets the new guidelines without expensive equipment replacements or modifications.

Adaptable Aspens

A long-term look at aspen forests shows they maintain the genetic diversity needed to adjust to changing environments.

By ERIC HAMILTON

Sunlight filters through leaves on aspen trees in the Aspen Competition Garden at Arlington Agricultural Research Station in September 2021.

Photo by MICHAEL P. KING

Watching paint dry has nothing on watching a forest grow. That achingly long wait has always made it challenging to study how forests adapt to environmental fluctuations. As a result, it's hard to predict how forests will fare, for example, in a changing climate or under pressure from new pests.

That's why a group of CALS researchers took the long view. Their recently concluded study — 10 years in the making — reveals how aspen stands change their genetic structure over time as trees balance pest defense with growth.

When faced with stiff competition, trees genetically predisposed to prioritize growth fare better as they win the battle for sunlight. But the survivors are less equipped to handle damaging insects. The experiment demonstrates how evolutionary forces can quickly shape entire forest stands. It also suggests that a litany of environmental changes can promote diverse forests capable of responding to different stresses.

"What this work has done is show how key traits, like growth and defense, can be coupled together and how genetic diversity will allow populations to adapt to new stresses," says **Rick Lindroth**, a professor of entomology who supervised the study.

Aspen is the most broadly distributed tree species in North America, and it's a bellwether for how forests will adapt to an onslaught of human-influenced environmental changes. The species often colonizes disturbed environments, including the barren landscapes that appear after wildfires, such as those in western North America in recent years. Thousands of trees will germinate in a small area, and the race begins to grow tall enough to escape the shade of their neighbors. This intense competition quickly selects for winners and losers.

Lindroth, along with collaborators **Eric Kruger**, professor of forest and wildlife ecology, and **Ken Keefover-Ring**,

FINDINGS

A PROTECTED FOREST'S BEST DEFENSE: MORE FOREST

A research team led by Zuzana Buřivalová, assistant professor of forest and wildlife ecology, conducted a satellite imagery analysis of trends in forest loss from 2000–2018 in all the world's protected forests and nearby territories. They discovered that **when more than 90% of a boundary zone remains forested, the protected area is likely to experience little or no deforestation**. When the adjacent territory drops to about 20% forest cover, however, the protected area starts to lose forest cover at equal rates to the nearby unprotected region.

Illustration by SHUTTERSTOCK

professor of botany and geography, simulated this environment by planting young seedlings in dense stands at UW's Arlington Agricultural Research Station. Then, they removed three-quarters of the seedlings in half the plots, which produced two types of tree stands: one with high levels of competition for sunlight and one with low levels.

Some trees were genetically predisposed to prioritize growth, while others put their resources into producing protective chemicals that deter attacks by insects and mammals. When the trees were five years old, **Olivia Cope**, a doctoral student in the Department of Integrative Biology at the time, started tracking how fast the trees grew and which survived for the next five years.

The scientists saw that the more trees focused on defense, the less they grew. The shorter plants were more likely to die as they were shaded out by their taller neighbors. By the end of the study, the tallest trees towered more than 40 feet; the shortest surviving trees were just seven feet tall.

"Because plants grow exponentially, a little bit of difference in height early on allows them to capture more light, and that difference in height can magnify over time," says Lindroth.

Because the defense-focused trees died more often, the genetic structure of the forest stands changed over time. Trees with fast-growing genetics came to dominate, especially in the densely planted and highly competitive plots. Over time, this divergence meant the low-competition stands and the high-competition stands developed different genetic structures.

During the study period, there was little insect damage on the trees. But during 2021, the invasive moth *Lymantria dispar* ate through almost all the leaves of a nearby experimental aspen stand. The researchers expect that similar periodic waves of pests would reward those aspen forests that balance growth with sufficient defense. This balancing act should help create a diverse forest capable of meeting changing threats.

"You have this shifting dynamic because of a changing environment that ultimately selects for the maintenance of diversity within a population," says Lindroth. "If that diversity has a genetic basis, the reason it can be maintained is that under some conditions one trait may be beneficial whereas under other conditions it may not be."

The study's findings are valuable for conservation biologists who want to preserve diverse forest ecosystems in the face of global warming, invasive species, and other environmental changes.

Lindroth, Cope, Kruger, and Keefover-Ring published their findings in September 2021 in *Proceedings of the National Academy of Sciences*. This work was supported by the U.S. Department of Agriculture (Grant WIS01842) and the National Science Foundation (Grants DEB-1456592 and DGE-1747503).

Aspen tree leaves begin to change color in the Aspen Competition Garden at Arlington Agricultural Research Station in September 2021.

Photo by MICHAEL P. KING

FOLLOW-UP

THE QUEST FOR SELF-FERTILIZING CROPS

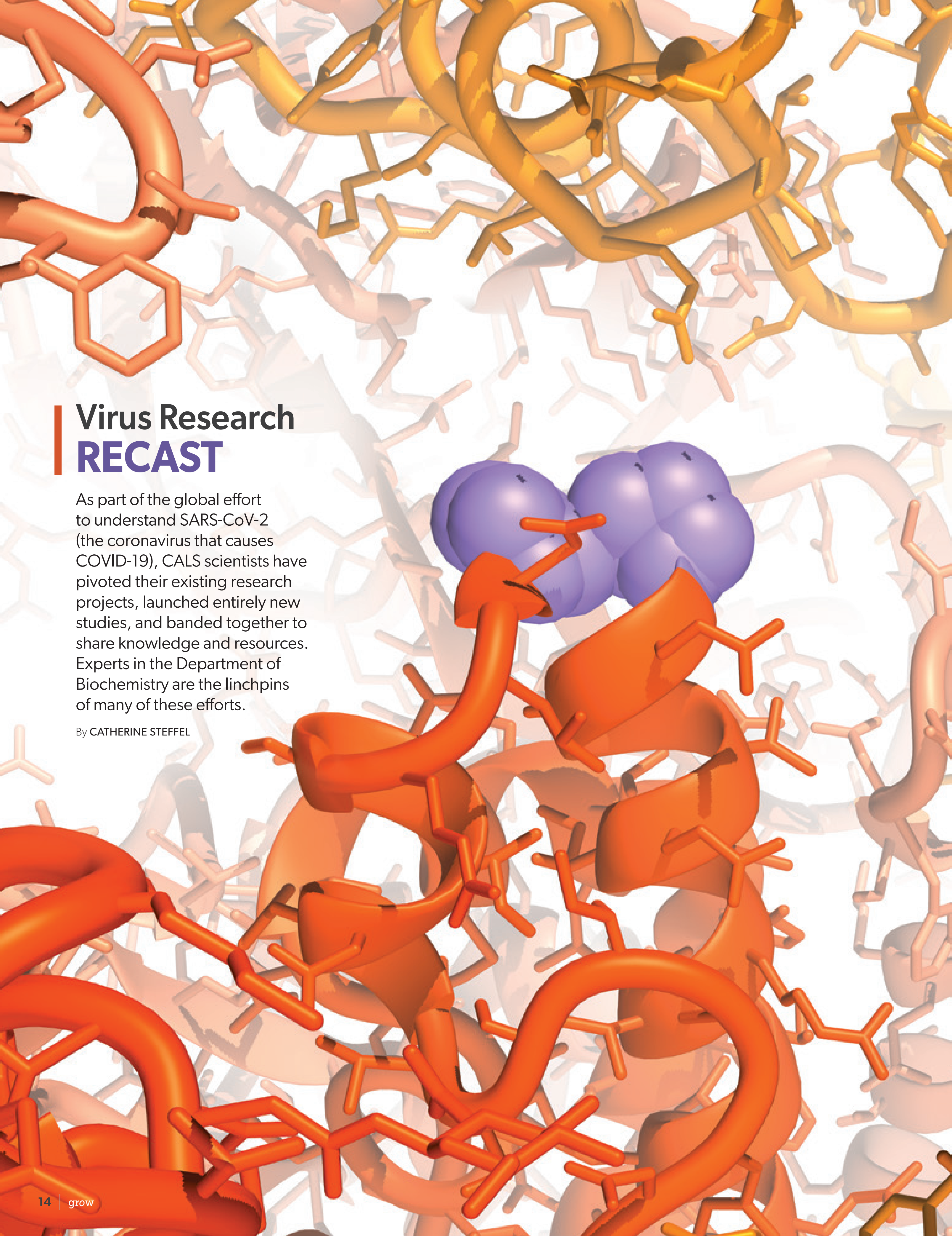
In the fall 2020 issue of *Grow*, **Eric Hamilton** highlighted a team of CALS scientists and their search for alternatives to synthetic crop fertilizers. The group is studying a possible substitute found in a variety of corn that indigenous Oaxacan communities have cultivated for centuries. The corn's aerial roots exude a viscous, slime-like gel, and the gel hosts bacteria that "fix" nitrogen (i.e., convert it into a usable form for plants). Preliminary experiments suggest that approximately 10% of these bacteria help the corn fix 30–80% of its nitrogen.

