Graduate students build excitement for insects, plants, and genetics through engaging outreach activities

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An art installation titled “Connecting Paths” hangs from the ceiling in a meeting room near the atrium of the Hector F. DeLuca Biochemical Sciences Building. Created by local artist Chloris Lowe, the installation (called “Hogiwe Hirokirere Hii” in Ho-Chunk) recognizes the Ho-Chunk history of the surrounding land — and Lowe’s heritage — as well as the more recent history of an adjacent courtyard and its stately elm tree, Elmer. The piece was created using wood from the tree, which stood at the center of the research complex as a meeting place and landmark for more than 100 years. Elmer was harvested in 2018 after several attempts to help it recover from Dutch elm disease. Read more at go.wisc.edu/connecting-paths. Photo by PAUL ESCALANTE
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ON THE COVER A Lego model of a tomato afflicted with blossom end rot, a disease caused by a calcium deficiency. The model, designed by Plant Disease Diagnostics Clinic director Brian Hudelson MS’89, PhD’90, is used for science outreach by graduate students from the What’s Eating My Plants? group. See page 20.
Photo by MICHAEL P. KING.
Images, from top: courtesy of DIANE BURKO, photo by ROMULO UEDA, photo of Conrad Elvehjem courtesy of the UNIVERSITY OF WISCONSIN–MADISON ARCHIVES
Back in November, at the annual meeting of the Association of Public and Land-Grant Universities, I was presented with some alarming statistics about rural America and the agricultural enterprise on which it depends. In his keynote talk, U.S. Secretary of Agriculture Tom Vilsack harkened back to the wave of farm foreclosures that struck the nation in the 1980s and the ongoing loss of small farms that has followed.

Vilsack cited some eyebrow-raising numbers that have since weighed heavily on me. First, there are 437,300 fewer farms in the U.S. today than in 1981. Second, there are 141 million fewer acres devoted to farming in the U.S. today than there were in 1981. (That’s equivalent to the combined land area of Florida, Georgia, Maryland, North Carolina, and South Carolina.) And third, although there was record-high farm income in 2022, only about 7.5% of the farms that sell more than $500,000 annually took in 89% of the income.

Those are staggering figures. Just as staggering is the impact these farm losses and consolidation have had on the prosperity of rural communities. As Vilsack discussed in his speech, the health of farms is the health of rural communities. If farms shut down, children move away. This means fewer schools, so they shrink and merge. It means fewer customers for local businesses, so they close, and local economies stagnate. It means fewer patients for hospitals, which makes it harder to recruit doctors, and hospitals then turn into clinics with fewer services.

But there is a path with the potential to avoid all of this. Going forward, successful farms will be productive, profitable, and protective of natural resources — what the White House calls “climate-smart” agriculture. Agricultural operations that pursue this path may be more likely to stay in business and help keep their communities thriving.

And that’s where land-grant universities can play a key role. CALS is positioned well to be a leader in the science of agricultural sustainability (and bring its benefits to Wisconsin) simply by doing what it already does well — but with a more focused strategy.

Last fall, we hosted “visioning sessions” in which our college community worked to identify areas where CALS has strong multidisciplinary teams working to solve big societal problems. The idea is to create a strategic scaffold, based on our key strengths, that can be used for our hiring, infrastructure, and fundraising activities. You can read more about this visioning process, what it yielded, and how the outcome will guide the college, toward the end of our cover story, “Five CALS Discoveries That Changed the World,” which starts on page 28.

Many of the areas identified through our visioning sessions fall under the umbrella of sustainable agriculture, which is one of our top priorities. For example, professor Randy Jackson in the Department of Plant and Agroecosystem Sciences is working to expand knowledge of how grasslands can benefit farming and environment. He also makes use of participatory research, which includes critical engagement with key stakeholders. And several of our faculty and staff are working on breeding climate-smart crops for the future. Plant pathology professor Erin Silva and outreach program manager Daniel Cornelius (plant pathology and the UW Law School) along with Tricia Gorby, director of the UW–Madison Division of Extension’s Natural Resources Institute, are leading efforts to develop resilient food systems for Indigenous groups in our state. This last project is part of the USDA-funded Wisconsin Rural Partnerships Institute, a research project designed to provide solutions to many types of rural challenges.

I look forward to seeing CALS at the forefront of a much-needed effort to partner with farmers and others on revitalizing rural communities.
Five Features of the Secret Ecosystem Under the Snow

By JONATHAN N. PAULI and BENJAMIN ZUCKERBERG

At first glance, the winter landscape in Wisconsin can appear relatively lifeless. But life is out there — in many places. For example, beneath the snowpack hides an insulated space called the subnivium (from the Latin words for below, sub, and snow, nivea). Here are some of its secrets.