To identify what the remaining 90% of the bacteria do, and to improve nitrogen fixation in other plants, one of the scientists, agronomy and bacteriology professor **Jean-Michel Ané**, has teamed up with **Ophelia Venturelli**, assistant professor of biochemistry. Venturelli's team aims to use computational modeling to identify microbial properties important to nitrogen fixation that scientists might not discover through less targeted approaches. They will also study nitrogen-fixing behavior in the lab by introducing different bacteria into microbial communities and observing microbe-to-microbe interactions.

Venturelli's team will apply these tuned microbial blends to both cross-bred and native crop varieties. In the future, farmers may see a shift toward fertilizers with gel-based sources of nitrogen.

–Catherine Steffel

Photo by MICHAEL P. KING



Virus Research
RECAST

As part of the global effort to understand SARS-CoV-2 (the coronavirus that causes COVID-19), CALS scientists have pivoted their existing research projects, launched entirely new studies, and banded together to share knowledge and resources. Experts in the Department of Biochemistry are the linchpins of many of these efforts.

By CATHERINE STEFFEL

It was a quiet evening in 2012, and Robert Kirchdoerfer BS'06 was missing yet another dramatic sunset over the Pacific Ocean. But it didn't bother him much. He had stumbled upon a riveting article, one that would guide his research for the next decade and contribute to lifesaving COVID-19 vaccines and therapeutics.

The paper reviewed how coronaviruses make copies of their viral genomes. At 26,000 to 32,000 bases, or nucleotides, in length, the seven coronaviruses known to infect humans have the largest known RNA virus genomes. How each coronavirus enters and replicates in cells is unique and extraordinarily complex, involving dozens of proteins and myriad processes.

Kirchdoerfer, then a postdoctoral researcher at The Scripps Research Institute in La Jolla, California, was intrigued by our limited knowledge of these viruses. Coronaviruses bring about common colds, but they also caused outbreaks of severe respiratory illnesses in the early 21st century and recently triggered the COVID-19 pandemic. As a structural biologist by training, Kirchdoerfer felt he could further our understanding by imaging virus structures (i.e., showing what virus components look like in three dimensions) and studying how these structures interact.

"After the SARS outbreak in the early 2000s, we knew a lot about coronavirus RNA synthesis structural biology," Kirchdoerfer recalls. "We had imaged these structures, and they were supposed to be contributing to our idea of how coronavirus RNA formation worked. But we didn't know the structure of the RNA synthesis machine itself, and I thought that was a rather glaring hole in our overall understanding."

Research suggested that new coronaviruses would emerge in the future, so Kirchdoerfer decided to focus on how these sometimes dangerous and always enigmatic viruses ensure their survival by entering and replicating in host cells. He and his colleagues surmounted well-known challenges in structural biology over the next 10 years. What they would learn would directly contribute to the fight against COVID-19.

Fortuitous Innovations

Soon after reading that life-changing article in 2012, Kirchdoerfer received a note from a friend at Scripps, Andrew Ward. Ward suggested that they work together to image coronavirus spike proteins, which are key to the virus's ability to attach to and infect healthy cells. Though he'd originally intended to study the RNA synthesis machinery needed after a virus fuses with a host cell, the idea of exploring the spike protein (one of four external proteins in coronaviruses) was too compelling for Kirchdoerfer to pass up.

That's in part because no one knew what complete coronavirus spike proteins looked like. Previously, scientists had passed X-rays through crystalline forms of spike proteins to create images of these structures. With this technique, called X-ray crystallography, they could only study *regions* of spike proteins — they didn't know what complete spikes looked like. Also unknown at the time: how spikes interact with other virus components to transport coronavirus genomes into host cells.

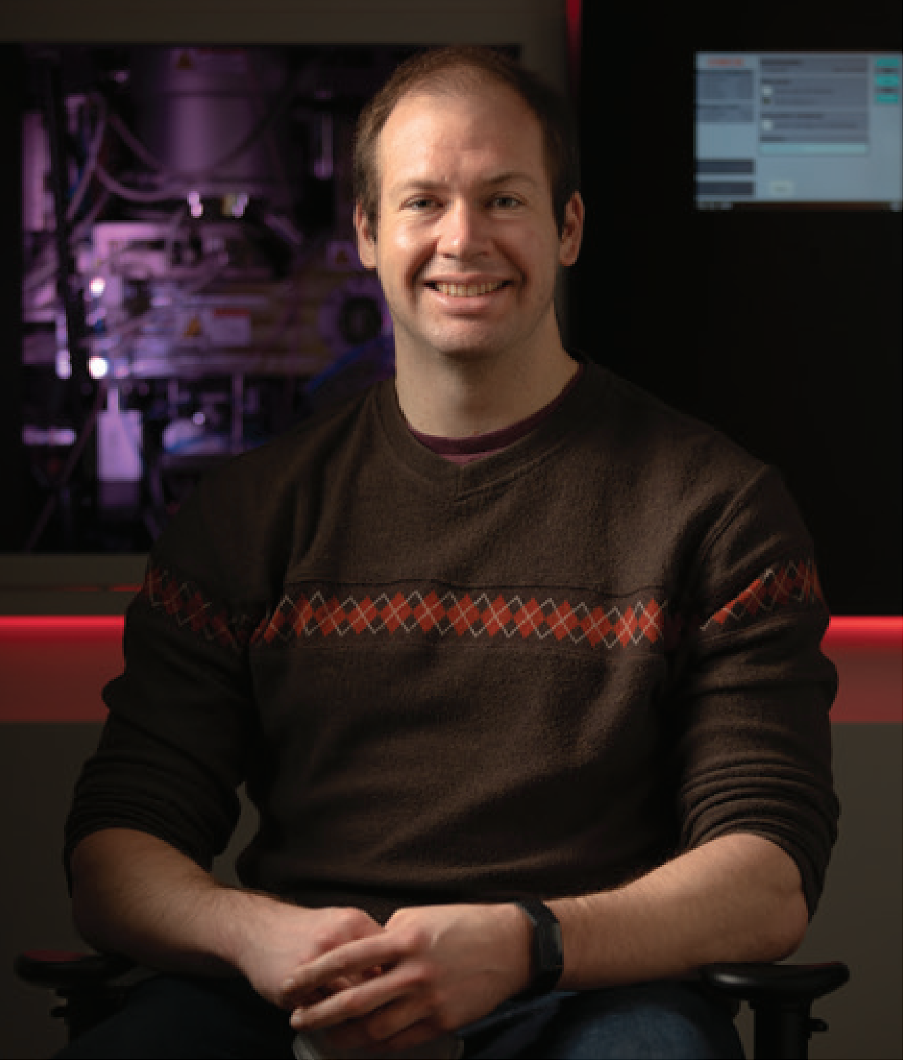
Developments almost half a century in the making changed the game. Transformed by advances in detector technology and software, a technique called cryogenic electron microscopy (cryo-EM) could image the natural state of complete spike proteins at near-atomic scales, no crystals required.

"A lot of the strengths for looking at viruses with cryo-EM are the general strengths of the technique," Kirchdoerfer says. "You don't need a crystal, and it's great for larger complexes. With cryo-EM, so much of the data is handled computationally that we can access even the moving regions of coronaviruses."

The first coronavirus spikes Kirchdoerfer imaged came from HKU-1, a coronavirus that causes symptoms resembling the common cold but can progress to pneumonia and other respiratory illnesses. He was also eager to image the spike proteins from two public health threats, MERS-CoV and SARS-CoV. (These coronaviruses, respectively, caused outbreaks of Middle East respiratory syndrome in 2012 and severe acute respiratory syndrome in 2003.) The catch was that the spikes from MERS and SARS are unruly — they rapidly change configurations so that antibodies can't stick to them, and they are difficult to make in a lab setting. But after one more year of hard work, inspiration struck.

Another of Kirchdoerfer's and Ward's collaborators, Jason McLellan, had an idea. A molecular bioscience professor at Dartmouth College at the time (now at the University of Texas at Austin), McLellan was motivated by work on other viruses, such as HIV. This prompted him and colleagues in his lab to team up with Barney Graham at the National Institutes of Health Vaccine Research Center, and together they took an innovative step in spike protein research. They substituted amino acids

This image, constructed from data gathered through cryogenic electron microscopy (cryo-EM), shows the substitution of two amino acids called prolines (in purple) into the SARS-CoV-2 spike protein. The innovative modification set the stage for improved imaging of the virus and spurred the creation of coronavirus vaccines. Image courtesy of ROBERT KIRCHDOERFER



called prolines into the spike protein, which kept the spike in a single configuration. They also boosted the amount of the protein that can be produced in the lab. Finally, the MERS and SARS spike proteins were ready for cryo-EM imaging.

A COVID-19 Vaccine

By fall 2019, Kirchdoerfer had returned to his research roots, his home state, and his alma mater. He had been an undergraduate during his first stint at the Department of Biochemistry; this time, the Oregon, Wisconsin, native came back as an assistant professor. A few months after his homecoming, his spike protein structures and nascent coronavirus research lab were thrust into the spotlight.

Robert Kirchdoerfer, assistant professor of biochemistry, used the Talos Arctica cryo transmission electron microscope (background) at the UW–Madison Cryo-EM Research Center to image coronavirus protein structures.
Photo by MICHAEL P. KING

"When we added these two prolines in the spike protein, they improved the amount of protein we got in the lab," says Kirchdoerfer, who was first author on the resulting paper about the SARS spike protein. "In a vaccine, they could help make more stable spike proteins to raise antibodies and combat infection. That was really the push to put the modified spike protein into vaccine candidates — the antibodies that you make with a spike [that is] stabilized with prolines could make a higher antibody response than just a regular spike from infection."