1. No matter how cold it is above the snow, it’s always right around freezing in the subnivium. The temperature there remains stable because snowpack traps heat released from the soil. As this heat slowly migrates upward, it creates a vertical gradient of decreasing temperature. Larger amounts of snow and fluffier, less-dense snow provide greater insulation. At around a half-foot or more of snow, temperatures in the subnivium will stay just around freezing (or above).

2. A diversity of winter-adapted species live and thrive in the subnivium. Most plants persist through winter by lying dormant as seed or root stock, and the moister, warmer subnivium helps them avoid drying out or freezing. Some plants even germinate or remain photosynthetically active in the subnivium. Microbes actively cycle nutrients in the subnivium, and some types of fungi (e.g., snow molds) proliferate there; they create extensive mats beneath the snow or grow vertically into the snow cover. Some invertebrates remain active in the subnivium during the winter as well, and a few species will sporadically emerge, especially toward the end of the season. Most vertebrates inhabiting the subnivium are small (less than 9 ounces, or 250 grams), although larger-bodied organisms enter the subnivium, in part to access their dens. Many rodents hibernate within the subnivium, and many amphibians and reptiles exhibit complex physiological responses to facilitate freeze tolerance. All these species depend on the fact that the subnivium is a stable, predictable, and warmer environment.

3. Warming winters threaten the subnivium. Rising temperatures brought about by climate change can result in thinner snowpacks or more frequent melting and refreezing. This reduces the insulating effect of the snowpack and the temperature stability of the subnivium environment, which leads to freeze-and-thaw cycles that make it more challenging for organisms to survive. Future warmer winters will decrease the extent and duration of the subnivium throughout the Great Lakes region.

4. Human activities, often linked to climate change and habitat disruption, can pose threats to the subnivium. Urban expansion creates more impervious surfaces (roads and buildings) that alter local hydrology. Precipitation runoff becomes more rapid and snow cover decreases, both of which degrade the subnivium’s stability. Land use changes, such as agriculture and deforestation, disrupt natural habitats and fragment ecosystems. This can reduce the availability of suitable subnivium habitats for various organisms. Winter recreation activities, such as skiing and snowmobiling, can compact the snow, reducing its quality and even collapsing the subnivium.

5. As the subnivium becomes less stable, certain species may struggle to adapt or find alternative habitats. During the winter, many living organisms depend on the subnivium as a food source; but warming temperatures disrupt its availability, which jeopardizes the ecosystem’s entire food web. With less snow cover, predators can access the subnivium more easily, making it a less reliable refuge for prey. These changes can produce cascading effects on ecosystems and the species that rely on a stable subnivium. Conservation efforts, such as habitat protection and climate change mitigation, are crucial for minimizing these impacts and protecting the delicate balance of winter ecosystems.

Jonathan N. Pauli and Benjamin Zuckerberg are professors in the Department of Forest and Wildlife Ecology.
The son of Hmong refugees, Magic Vang BS’23 was urged by his parents to pursue a higher education — not just for his future but for theirs as well. And he felt their encouragement push him even further.

“I think the deeper message from my parents is to help the community that we come from, the Hmong,” says Vang, a first-generation college student. “That was my inspiration to come to UW.”

That deeper message continued to guide Vang during his time on campus. It led him to UW’s Midwest Center of Excellence for Vector-Borne Disease, where entomology professor Susan Paskewitz and scientist Xia Lee MS’12, PhD’18 lead a project designed to engage and assist Hmong people in Wisconsin. The first goal is to better understand Hmong knowledge, attitudes, and behaviors related to ticks and tick-borne illnesses. The second is to use that understanding to create outreach materials in the Hmong language (something currently lacking) that increase awareness of these diseases in the Hmong community.

When Vang learned about the project’s existence, he was ecstatic — it was exactly what he came to UW to do. “This [was] a good starting point for me because I want to help,” says Vang. “I want to get involved in public health, and I want to get involved in learning and helping my community.”

Soon after joining the project team, Vang applied for a Wisconsin Idea Fellowship grant to support the effort. The fellowships, which come with financial support, are awarded annually by the UW Morgridge Center for Public Service to undergraduate student research projects aimed at addressing issues in a local or global community.

The grant allowed Vang and his team to travel to Hmong community events. There, they staffed booths and surveyed Hmong people to discover what they know — or don’t — about ticks. After gathering survey data from more than 200 community members, the team had what they needed to develop outreach materials. Vang and Lee are also using the survey results as the basis for a scientific paper. It will be submitted to a peer-reviewed academic journal this year.

Wisconsin Idea Fellowships require collaboration with a relevant community partner; in this case, Vang worked with multiple Hmong organizations around Wisconsin and neighboring states, including The Hmong Institute in Madison.

“Many in the Hmong community enjoy spending time outdoors, such as fishing, hunting, camping, and hiking,” which puts them at greater risk for tick-borne diseases, says Hmong Institute CEO Peng Her. “It’s important to have information about Lyme disease in the Hmong language and available to the Hmong community.”

One way Vang plans to convey this information is through infographics. Simple, full of engaging images, and presented in the Hmong language, the infographics will be a useful reference for Hmong people. Vang intends to make them available at The Hmong Institute and similar locations.

“We don’t expect everyone to use bug spray or apply pesticides to their clothes, but if we can get people to do tick checks or even just be conscious of the dangers that are in the outdoors, then that is a great win,” Vang says.

Vang graduated in December with a degree in global health, but he’ll continue working on this project through spring 2024. He also hopes to pursue a graduate education.

“I really like research,” Vang says. “I think if I can get involved in research and become a scientist, I could really make a big impact, especially in public health.”
Once thought to be the trash can of the cell, a little bubble of cellular stuff called the midbody remnant is actually packing working genetic material with the power to change the fate of other cells — including turning them into cancer.

It’s a surprise to many people, according to genetics professor Ahna Skop, that when one cell divides into two (a process called mitosis), the result is not just the two daughter cells.

“One cell divides into three things: two cells and one midbody remnant, a new signaling organelle,” says Skop. “What surprised us is that the midbody is full of genetic information — RNA — that doesn’t have much to do with cell division at all but likely functions in cell communication.”

In a study published in the journal *Developmental Cell*, members of Skop’s lab and collaborators from the Pasteur Institute in Paris, Harvard Medical School, Boston University, and the University of Utah analyzed the contents of the midbodies (which form between daughter cells during division) and tracked the interactions of the midbody remnants set free after cell division. Their results point to the midbody as a vehicle for the spread of cancer throughout the body.

“People thought the midbody was a place where things died or were recycled after cell division,” Skop says. “But one person’s trash is another person’s treasure. A midbody is a little packet of information that cells use to communicate.”

The midbody’s involvement in cell signaling and stimulating cell proliferation has been investigated before, but Skop and her collaborators wanted to look inside the midbody remnants to learn more.

What the researchers found inside midbodies was RNA — which is a kind of working copy of DNA used to produce the proteins that make things happen in cells — and the cellular machinery necessary to turn that RNA into proteins. The RNA in midbodies tends to be blueprints not for the cell division process but for proteins involved in activities that steer a cell’s purpose. This includes pluripotency (the ability to develop into any of the body’s many different types of cells) and oncogenesis (the formation of cancerous tumors).

“A midbody remnant is very small. It’s a micron in size, a millionth of a meter,” Skop says. “But it’s like a little lunar lander. It’s got everything it needs to sustain that working information from the dividing cell. And it can drift away from the site of mitosis, get into your bloodstream, and land on another cell far away.”

Many midbody remnants are reabsorbed by one of the daughter cells that shed them, but those that touch down like a lunar lander on a distant surface may instead be absorbed by a third cell. If that cell swallows the midbody, it might mistakenly begin using the enclosed RNA as if it were its own blueprints.

Previous research has shown that cancer cells are more likely than stem cells to have ingested a midbody and its potentially fate-altering cargo. Stem cells, which give rise to new cells and are valuable for their pluripotency, eject a lot of midbodies (perhaps to maintain their pluripotency).
Future research may be able to harness the power of midbody RNA to deliver drugs to cancer cells or to keep them from dividing. “We think our findings represent a huge target for cancer detection and therapeutics,” says Skop, whose work is supported by the National Institutes of Health.

The researchers also identified a gene, called Arc, that is key to loading the midbody and midbody remnant with RNA. Taken up long ago from an ancient virus, Arc also plays a role in the way brain cells make memories.

“Loss of Arc leads to the loss of RNA in the midbody and a loss of the RNA information from getting to recipient cells,” Skop says. “We believe this memory gene is important for all cells to communicate RNA information.”

Sungjin Park, a senior scientist in Skop’s lab, is the lead author of the study. Skop and collaborators also have a patent pending on two new methods that make it easier to isolate midbody structures from cell media or blood serum, improving cancer diagnostics.