The scientists' ingenious modification of the spike, which they had used to image spike protein structures from MERS and SARS, had also resulted in plans for a MERS vaccine with clinical trials led by Moderna. When the COVID-19 pandemic hit, these efforts were redirected to SARS-CoV-2, the virus that causes COVID-19.

"The Moderna COVID-19 vaccine was turned around so quickly because there was a vaccine for MERS already in the pipeline," Kirchdoerfer says. "People could pull up our first SARS structures and say, 'This is what we think SARS-CoV-2 is going to look like,' and that was borne out by additional studies." (The genome sequence identity for spike proteins in SARS and SARS-CoV-2 is around 80%, high enough to be similar in structure.)

Moderna, Pfizer, Johnson & Johnson, and other pharmaceutical companies use similar strategies to make COVID-19 vaccines with stabilized spike proteins as an active ingredient. Ongoing research will reveal whether substituting more prolines can make the spike even more immunogenic.

INTRO TO CRYO-EM

In cryo-EM, proteins are placed on grids that are the size of a pencil eraser. The grids are rapidly submerged in liquid ethane, which immobilizes individual particles in random orientations. The frozen grids are then placed in the cryo-electron microscope, where several hundred to several thousand images are collected. Images are turned over to computers, which isolate each particle and digitally combine them to reconstruct a 3D picture of a biomolecule. For more, see "A Cold, Hard Look at Macromolecules" in *Grow*, Spring 2021.

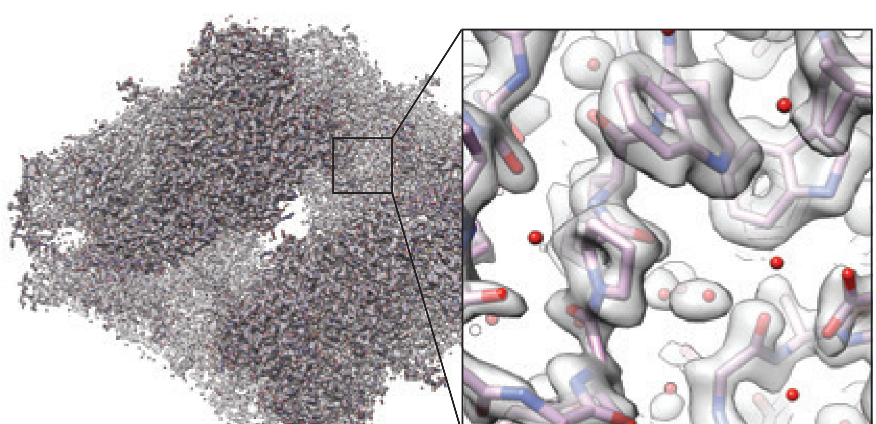


Image courtesy of THE UW–MADISON CRYO-EM RESEARCH CENTER

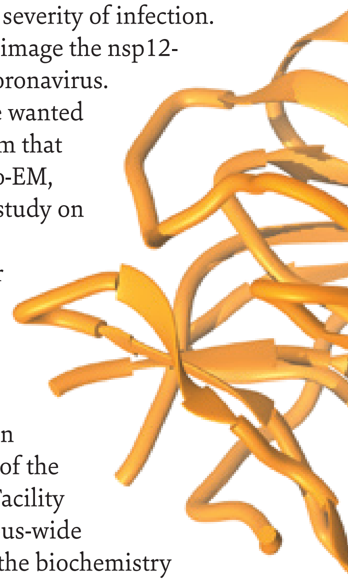
Kirchdoerfer is now known around the UW campus as "the coronavirus guy" for his expertise and collaborative nature. He synthesizes results from several state-of-the-art technologies and multiple disciplines to create a more precise map of what SARS-CoV-2 proteins look like and how they interact. Together, he and his colleagues at UW are demonstrating just how much we have yet to learn about SARS-CoV-2. Every research study, every experiment informs another, and lives hang in the balance.

Complementary Data

Toward the end of his postdoc at Scripps, and shortly after he started at UW, Kirchdoerfer took a revolutionary step in the field of structural biology. He used cryo-EM to image a protein vital to the coronavirus replication process.

After SARS-CoV-2 enters a host cell, viral RNA is translated by the host. Then, virus polymerases (replicative enzymes produced by the host cell) generate new RNA genomes and messenger RNA. These RNAs, in turn, create the components needed to assemble new virus particles. Though much remains unknown, scientists do know that the 16 nonstructural proteins in SARS-CoV-2 — including nsp12, nsp7, and nsp8 — are critically important to these processes. By imaging the nonstructural proteins (named as such because these proteins are produced by the virus but aren't components of a virus particle), scientists can learn more about RNA synthesis, processing, and replication. This knowledge can then contribute to new antivirals that halt virus replication and lessen the severity of infection.

Kirchdoerfer was the first to image the nsp12-nsp7-nsp8 complex from any coronavirus. When SARS-CoV-2 emerged, he wanted to image the nsp7 and nsp8 from that virus individually, but with cryo-EM, these subunits are too small to study on their own.



For this project, Kirchdoerfer turned to a different imaging method — and the people using it at UW. At the top of his list were biochemistry professors Katherine Henzler-Wildman and Chad Rienstra, codirectors of the National Magnetic Resonance Facility at Madison (NMRFAM), a campus-wide and national facility housed in the biochemistry department.

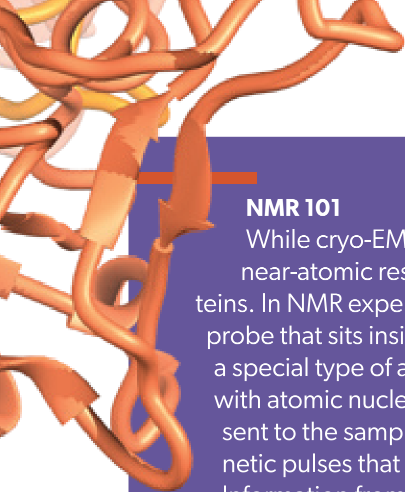
"We were talking to Rob Kirchdoerfer, and we asked what we could do that would be helpful. He said that we could look at things that are too small for cryo-EM or things that we want to look at in solution rather than in crystals," says Henzler-Wildman, who is the Jean V. Thomas Professor in Biochemistry.

Nuclear magnetic resonance (NMR) spectroscopy would provide insights into the SARS-CoV-2 nonstructural proteins, the team decided.

Over the next year, the group would tackle nsp7, nsp8, and a structural protein called the membrane protein. Their first experiments, performed using

+ Virus and Vaccine Primer
Need a refresher on how RNA viruses and vaccines work? Check out the full version of this article online at **grow.cals.wisc.edu**.

Biochemistry professor Katherine Henzler-Wildman stands on a platform attached to Fleckvieh 1, a Bruker Avance III HD 900 MHz instrument, which she used to image nonstrucutral coronavirus proteins, at the National Magnetic Resonance Facility at Madison. Photo by MICHAEL P. KING



NMR 101

While cryo-EM can handle imaging larger complexes at near-atomic resolution, NMR is restricted to small proteins. In NMR experiments, biological samples are placed in a probe that sits inside a powerful magnet. The probe contains a special type of antenna called a coil, which communicates with atomic nuclei in the sample. Radiofrequency signals are sent to the sample through the probe in a series of magnetic pulses that cause the nuclei in the sample to respond. Information from these interactions is picked up by the probe and sent to computers for analysis.

proteins produced by Kirchdoerfer's lab and as part of an international consortium called the COVID19-NMR Project, confirmed that SARS-CoV-2 nsp7 and the nsp7 in the original SARS virus are similar both in their NMR signals and in their actual structure.

The scientists didn't find this surprising — depending on which protein in the RNA replication machinery you compare, 94–96% of SARS and SARS-CoV-2 amino acids match. In an ideal world, the scientists' studies on nsp8 and the membrane protein (which has 91% sequence identity with the membrane protein in the original SARS) would be just as straightforward. But that isn't how research often progresses.

"We can't say much more right now, but our results for nsp8 aren't what we expected," Henzler-Wildman says. She and her collaborators thought nsp8 would be flexible and would have multiple different shapes. What they found was that its structure depends on how much nsp8 is in solution. Now, the scientists need to figure out what nsp8 does in solution as well as how it ends up in its various configurations.

The NMRFAM team faces different challenges with the membrane protein. Perhaps counterintuitively, this protein doesn't want to fold into a well-behaved three-dimensional structure, so scientists haven't been able to produce it in the lab. So, while virologists believe the membrane protein plays an important role in how coronaviruses exit host cells, it remains understudied — and, some experts say, underutilized — in the fight against COVID-19.

By fall 2021, the UW–Madison team was making significant progress at purifying the membrane protein and was contemplating their next steps. Data they collect may be especially critical — research conducted a few hundred yards away suggests that this protein might be an active ingredient in the next COVID-19 vaccine.

A Pan-Coronavirus Alternative?