This research was funded in part by grants from the National Institutes of Health (R01 GM139695-01A1, R01 NS115716, R01 GM122893, and GM144352) and the French Foundation ARC for cancer research.

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**FOLLOW-UP**

**THE FATE OF MICROBES AND CARBON IN THE AFTERMATH OF WILDFIRES**

In “Controlled Burn” (Grow, fall 2018), Erik Ness introduced readers to the Charcoalator, a small furnace that sustains tiny fires under controlled conditions. Associate professor of soil science Thea Whitman and colleagues in her lab use the apparatus to expose organic matter to oxygen deprivation at 300–600 degrees Celsius and then see how these conditions influence soil microbes and the carbon cycle. The idea is to better understand what happens to carbon stores in the soil after wildfires strike.

Whitman and her team are also conducting these studies in the field. In a recently published paper, they examined soil bacterial communities at one and five years after a wildfire swept through a boreal forest in northern Canada. The research team focused on taxa (groups) of bacteria that, according to their laboratory studies, either survive fire, grow quickly post-fire, or thrive in the post-fire environment.

The study, led by graduate student Dana Johnson MS’21, found that only a small number of bacterial taxa survived the fire. Many taxa detected in the first year were instead from the fast-growing groups, especially following severe fire. These bacteria likely take advantage of the low numbers of competing bacteria and feed on the plentiful carbon sources left behind, such as dead microbes and fine roots. However, these fast-growing taxa almost disappeared by the five-year increment. Taxa that thrive in the post-fire environment took over after the first year, possibly because of their greater tolerance for fire-induced changes in soil properties, such as shifts in acidity or alkalinity or alterations in organic matter makeup.

The researchers also determined that the post-fire bacterial communities, although changed, could still readily feed on organic matter and release carbon dioxide into the air when respiring. So, shifts in soil bacteria post-fire did not hinder the microbiome’s ability to cycle carbon.

“Where, when, and how fires burn is changing,” says Whitman. “We need to understand how soil microbes are affected by fires, since they perform so many essential functions. They play important roles in nutrient cycling, which, in turn, affects which plants reestablish in the years following a fire. We’ve had a pretty good understanding of fire ecology for plants for decades. This study takes a strong step in the direction of establishing the importance of microbial responses to fires.”

—Caroline Schneider MS’11
Flexibility + Preparation = Resilience

Economic modeling reveals strategies that can keep food supply chains functioning during extreme events.

By SILKE SCHMIDT

The COVID-19 pandemic expanded our everyday vocabulary to include words such as “PCR test” and “supply chain.” Economists and the general public alike wondered what it would take to make those supply chains more resilient to external shocks — and not just pandemics but also military conflicts such as the Russia-Ukraine war and extreme weather events like heat waves, wildfires, and floods.

To help answer this question, Jeff Hadachek and his colleagues developed a mathematically rigorous framework for modeling shocks to food supply chains. The framework allowed the researchers to evaluate different policies aimed at boosting the ability of food supply chains to withstand major disturbances.

“Researchers have studied how food supply chains in normal times responded to the concentration of agricultural production processes during the last five decades,” says Hadachek, an assistant professor of agricultural and applied economics. “But that framework has not yet been extended to modeling major shocks from extreme events.”

The study, published in the American Journal of Agricultural Economics, focuses on a closed economy without international trade (since almost 90% of U.S.-consumed food is produced domestically). The researchers used meat as a specific example. Hadachek notes, however, that the study’s lessons apply to many other food products, especially those that remain in the same state from production to consumption.

In the meat supply chain, meat-packers are the middlemen or “intermediary” between farmers and consumers. The researchers combined processing and retailing into a single intermediary category and developed statistical models to simulate how major shocks affect the farmer-middleman-consumer supply chain. Next, they compared the performance of four different policies for mitigating those shocks on the simulated data.

The researchers found that the first policy — increasing competition among intermediaries — improved the resilience of most markets, making it a win-win for farmers and consumers. A real-world example is the U.S. Department of Agriculture’s Packers and Stockyard Act for meat-processing industries, which prohibits manipulating prices, restricting the flow of foods, and creating monopolies. This 1921 law, says Hadachek, has been an effective tool for combating anticompetitive practices among food intermediaries for many years.

The second policy encouraged the entry of new processors into the industry. The USDA used this tool in 2021 by providing $500 million to support the launch of new meat and poultry processing firms. The analysis found that this strategy only worked well in markets with “imperfect competition.” The researchers measured the level of competition on a scale of 0 (perfectly competitive market where processors have no control over prices) to 1 (pure monopoly in which processors can set prices at will). Market power, which is the ability to reduce capacity to raise prices, ranges from low to high in these settings.