When the pandemic hit, preeminent virologist Ann Palmenberg, known for sequencing the genetic code of the common cold virus, had been identifying molecular interactions between rhinovirus C (a virus closely linked to wheezing and asthma) and its cellular receptor.

Palmenberg's team was using a chip technology created by a group of UW–Madison scientists, including biochemistry professor Michael Sussman. Each chip contains the entire genome of a virus in the form of protein fragments. By identifying where antibodies stick on these fragments and then comparing this information to viral structures obtained with cryo-EM, scientists can improve our understanding of immune responses to viruses.

"We were just about to make the next batch of chips and collect data [on rhinoviruses, which cause the common cold] . . . when COVID-19 came," recalls Palmenberg, a biochemistry professor and Institute for Molecular Virology affiliate. "We said, you know what, instead of designing the rhinovirus sequences

Viroloist Ann Palmenberg redirected a rhinovirus C research project so she could lend her expertise to a study of SARS-CoV-2 on the UW campus. Photo by JOHN MANIACI/UW HEALTH

on this chip, let's put coronavirus sequences on it."

Palmenberg and her collaborators at the UW School of Medicine and Public Health decided to pivot their long-standing rhinovirus C project to study how protein snippets from SARS-CoV-2 and the six other coronaviruses known to infect humans responded to plasma samples from two groups of people — patients with COVID-19 and individuals who hadn't been exposed to the virus. Nimble

Therapeutics — a Madison-based company with ties to the biochemistry department that was spun out of Roche Sequencing Solutions — played a critical role by building the chips at a substantial discount. Kirchdoerfer, also an Institute for Molecular Virology affiliate, helped match antibody-sequence pairs from the protein chips to cryo-EM structures.

Results of the study demonstrate that humans mount strong, broad antibody responses to the spike and membrane proteins along with a third type of structural protein, the nucleocapsid.

"The signal from the membrane protein, in fact, is about six times stronger than from the spike protein, and future iterations of vaccines will be able to take that into account," Palmenberg says.

The scientists suggest that membrane proteins could be a promising target for future diagnostics, vaccines, and therapeutics for several coronaviruses. They note that the immunogenicity of spike-based mRNA vaccines is variable, and not all individuals who get COVID-19 produce detectable antibodies against the spike or nucleocapsid proteins.

"There's a lot of doors that were opened through this research," says Palmenberg. "It's possible that the cross-reactivity that can be conferred across coronaviruses is not the spike but the membrane protein. That's where research is going to go . . . If you have immunity against a spike or a membrane protein, does that confer immunity against every other kind of coronavirus?"

Signal from Noise

Although his role might not always be obvious, Kirchdoerfer has contributed to many such projects that aim to understand SARS-CoV-2. He's played an important role, for example, in devising new strategies to characterize the activity of enzymes, which catalyze biological processes. This project, led by Sussman, is expected to be central to rapid characterization of enzymatic activity in SARS-CoV-2.

Kirchdoerfer and his students, along with Henzler-Wildman and Rienstra, have contributed to a large, multi-institution project that standardized the production of SARS-CoV-2 proteins for screening and structural biology applications. And throughout the pandemic, Kirchdoerfer's lab has been manufacturing and shipping high-quality proteins to labs around the world to assist with SARS-CoV-2 research.

Yet, cryo-EM remains at the core of Kirchdoerfer's work.

"Rob works on a number of fronts surrounding how coronaviruses function, from isolated components to intact viruses," says Elizabeth Wright, a biochemistry professor and affiliate at the Morgridge Institute for Research. "To investigate how SARS-CoV-2 replicates, he has started by assembling and examining the structure and function of components of the virus replication complex."

+ Coronavirus Ed, On Campus and Off
Formally and informally, in lecture halls, by email, and even on city buses, biochemistry faculty advance greater understanding of COVID-19. More at **go.wisc.edu/grow-coronavirus-ed**.
Photo by MICHAEL P. KING

Wright directs the Cryo-Electron Microscopy Research Center, which provides services to UW investigators who are working on SARS-CoV-2 and other projects. "Rob does the fundamental molecular biology, protein expression, and functional assays in his lab to determine if samples are of sufficient quality for cryo-EM imaging," Wright says. "We then support him during the sample preparation, imaging, and initial data processing steps."

Kirchdoerfer's work on RNA polymerases represents a turning point in structural biology. "Our structures opened the door for coronavirus polymerase structural biology, and I think now there's 25 or 30 structures of coronavirus polymerases in the database, all from the last two years," he says. "We were really the first ones, I'd say, to kick that door down."

His ongoing studies on coronavirus replication and transcription may be especially important as SARS-CoV-2 evolves. Virus function is often coupled to structure, and that's to our advantage as scientists combat COVID-19 on all fronts.

"A virus has to be able to bind and interact with host cells and undergo fusion, so the structural elements in the spike protein [that accomplish those functions] are going to be conserved. When a virus mutates, it has positions that can also mutate, and that's how you can get antibody escape or receptor switching and that sort of thing," Kirchdoerfer says.

But understanding the SARS-CoV-2 replication machinery and characterizing the prolines inserted into proteins for vaccine candidates isn't his end goal — it's just the beginning.

"During an outbreak, there's intense scientific interest, but as soon as that outbreak ends, interest also ebbs," he says. "What I would like to do with my lab is more pandemic preparedness and looking for the next virus that's going to cause a pandemic."

To that end, Kirchdoerfer is studying other coronaviruses and other virus families, and he's launching projects on viral entry in collaboration with classical virologists, veterinary medical biologists, and epidemiologists at UW. After all, as Kirchdoerfer says, the best way to battle a novel virus is to already understand how viruses work. g

GOOD IDEAS, GROWN & SHARED

Photo essay by
MICHAEL P. KING

They are unconventional laboratories, classrooms, and proving grounds — places to connect with the land and with nature. UW's **Agricultural Research Stations** are the crown jewels of CALS. The product of more than a century of expansion and evolution, this statewide network of farms, forests, and greenhouses allows faculty, staff, and students to study the unique agricultural and environmental challenges of Wisconsin's distinct regions.

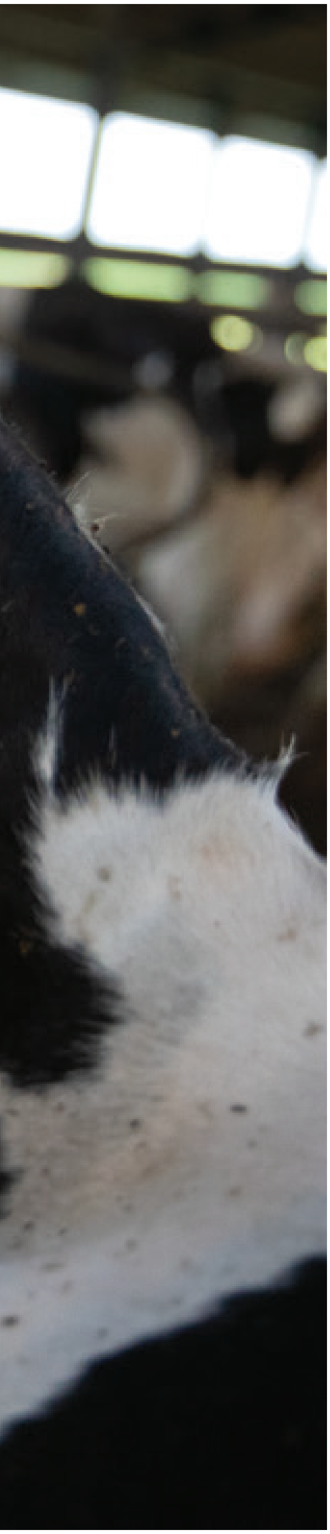
With the big-picture goals of developing profitable, sustainable farming systems and preserving environmental quality, hundreds of research projects are conducted at these facilities each year, and the findings are shared widely — all to help address the immediate needs of those who produce our food and protect our ecosystems.

PENINSULAR
George Nooyen, agricultural research equipment operator, harvests Marquette wine grapes at Peninsular Agricultural Research Station.

ARLINGTON

[Above] Dairy science intern Naomi Waldon takes a blood sample from a dairy cow at Emmons Blaine Dairy Cattle Research Center at Arlington Agricultural Research Station. Waldon, a 2019 summer intern from Tuskegee University, assisted with a study on subclinical ketosis in dairy cows.

[Right] Haleigh Ortmeier-Clarke, a research assistant in the Department of Agronomy, conducts spectral imaging on an industrial hemp test plot at Arlington Agricultural Research Station.



O.J. NOER

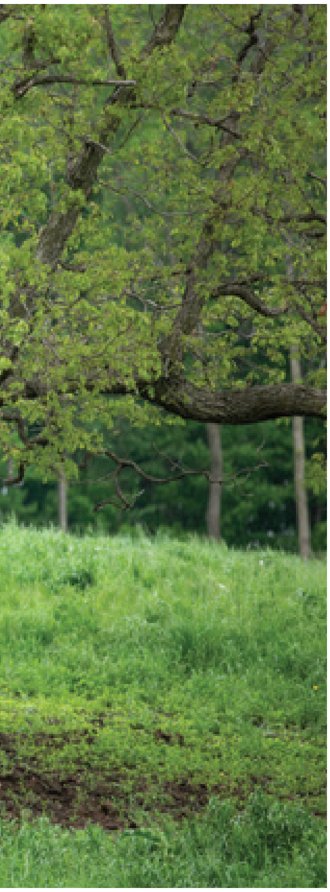
[Above] Associate professor of plant pathology Paul Koch PhD'12 shows a test plot study on the use of iron sulfate to control a fungal turfgrass disease known as "dollar spot" during the 2019 Wisconsin Turfgrass Association Field Day at O.J. Noer Turfgrass Research and Education Facility.

LANCASTER

[Right] Cattle graze in a pasture at Lancaster Agricultural Research Station.

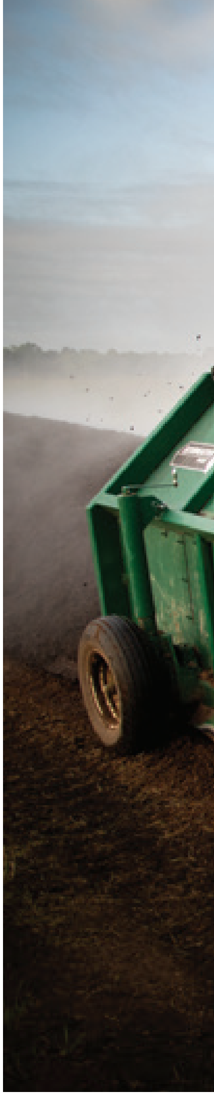
HANCOCK

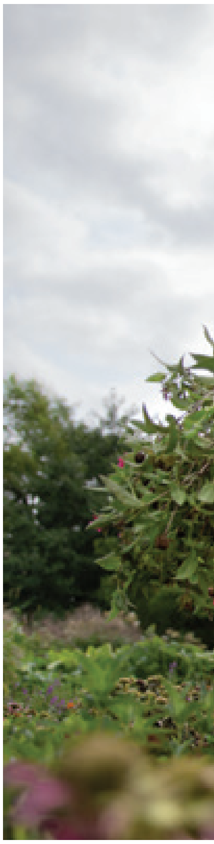
[Below] Paul Bethke, an associate professor with the Department of Horticulture and the USDA Agricultural Research Service, talks with attendees during Potato Research Field Day at Hancock Agricultural Research Station.



SPOONER

[Left] September soybeans turn from green to gold at Spooner Agricultural Research Station.





GREENHOUSES

[Opposite page] Biological systems engineering researcher Jessica Drewry PhD'17 works with a drone fitted with thermal imaging cameras to study the effects of pests and disease on cranberry plants at the Walnut Street Greenhouse.

WEST MADISON

[Above] Equipment operator Ralph Siegenthaler pulls a windrow compost turner to aerate and mix a pile at West Madison Agricultural Research Station.

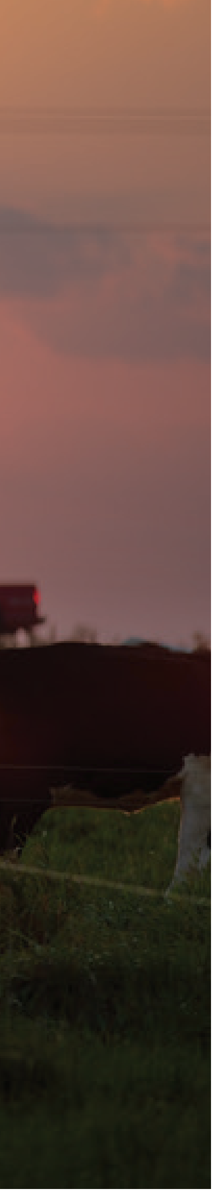
[Left] Garden intern and environmental science major Grace Puc, left, and station superintendent Janet Hedtcke BS'93, MS'99 relocate a plant in the display garden at West Madison Agricultural Research Station.

MARSHFIELD

[Above] Dairy cattle graze on a paddock as the sun rises at Marshfield Agricultural Research Station.

[Right] Soil science professor Alfred Hartemink and students in Soil Sci 325 Soils and Landscapes discuss their observations in a soil pit during a visit to Marshfield Agricultural Research Station. The class visits several stations around the state to study the different soils at each location.

Explore Online
Learn more about the Agricultural Research Stations at **ars.wisc.edu**.



KEMP

[Above] Michal Michiels BS'19, left, and Bridget Motiff BS'21 chat while taking notes during evening trap checks at Kemp Natural Resources Station in May 2019. As undergraduates at the time, the two were taking a wildlife ecology summer practicum in which students utilize trapping and surveying techniques to inventory the flora and fauna on assigned parcels of land.

Season *of* Learning

Summer courses are an abiding tradition at UW. They've long been the boon of undergrads looking to stay on track to graduation, lighten their fall/spring academic loads, or sneak in classes that give them an edge in the job market. But summer offerings have grown even more robust in recent years, and enrollment has risen, especially during the COVID-19 pandemic. A record 10,000 undergraduates registered in 2020 for what is officially called Summer Term.

It's not just traditional undergraduates who take advantage of Summer Term's mix of online and in-person classes. Others include visiting, international, and high school students. And incoming freshmen who enroll in "early start" programs, such as QuickStart at CALS, can earn credit through Summer Term while meeting their professors and peers — all before their first fall semester even begins.

A rigorous Summer Term remains a priority at CALS. To increase access and flexibility for students, the college's instructors have taken some of their most engaging courses and adapted them for online delivery during the warm, sunny season of Wisconsin. Here are some fine examples.

Photo illustration: original photos by BRYCE RICHTER, JEFF MILLER (4), iSTOCKPHOTO.COM/RAPIDEYE

Data Science *from a* Distance

By **Nicole Miller MS'06**

Situated just north of Bozeman, the rocky peaks of Montana's Bangtail Mountains rise above nearby pine forests and scattered grasslands. Paige Sauer has never visited the striking locale, but she's rather well acquainted with one of the meadows there.

It's the site of an ecological observation station that generates a stream of data, one that she learned to access and analyze in an online course last summer called BSE 375 Introductory Data Science for the Agricultural and Life Sciences. And, in some ways, the remote experience transported her there.

"I'm always in Wisconsin. It's where I live; it's where I go to school," says Sauer, a senior majoring in biological systems engineering. "I've never been to [the Bangtail Mountains] or even heard about them before the class, but I feel like I know everything that's going on there."

In the course, students learn how to write computer code and then use it to gather, analyze, interpret, and visualize data, sometimes utilizing large datasets with hundreds of thousands of datapoints. As they build their data science skills, students work with real-world information from the agricultural and life sciences fields, which helps bring their coursework to life.

"There are so many rich data resources in the world, including for agricultural systems and natural systems, but we have to know how to use [the data] to be able to benefit from it," says instructor Paul Stoy, an associate professor in the Department of Biological Systems Engineering. "Data science holds the key to unlocking how to manage systems for productivity and sustainability."

At the start of the semester, each student is assigned a research station from among the sites Stoy is actively studying. Each station produces hundreds of thousands of measurements, including data points taken every half hour for temperature, carbon dioxide levels, and vapor pressure. Students use the data from their assigned sites to complete homework projects and for quizzes, which often take the form of coding challenges.

Sauer and her classmates used data from sites in Montana, where Stoy used to live and work, but subsequent classes are now accessing data from Wisconsin research stations.