Most U.S. food markets, says Hadachek, are in the 0.15 to 0.25 range, meaning that processors exercise 15–25% of the market power they would have under a monopoly. The fact that the performance of the second policy...
was highly dependent on the level of intermediary market power was one of the study’s key findings.

The third policy was the introduction of laws against price gouging, which are determined at the state level in the U.S. An example is California’s spring 2020 executive order to cap price increases for eggs at 10% relative to average prices before the state declared its COVID-19-related emergency. The researchers found that restrictive price caps were more likely to cause product shortages and could be harmful in highly competitive markets, another key finding of the study. However, price caps performed much better in less competitive markets with higher processor market power.

The fourth policy — diversifying production into multiple geographical regions — offered limited benefits regardless of market features. This is largely because, in the meat industry, starting new cattle farms requires substantial upfront equipment, building, and labor costs that reduce the efficiency of meat production more than they improve resilience. This trade-off between efficiency and resilience was also observed for the third policy and is typical for many supply chains.

“Fruits and vegetables that are grown exclusively in California are another example,” says Hadachek. “If a drought wipes out a fraction of California’s production, other states could make up for that loss, but this reduces market efficiency if both lines of production are maintained in normal times.” For consumers, less efficient production lines result in higher prices and greater fluctuation in shelf availability. Factors that boost efficiency include mechanization and the development of robust transportation networks, adds Hadachek.

The study’s take-home message, relevant not only to researchers but also to farmers and consumers, is stay flexible. “Consumers should be willing to substitute beef with chicken or pork, and farmers should avoid being pigeonholed into specialized facilities,” says Hadachek.

An example of the latter is that some California farmers produced lettuce only for restaurants and others only for grocery stores before the pandemic. The restaurant-specific producers, who struggled greatly during COVID-19, now know how to switch between multiple intermediaries.

“The meat-packing industry is the primary link between farmers and consumers in the meat supply chain,” says Hadachek.

An example of the latter is that some California farmers produced lettuce only for restaurants and others only for grocery stores before the pandemic. The restaurant-specific producers, who struggled greatly during COVID-19, now know how to switch between multiple intermediaries.

“U.S. food supply chains were generally pretty resilient, with most products for most consumers being back on the shelves six to eight weeks after March 2020,” says Hadachek. “But our study and others highlight the importance of being as flexible and prepared as possible because future shocks may be different and could cause more disruption.”
Recipes for the Origins of Life

UW scientists have compiled a “cookbook” of self-sustaining chemical reactions that could help focus the search for living things on other planets.

By CHRISS BARNCARD

Life on a faraway planet — if it’s out there — might not look anything like life on Earth. But there are only so many chemical ingredients in the universe’s pantry, and only so many ways to mix them. A team led by UW scientists has exploited those limitations to write a cookbook of hundreds of chemical recipes with the potential to give rise to life.

Their ingredient list could focus the search for life elsewhere in the universe by pointing out the most likely conditions — planetary versions of mixing techniques, oven temperatures, and baking times — for the recipes to come together.

The process of progressing from basic chemical ingredients to the complex cycles of cell metabolism and reproduction that define life, the researchers say, requires not only a simple beginning but also repetition.

“The origin of life really is a something-from-nothing process,” says Betül Kaçar, a professor of bacteriology at CALS and a NASA-supported astrobiologist. “But that something can’t happen just once. Life comes down to chemistry and conditions that can generate a self-reproducing pattern of reactions.”

Life requires repetition of chemical reactions. Describing the kinds of reactions and conditions required for self-sustaining repetition — called autocatalysis — could focus the search for life on other planets. Image by ELLA MARUSHCENKO

FINDINGS

CAN TICKS SPREAD CHRONIC WASTING DISEASE IN DEER?

Research by CALS scientists and their collaborators finds that ticks can harbor transmissible amounts of prions, the protein particles that cause chronic wasting disease (CWD). CWD is a neurodegenerative disease known to pass from deer to deer through contact with prion-contaminated soil and infected bodily fluids. This study, published in the journal Nature, implicates the parasitic insects as another possible agent in the spread of the disease. The research team was led by Heather Inzalaco, a researcher with the Wisconsin Cooperative Wildlife Research Unit in the Department of Forest and Wildlife Ecology.

EXPLORE ONLINE  Read about more CALS research at news.cals.wisc.edu.