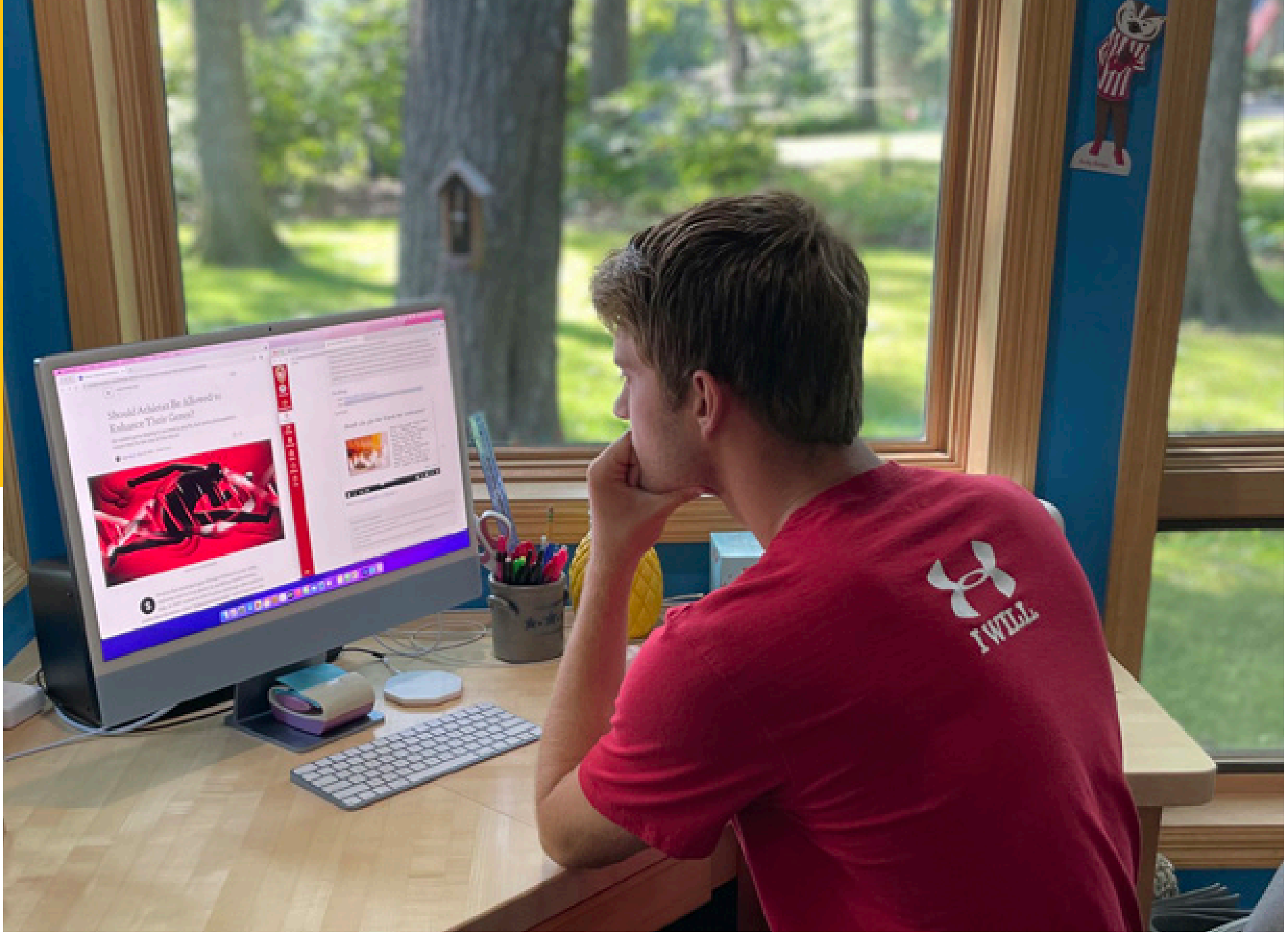
"I'm still building up my research activity in the state, where I will be utilizing the same [ecological observation stations]. They're exactly the same instruments, just put up in Adams County, Wisconsin," says Stoy, who joined CALS in 2019. He studies how environmental conservation affects what is called the "earth system" — earth's interacting physical, chemical, and biological processes — including on managed and unmanaged lands.

Stoy plans to offer the course (now renumbered as BSE 380) in person during the school year and virtually during summers to offer students the greatest flexibility. Students use a free, open-source software known as "R" for coding; no prior experience is required.

Things start slow, says Stoy, and then ramp up,

Lab technician James Irvine installs a research station in a meadow in Montana's Bangtail Mountains.

Photo courtesy of PAUL STOY



Undergraduate Brenen Skalitzky participates in Genetics 133 via the Canvas online learning platform.
Photo by JESSE SKALITZKY

with the goal that everyone reaches the same coding level by the end of class. Students leave with a solid foundation in coding, a valuable career skill.

"R is an important program to use in the engineering world," says Constantin Bensch, a junior majoring in biological systems engineering. "I had some base knowledge of R coming in from a previous statistics class I took. This class did a great job of using real-world examples of projects that I would do in [my career]."

It's no secret that coding can be frustrating. It requires an attention to detail that can drive a person crazy; but, when everything works, it can lead to satisfying breakthroughs.

"The hardest part, probably with any computer language, is just trying to find where you messed up, like a missing comma or quotation mark or whatever it is," says Sauer. "I would have to reread through [my code], trying to figure out why things weren't working, and tweak things. But once you get a few tips and tricks under your belt, it's [easier]."

Throughout the course, everything builds towards a final project, where each student produces a report with numerous figures, tables, and visual aids that describes their assigned research site.

"Completing the project used all of the skills we learned in class," says Bensch. "I really enjoyed the satisfaction of finishing my project and getting my code to work."

Into the Heart *of the* Science Headlines

By **Caroline Schneider MS'11**

Precision medicine, genetic testing, antibiotic resistance, GMOs, cloning. Open almost any newspaper or click on any online news site, and you're likely to see headlines about many of these scientific topics. Woven through these stories is a common thread — genetics.

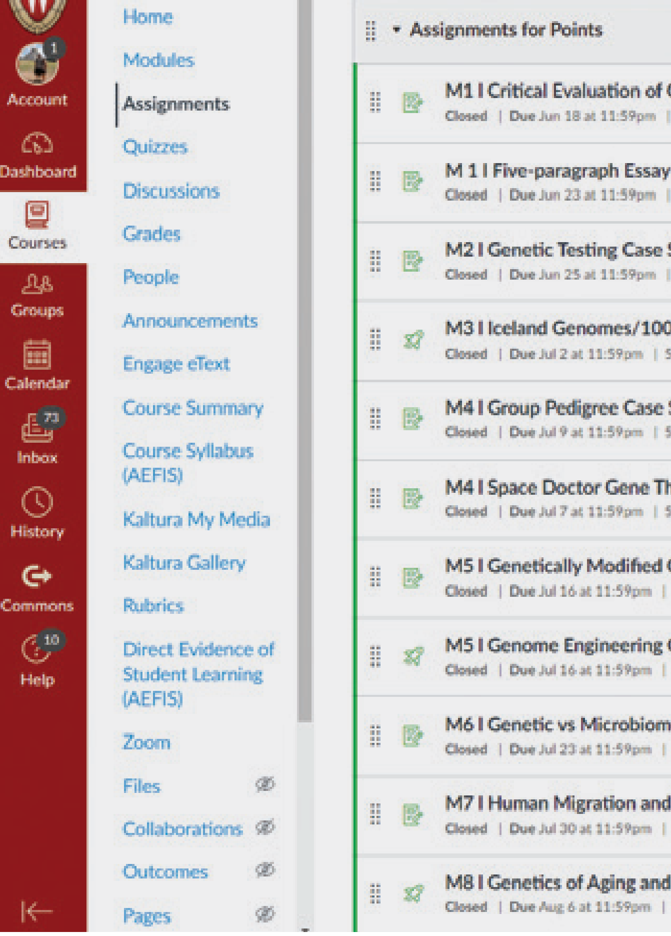
But how much do readers really know about genetics? And how much does our knowledge — or lack of it — affect our opinions about these scientific issues and the stories that cover them? These are the questions students get to answer in a Summer Term course called Genetics 133 Genetics in the News.

"Genetics is at the heart of many issues facing society," says course instructor Katie Vermillion Kalmon, who is director of undergraduate studies in the Department of Genetics. "In Genetics 133, we gain a deeper understanding of the science behind the headlines so that the students can make informed decisions and help educate those around them."

It's a vital goal for students who run into genetics in so many corners of their lives, from the news to dinnertime discussions to genealogical testing kits. And in addition to the science, Vermillion Kalmon introduces the underlying ethics of these issues, an aspect that has been missing from many science classes.

"We may be able to cure diseases, but should we? What if the genetics changes can be passed on to future generations? Who has access to the treatment?" says Vermillion Kalmon, recipient of the 2021 Spitzer Excellence in Teaching Award. "Social and ethical issues surround every topic, and the students need to think about these questions."

For many students, being able to take both the genetic information and the bioethics questions to other parts of their lives is one of the highlights



A screen capture of the Genetics 133 course module on Canvas.

Image courtesy of BRENEN SKALITZKY

of the class. "I learned a lot of material and was able to talk to my family, coworkers, and friends about these types of topics. Everyone is interested," says Brenen Skalitzky, a first-year genetics and genomics student who took the course in summer 2021.

Genetics 133 is offered year-round but in different formats — in person during the semester and virtually over the summer. Vermillion Kalmon was able to fine-tune her online class, even before the pandemic hit, through help from Teach Online@UW (a campus learning community of instructors and instructional designers) and a UW–Madison Continuing Studies grant.

Through the grant, an instructional designer showed her how to take her course from the classroom to the computer.

"We knew as a department that online options were something we wanted to provide to students, so when Continuing Studies offered grants, we applied," says Vermillion Kalmon. "The grant was greatly timed since I moved my course online prior to coronavirus. When the pandemic came, it was ready to go, and that allowed me to help train other faculty in my department to get ready for online teaching.

The summer online course is broken up into eight modules, each including lectures, news articles, group learning activities conducted via Zoom, and exams. The lectures and reading can be done on each student's schedule, giving them flexibility during the summer when they might be working or studying in different time zones. And it's a structure that has received universally positive feedback.

"The class was taught incredibly well," says Alyssa Bhoopat, a first-year student who took Genetics 133 in summer 2021. "While there definitely was a lot of information to cover and take in, lecture videos were engaging, and the content was very interesting."

Skalitzky agrees, adding, "I had lots of fun with the weekly team assignments. Hearing other students' opinions about more controversial issues is eye-opening. I also wanted to be able to understand scientific journals and judge the reliability of news stories. Genetics 133 helped me with these skills, and the media-literacy component was very important to me."

The course is popular with non-genetics majors, Vermillion Kalmon says, but she's seeing more genetics majors enroll, especially through early-start programs. This includes both Bhoopat, a CALS QuickStart student, and Skalitzky, a participant in the Wisconsin Experience Summer Launch Program.