Ticks and other insects suspended in resin. Photo by MICHAEL P. KING
Chemical reactions that produce molecules that encourage the same reaction to happen again and again are called autocatalytic reactions. In a study published in the *Journal of the American Chemical Society*, Zhen Peng, a postdoctoral researcher in Kaçar’s laboratory, and collaborators compiled 270 combinations of molecules — involving atoms from all groups and series across the periodic table — with the potential for sustained autocatalysis.

“It was thought that these sorts of reactions are very rare,” says Kaçar. “We are showing that it’s actually far from rare. You just need to look in the right place.”

The researchers focused on what are called comproportionation reactions. In these reactions, two compounds that include the same element with different numbers of electrons, or reactive states, combine to create a new compound in which the element is in the middle of the starting reactive states.

To be autocatalytic, the outcome of the reaction also needs to provide starting materials for the reaction to occur again, so the output becomes a new input, says Zach Adam, a coauthor of the study and a UW geoscientist studying the origins of life on Earth. Comproportionation reactions result in multiple copies of some of the molecules involved, providing materials for the next steps in autocatalysis.

“If those conditions are right, you can start with relatively few of those outputs,” Adam says. “Every time you take a turn of the cycle, you spit out at least one extra output, which speeds up the reaction and makes it happen even faster.”

Autocatalysis is like a growing population of rabbits. Pairs of rabbits come together, produce litters of new rabbits, and then the new rabbits grow up to pair off themselves and make even more rabbits. It doesn’t take many rabbits to soon have many more.

Kaçar hopes chemists will pull ideas from the new study’s recipe list and test them out in pots and pans simulating extraterrestrial kitchens.

“We will never definitively know what exactly happened on this planet to generate life. We don’t have a time machine,” Kaçar says. “But, in a test tube, we can create multiple planetary conditions to understand how the dynamics to sustain life can evolve in the first place.”

Kaçar leads a NASA-supported consortium called MUSE, which stands for Metal Utilization and Selection Across Eons. Her lab will focus on reactions involving the elements molybdenum and iron, and she is excited to see what others cook up from the most exotic and unusual parts of the new recipe book.

“Carl Sagan said if you want to bake a pie from scratch, first you must create the universe,” Kaçar says. “I think if we want to understand the universe, first we must bake a few pies.”

This research was funded in part by grants from NASA Astrobiology Program (80NSSC22K0546), the John Templeton Foundation (62578 and 61926), the Research Corporation for Science Advancement (28788), and the Australian Research Council (DP210102133 and FT220100757).
As an associate professor and extension specialist in the Department of Plant and Agroecosystem Sciences, Julie Dawson studies plant genetics and breeding as well as organic agriculture. For part of her work, she connects plant breeders, farmers, and chefs through the Seed to Kitchen Collaborative (see “Breeding for Flavor,” Grow, summer 2016). In that role, Dawson sees firsthand how changes in the landscape of the seed industry, which affect access to seeds, can help or hinder independent breeders and growers. And that background has made her uniquely suited to help address a major area of concern in agriculture.

In early 2021, an executive order to study the effects of competition in the seed industry arrived at the doorstep of the U.S. Department of Agriculture (USDA). Dawson, who is also the Clif Bar and Organic Valley Chair in Plant Breeding for Organic Agriculture, was chosen to lead development of a report. She worked with a team of experts to talk with agencies, review intellectual property rights, host listening sessions, and then summarize findings. The final report, published in March 2023, outlines concerns about intellectual property in the seed industry as well as suggestions and next steps, some of which Dawson recently discussed with Grow.

How has intellectual property been handled in the seed industry historically?

Early on, when the USDA was developed, a key part of its mission was to procure, propagate, and distribute new seeds and plants. But in the 1920s, the seed industry began to grow, and they pushed for the USDA to stop free distribution because it competed with the private sector. The industry also pushed for IP (intellectual property) protection because they felt, without it, there was no protection for their investment in creating new varieties. The Plant Patent Act [of 1930] and the Plant Variety Protection Act [in 1970] were developed to protect new varieties. Utility patents can cover a number of things, including varieties, traits, or breeding methods.

How have advances in seed breeding changed the landscape of the industry?

As seed breeding became more predictable and pure lines were developed in the mid-20th century, it became possible to develop uniform varieties. A small number of companies were able to rapidly adopt key technologies, and they took over a large share of the market. Over the last few decades, companies consolidated further as seed companies that owned traits [such as resistance to a disease] began to acquire companies that had valuable germplasm, such as adapted varieties and elite breeding lines. This led to companies controlling both the germplasm and the traits. Currently, there are three companies that own most of the IP on varieties in major crops, such as corn, soy, and cotton.
How does the concentration of IP rights with a few companies affect the industry?

IP restrictions make research and breeding difficult for those who don't hold the patents. Newer or smaller companies have a hard time competing in the market. Also, independent seed companies have limited options to offer to farmers. What we heard from public comments was that it is hard for an independent company to get a license for corn varieties unless they also carry soybean varieties from the same larger company, and that it's hard to stay in business if they don't have a license from one of the big three companies. If farmers want seeds from two different IP owners, they have to use different dealers, but that can cost more. The current IP licensing options are not going to keep independent seed companies in business. We wanted to highlight in the USDA report that the current situation is such that the IP owners control enough of the market that they are able to set the terms of licenses in ways that are favorable to them.

As the seed industry and private sector have undergone this concentration, what has changed for universities and public programs?

Over the course of the last century, investment in agricultural research has not grown in real dollars in the public sector, while in the private sector it has grown a lot. Infrastructure like research stations and programs that are supported by state and federal funding have not been maintained. So a lot of the small companies aren't able to carry varieties from the public sector as much as they used to, and these public releases were an important source of support for independent seed companies.

A lot of public sector institutions have also gone through several rounds of consolidation to the point where very few full plant breeding programs now exist. With decreasing investments in universities, those institutions don't replace plant breeders. And once you stop a program, the plants and the germplasm die. You can't restart those programs easily.

The capacity to provide varieties to farmers has shifted to the private sector and consolidated, so we've lost some of that infrastructure that can support a diverse range of seed businesses. That's a food security issue.

Why is the loss of infrastructure a food security issue?

It's better for farmers to plant varieties that are adapted to their location, so those varieties need to be available. Those varieties will be more adapted to the stress, pests, and pathogens they are likely to face and, thus, more likely to perform well in that region. Also, concentration of the production of a crop in one region puts it at higher risk of failure if there is a drought or other disruption.

While the private sector can produce regionally adapted varieties, with consolidation there has been a trend to focus on larger volume crops and growing regions. Decentralizing variety development and seed production builds more resilience into the system. To do this, we need regional infrastructure, and the land-grant system has historically been a large part of that infrastructure.

What recommendations are made in the report to address some of these concerns?

The goal of this isn't to say we shouldn't have IP for seeds. We just need IP that works in a way that doesn't shut down competition. Often, people refer to the Plant Variety Protection Act as a model that really worked to promote competition. That act allows the breeders to recoup investments on a variety but doesn't exclude others from building on that innovation. We need to allow people to have space to operate and ensure that utility patents are only issued when an innovation meets all the requirements of utility patents.

We also want to ensure that private and public sector innovators can fairly compete based on the merits of their varieties. If you have a great variety, you should be able to get it to farmers. You shouldn't need to negotiate a system where no one can carry your variety because they've signed a license with a larger company that restricts their ability to deal with you as a small business.

And third is ensuring we have a resilient seed system so we have the infrastructure and capacity to really provide varieties for all farmers. This has historically been in the public sector with foundation seed programs, pre-breeding, and cultivar development that supported independent seed companies.

What are the next steps now that the report has made recommendations?

Trying to implement some of these recommendations takes a lot of dissecting them and seeing what would require new legislation, what would require new agency regulations, and what could be done with existing laws, so we have an interagency working group looking at these issues. Within the USDA, there's a new Farmer Seed Liaison initiative. It's a cooperative agreement with UW–Madison, but the goal is that it will eventually be a more permanent program within the USDA.

Another goal is to provide a resource that improves the transparency of IP. It's hard for seed companies and researchers to find what's available to work with. Without an attorney, it's hard to figure out how to get a utility patent if you want one.

We also want to be sure that independent seed companies, farmers, and plant breeders are involved in discussions around IP. The Farmer Seed Liaison will work to get more voices into the conversation, particularly in discussions with other federal agencies.

Finally, getting access to germplasm for research and breeding is critical to allow breeders and innovators to continue to build on what's been done before. We're looking at ways that we can ensure that there is research access. And we're looking at how to develop more cultivars in the public sector that will be available for continued research and breeding to ensure that innovation continues.

The views expressed in this article do not necessarily reflect the position of the USDA.
A life sciences communication study shows that artistic representations of data may help bridge the political divide over climate change.

By Elise Mahon
This painting by Diane Burko, titled “Summer Heat, 2020,” depicts red, orange, and blue motifs of wildfires and melting glaciers that overlap with maps that appear to drip over a graph of global atmospheric carbon dioxide levels. Research from the Department of Life Sciences Communication shows that combining climate data with visually engrossing art can make data more meaningful to viewers and bridge political divides related to climate science.
Communicating science to a general audience can be challenging. Successfully conveying research on polarizing topics such as climate change can be even more difficult. But there are tools that could make it all a little easier, and a research team led by Nan Li has identified at least one.