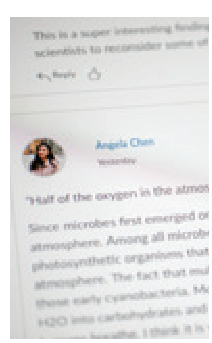
For Bhoopat, a genetics and genomics major, the advantages of taking the course early went beyond the class content. "Being able to connect with faculty before starting the fall semester was invaluable," she explains. "Dr. Vermillion Kalmon answered so many questions, even about topics outside the class, and she helped ease my nerves as the year started."

Vermillion Kalmon is happy to see more early-start students in her summer course. And although Genetics 133 isn't part of the curriculum for genetics and genomics majors, she would like to find more ways for those students to fit the class into their schedules and use it as a basis for their science courses to come.

"Students really learn a lot of genetics, and how much genetics relates to every aspect of our lives becomes very evident to them early on in the course," explains Vermillion Kalmon. "It gives them an overview of the topics they're going to see throughout their classes." g

Summer Term, and the Learning's Ready

Get to know UW's Summer Term offerings at **summer.wisc.edu**.



+ Meet the Microbes

Designed with non-science majors in mind, Microbiology 100 The Microbial World introduces students to bacteria and viruses — how they influence the foods we eat, the products we use, and diseases that impact our health. For more, read the full version of this article online at **grow.cals.wisc.edu**.

Photo by MICHAEL P. KING

Listeria's Archnemesis

Tu-Anh Huynh is uncovering how a single molecule can help fight a common pathogen — and its resistance to antibiotics.

Interview by CATHERINE ARNOLD

Tu-Anh Huynh spends much of her time tracking tricksters that alter their shape and function to survive in extreme conditions. In other words, she studies bacteria.

Unique among such change artists, the pathogen called *Listeria monocytogenes* (listeria) has long fascinated Huynh with its ability to grow in cold refrigerators and garden soil. It thrives under preservation and harsh storage conditions, where most other bacteria don't survive, and infects more than 40 animal species, including humans. Listeria can easily contaminate many types of foods, such as poultry, hot dogs, lunch meat, melons, unpasteurized cheeses, and coleslaw. And although listeria infection (listeriosis) occurs through eating contaminated foods, it can go on to cause severe infections in susceptible people, also called the YOPI group (young, old, pregnant, immunocompromised). Each year, an estimated 1,600 people contract listeriosis, and about 260 of them die, according to the Centers for Disease Control. Huynh wants to change those numbers.

As an assistant professor of food science and microbiology, Huynh focuses her research on bacterial signaling, or how bacteria — such as listeria — identify their surrounding environment, locate nutrients, avoid hazards, and sometimes communicate with other bacteria. In particular, she's looking at how a messenger molecule called cyclic-di-AMP (c-di-AMP) can govern this process.

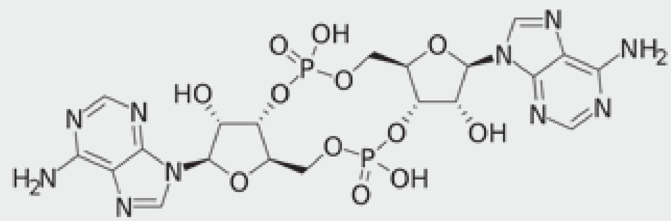
Huynh's research group has already found that when bacteria can't maintain proper control of c-di-AMP levels, they become very sensitive to many antibiotics. By learning more about how c-di-AMP regulates antibiotic resistance, Huynh wants to disrupt its balance to combat bacterial infections in humans and animals.

Photo by MICHAEL P. KING

Huynh's c-di-AMP Findings and Implications

In November 2020, Huynh coauthored a study in the *Journal of Bacteriology* finding that, much like a shortage of c-di-AMP can cause problems for bacteria, too much of the signal messenger in certain spots could make it vulnerable to the antimicrobial agents used in many antibiotics.

In the April 2021 issue of the *Journal of Dairy Science*, Huynh and a research team reported finding resistance to the antibiotic ampicillin (and, to some extent, gentamicin) in listeria that was sampled from the feces of a herd of lactating dairy cattle in Wisconsin. They detected a greater abundance of certain strains of listeria in cows that were shedding the pathogen and suggested that targeting the strains present within a particular ecological niche may be a more effective control strategy. This is an important finding because listeria in cattle feces can spread to the herd — and within the human food supply.



The chemical structure of c-di-AMP. Image by INNERSTREAM

WHAT DRIVES YOU TO STUDY LISTERIA?

Listeria is an important human and animal pathogen, so we want to learn how it adapts and responds. We want to do that at both the molecular level and the population level — looking at listeria as a group of organisms.

Because this pathogen is so adaptive and can survive in so many locations, it's notorious for being introduced within butchered meat or other products in food processing plants and can persist for decades.

It's also good at growing in the cold — in refrigerators or in winter, under grass, where cattle will graze on it after the spring thaw. That often causes listeria outbreaks among cattle in the spring, which can affect farmers, the food supply, and processing plants.

And we want to understand why c-di-AMP is essential to listeria's antibiotic resistance. If listeria cannot regulate c-di-AMP, the bacteria fall victim to antibiotics that target the cell wall; that's certainly what we want to happen. In our [November 2020] *Journal of Bacteriology* paper, we learned if you disrupt the c-di-AMP balance in listeria, the bacteria become more susceptible to antibiotics.

HOW DID YOU GET INTERESTED IN BACTERIA SIGNAL MESSENGERS?

As an undergrad, I worked in a lab studying microbial ecology in food fermentation. I had a project looking at how biochemical activities by different microbes contribute to cocoa bean fermentation — how they interact with one another to produce yeast, ethanol, and heat. The high temperature in those products kills the beans and creates the flavoring of chocolate. I became interested in the tiny processes within biology and took it from there. In graduate work, I studied bacterial signaling mechanisms, exploring how bacteria identify environmental signals to adjust their growth and reprogram themselves.

Toward the end of my doctoral work, c-di-AMP was discovered. At the time, it was a completely novel second messenger molecule synthesized by bacteria. Excited by this, I decided to pursue postdoctoral training on its signaling mechanisms.

WHAT EXCITES YOU ABOUT YOUR WORK?

I'm excited that, in terms of antibiotic resistance, we're exploring a pathway — controlled by c-di-AMP — that isn't well studied yet. Trying to understand how listeria acquires antibiotic resistance and passes it around to other bacteria among agricultural animals is also a unique approach.

The work we published in the *Journal of Dairy Science* provided valuable information about the prevalence of antibiotic resistance in listeria among a small number of animals in Wisconsin, which is essential information in managing the spread of antibiotic resistance.

Understanding how c-di-AMP works can lead to the development of new antibiotics. If we can block that messenger molecule, that might be a good way to target antibiotics to make them more effective.

HOW DID BEING AT CALS HELP WITH THIS WORK?

In my program, I enjoy exploring research directions I wouldn't have thought of before arriving in Madison. For instance, I began studying listeria in the feces of dairy cattle because of the vibrant dairy research community here in the Dairy State.

For cattle work, I coordinate with the director of the Wisconsin Veterinary Diagnostic Laboratory, **Keith Poulsen** BS'00. Along with directing the lab, he is a large animal vet who connected me to dairy farms and advised us on animal physiology and reproductive health. He helped us select the 20 animals we worked with in our study.

WHAT'S NEXT?

To follow up on our studies, I'm working with the rest of my lab members to understand what underlies antibiotic resistance among *Listeria monocytogenes* isolates from dairy cows. We're also exploring the molecular pathways that c-di-AMP regulates within the bacterial cell so that we can manipulate them for therapeutic and genetic engineering applications.

ED HIMELBLAU

The Lighter Side of the Lab

This alum combines science expertise with artistic skill for a successful and humorous side gig.

Story by GEORGE SPENCER | Cartoons by ED HIMELBLAU

Ed Himelblau PhD'00 leads a double life — and it's hilarious. As a biology professor at California Polytechnic State University in San Luis Obispo, students find him in the lab hunched over a PCR machine. (Think Xeroxing but for DNA.) With precision, he wields a micropipette to transfer drops of liquid for analysis.

But those who visit his office may see him hard at work on something different. He sits at his tilt-top drafting table, perched over Bristol drawing paper, holding a dip pen. (Think fountain pen but simpler.) With equal precision, he fills in the outlines of one-panel cartoons destined for *The New Yorker*.

Ed Himelblau uses his cartoon self-portrait on his social media accounts.

Himelblau earned his Ph.D. in cellular and molecular biology at CALS. Though he hasn't won a Nobel Prize in his field, among cartoonists he's already found nirvana — his droll drawings appear in a magazine whose pages were once graced by Charles Addams's mirthfully macabre family, James Thurber's harried husbands, and Saul Steinberg's modernist musings.

He battled steep odds to join their legendary ranks. *The New Yorker* can get a thousand submissions a week, according to former cartoon editor Bob Mankoff. Each weekly issue has room for no more than 20 cartoons, not including one published each day online. Himelblau submitted dozens for two years before the first of several was accepted for publication in 2021.

His parents subscribed to the magazine when he was a child. And Himelblau's love of drawing began at age 7, when he began poring through the publication's pages and the comic strip, *Peanuts*. Linus and his pontifications on all things scientific fascinated Himelblau. Later, *The Far Side* and its googly-eyed mad scientists cracked him up.

Many of Himelblau's cartoons have a lab setting. His characters often find themselves buried in foam, battling haywire gadgets, or, worst of all, reduced to eyeballs floating in puddles thanks to experiments gone awry.

"I try to break the perception of scientists as being overly serious because I've worked with a lot of different personalities in the lab," Himelblau says. "They have their foibles like anybody else — they can be brilliant one minute, then superstitious, lazy, or sloppy the next. I'm trying to disrupt that serious veneer of science."

Himelblau first started selling cartoons for $50 apiece in 1995 to Promega Corporation, a Madison-based lab supply company, which posted them on its website. His work later appeared on the covers of scholarly publications such as *Molecular Plant* and the *Journal of Plant Physiology*.

His thesis advisor, **Richard Amasino**, encouraged Himelblau's hobby. "His cartoons were wonderful and never insulted anyone," recalls the biochemistry professor. Amasino recently invited Himelblau back to give a seminar titled "A Cartoon Guide to Life in the Lab and

"The journal rejected our manuscript — but the editors suggested it might make a good tweet."

Typically set in science labs, Ed Himelblau's cartoons have appeared on biotech company websites, on the covers of peer-reviewed journals, and in *The New Yorker*.

In this cartoon, Ed Himelblau depicts the Learn By Doing Lab (which he cofounded), where students from California Polytechnic State University in San Luis Obispo offer hands-on science lessons to visiting middle schoolers.

the Classroom." "It was one of those lectures where everyone was paying attention," Amasino recalls. "People were laughing and having a good time."

As an undergraduate at the University of California San Diego, Himelblau studied art history and took art classes while majoring in biology. His decision to specialize in the one-panel format came due to academic pressures at UW. He believed he could "knock out those cartoons pretty fast" between more scholarly endeavors.

But today he labors over every piece. He carries a notebook to jot down ideas. A current fixation is vortexers, a common laboratory mixing tool. "I've been thinking there's got to be something funny about vortexers," he muses. He mulls ideas for weeks, even months, and sketches and re-sketches drafts before going through a multistep process that involves scanning images and revising them in ink.

What makes a cartoon great, according to Himelblau? "It makes you laugh out loud, or it feels like a joke that must have always existed, but you didn't know it until that moment. Suddenly, it's just a great surprise," he says.

LAUGH ALONG WITH ED

- himelblau.com
- @himelblog on Instagram and Twitter

When not at his drafting table, Himelblau focuses his research on *brassica*, a genus that includes broccoli, cauliflower, and cabbage. All of these are polyploids, plants with a duplicate genome, something that is a rarity among animals but can be an evolutionary advantage for crops. He cofounded Cal Poly's Learn By Doing Lab, in which students give hands-on lessons to visiting middle schoolers, and his school honored him in 2018 with a Distinguished Teaching Award.

Since his days at UW, visual communication in science has seen an explosion of interest, thanks to the internet. When he started out, Himelblau joked, "I'm one of the top 10 molecular biology cartoonists." Today, the notion of numerous science cartoonists doesn't seem so absurd. It delights him when students drop by his office and see him drawing because he believes science and art complement each other. "There are more and more ways to do both, and a student's love of one can feed the other," says Himelblau. "I hope people feel the freedom to do what I've done."

ENGAGE

CRYO-EM GRAND OPENING

Save the date! The 42nd Steenbock Symposium and the grand opening of the Cryo-Electron Microscopy Research Center and the Midwest Center for Cryo-Electron Tomography will take place on June 7–8, 2022, at UW's Discovery Building. Details at **go.wisc.edu/steenbock42**.

ACCOLADES

GENIUS GRANT

The MacArthur Foundation has named landscape ecologist **Lisa Schulte Moore** PhD'02 a 2021 fellow. The honor, which comes with a $625,000 award, is reserved for "extraordinarily talented and creative individuals." Schulte Moore is a professor in the Department of Natural Resource Ecology and Management at Iowa State University.

LATINO LEADER

Mario García Sierra BS'10 is among six UW alumni recognized as Wisconsin's most influential Latino leaders in 2021. He is the senior customer engagement and community development manager at Madison Gas and Electric and served as board president for Centro Hispano of Dane County from 2017 to 2019.

Potato Industry Invests in Future Harvests

By NICOLE MILLER MS'06

Photo by SEVIE KENYON

Back in 2017, Wisconsin's potato producers made a big commitment to CALS. In January of that year, industry leaders announced their intention to raise $5 million over 10 years to help support the college's potato program. Since then, they've been taking the steps needed to reach their goal.

The state's 160 licensed potato producers, who are represented by the Wisconsin Potato Industry Board (WPIB), harvested over 65,000 acres of the crop in 2021 — the third most in the nation. The industry clears millions in sales every year, and growers pay an assessment on those sales, a fee that goes towards the industry's marketing efforts and research and education programs. Between 2016 and 2018, the WPIB voted twice to increase the assessment. The resulting hike (2 cents per 100 pounds) now generates around $500,000 per year toward a gift to CALS, which is intended to help maintain the strength and numbers of the university's potato research team.

"Wisconsin potato growers have shown great vision and leadership with this gift," says **Tamas Houlihan**, executive director of the Wisconsin Potato and Vegetable Growers Association. "They realize that this is a long-term commitment, one that will ensure the future success of the industry."

The money raised thus far has been accumulating in a fund established at the Wisconsin Foundation and Alumni Association, which serves as UW–Madison's nonprofit gift-receiving organization. An advisory board of potato industry members meets annually to review the pool of money, called a "donor-advised fund," and make decisions related to spending. So far, they've mostly been watching the pot grow, biding their time until there's enough to make impactful investments in faculty, research, and facilities. But they've also taken some action.

In 2020, thanks to the generosity of alumni **John** and **Tashia Morgridge**, a $70 million matching gift became available to help fund new endowed titles at UW. Offered as professorships, chairs, and distinguished chairs (depending on the level of funding), endowed titles provide appreciation, resources, and professional status for highly productive UW faculty. The Wisconsin Potato Industry Board acted on this opportunity, dedicating four years of incoming funds to generate $2 million, which will be matched to create a pair of $2 million endowed faculty chairs.

"Funding these chairs fits very well with the goals of the original donor-advised fund," says Houlihan. "Gifts to support endowed faculty positions help the university attract and retain the very best thinkers, teachers, and researchers in an increasingly competitive hiring market."

The two endowed chairs are named for UW researchers who made outstanding contributions to potato research. The Wisconsin Potato and Vegetable Grower BCS Chair honors **Larry Binning** BS'65, **Dave Curwen**, and **John Schoenemann** BS'50, MS'54, PhD'59, and the Wisconsin Potato and Vegetable Grower KWS Chair honors **Keith Kelling** MS'72, PhD'74, **Jeff Wyman** MS'68, PhD'71, and **Walt Stevenson** PhD'73.

"We sincerely appreciate the potato industry's support for these new chairs and the visionary investment in the college through the donor-advised fund," says **Doug Reinemann**, CALS associate dean for extension and outreach. "These investments will help ensure the ongoing strength of our potato research program and our ability to support Wisconsin's potato producers."

INVEST IN CALS

To make a gift, contact Annie Louis at annie.louis@supportuw.org or 608-308-5523.

SUPPORT STUDENT SUCCESS at CALS

On **April 5–6, 2022**, the Day of the Badger, CALS raised nearly $30,000 for "strong start" programs, such as **CALS QuickStart** and **First-Year Interest Groups**. These programs help students explore different areas of study, learn how to access student services, and develop a network of mentors, classmates, and friends. You can still support this effort by making a gift at go.wisc.edu/GiveToCALS.

DAY OF THE BADGER

dayofthebadger.org

#dayofthebadger

Photo by Michael P. King

College of Agricultural & Life Sciences
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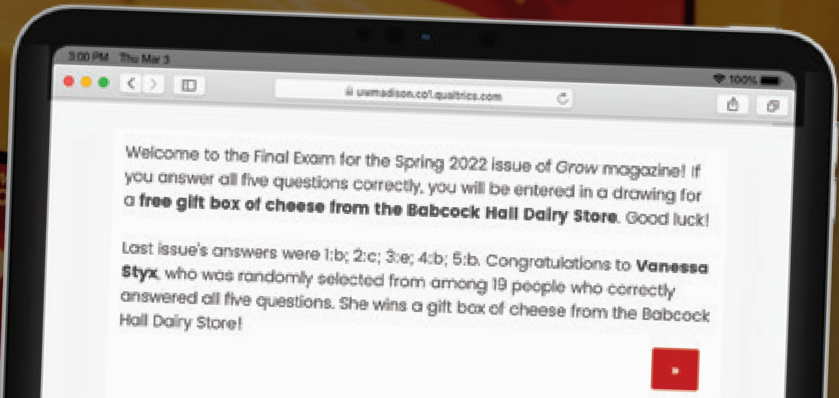

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These piping and valve clusters are located in the raw room, where various milks are processed, blended, and standardized, in the new Center for Dairy Research addition in Babcock Hall. The addition and the Babcock Dairy Plant renovation are scheduled to be complete in fall 2022.

Photo by MICHAEL P. KING