In their recent study, the team shows that intentionally integrating art with data visualizations can help non-expert audiences more meaningfully engage with the issue of climate change. It can also bridge political divides in ways that data alone cannot. In fact, the study shows, data graphs on their own can exacerbate political division on climate change.

As an assistant professor in the Department of Life Sciences Communication (LSC), Li studies how innovative visual representations of science can shape people’s understanding and opinions about various scientific issues. For this study, she teamed up with LSC graduate students Isabel Villanueva and Thomas Jilk, LSC professor and chair Dominique Brossard, and LSC alum Brianna Rae Van Matre BS’20, MS’22 from EcoAgriculture Partners. Through a survey of people across the political spectrum, they gauged responses to a painting by Diane Burko titled “Summer Heat, 2020.”

The painting depicts red, orange, and blue motifs of wildfires and melting glaciers that overlap with maps that appear to drip over a graph of global atmospheric carbon dioxide levels. It’s not just art and science side-by-side or pretty colors added to a graph: The two are combined to tell a larger story that makes people stop and think about climate change.

Li thinks this intentional integration of the data into the piece of art is part of its success. “For art to maximize its potential as a tool for public engagement, you really need to use it as a catalyst for triggering self-reflection,” Li says. “People use this piece of art as a starting point to think about what this all means to themselves.”

For the study, published in Communications Earth & Environment, the team divided 671 survey participants from across the U.S. into groups and showed each group one of four different presentations of the painting and the data it contains: the original painting, a detailed version of the graph it includes, a simplified version of that same graph, or an edited version of the painting with a detailed graph.

In the first iteration of the survey, participants were instructed ahead of time to reflect on the meaning of the visuals and the emotions they evoke. Survey participants who saw the paintings reported stronger positive emotions — such as happiness, awe, inspiration, and hope — than participants who were shown just the graphs.

The researchers then used a digital editing tool to represent what it would look like if “Summer Heat, 2020” and other visuals were posted to an Instagram feed. The caption contained more details about the painting and facts about climate change.

Participants felt the artwork post was as credible a source of information as the data graphs post. This finding supports the idea that galleries aren’t the only way these kinds of artwork can be successful, Li says. Bringing them to a larger audience through social media is beneficial as well.

In the intricate symphony of life’s development, there exists a genetic composer. The Hox gene family orchestrates the breathtaking diversity of forms found in the natural world, from the elegant curve of a swan’s neck to the delicate fingers of a pianist.

During their orchestrations, Hox genes undergo complicated processes that can be difficult to describe. But art can help people visualize and understand such complex scientific concepts in better ways. This is the inspiration behind Genetic Symphonies: The Building Hox of Life, an interactive, art-science fusion exhibit, developed by CALS graduate students Katharine Hubert MS’21 and Sharon Tang MS’22, that reveals the captivating world of Hox genes.
In general, when people see graphs about climate change, their self-identified political ideology (conservative or liberal) influences how they perceive the relevance of the issue. But in the new study, Li’s team noted a reduction in the gap between political affiliations when survey participants saw the painting in a social media format. In other words, when liberals and conservatives both see artistic representations of climate data rather than data alone, they are more likely to share the perception that climate change is relevant to them.

Another iteration of the survey did not instruct participants to reflect on the meaning and emotions the visuals inspired before seeing them. Instead, they viewed the simulated Instagram posts and then later reported their perceived relevance of climate change. This time, participants’ perceived relevance of climate change was equally polarized along their political ideology despite the different visuals they were shown. To Li, this suggests that priming people for introspection is important for breaking down political barriers.

While the findings are exciting, Li also recognizes this case study is very specific. The study is limited to the use of one painting in one style from one artist.

The exhibit conveys developmental biology concepts using light and sound. To reflect the pivotal role of Hox genes in embryonic development, this multimodal exhibit uses 13 painted building blocks to represent the 13 groups of mammalian Hox genes. The blocks are controlled by 13 respective buttons on an accompanying podium. Because Hox genes must be activated in a specific order for development to occur, viewers must figure out the correct sequence for pressing the buttons. When pressed in the correct order, the buttons switch on the exhibit’s light and sound.

Hubert and Tang conceived and created the exhibit as part of the Marie Christine Kohler Fellowship at the Wisconsin Institute of Discovery (WID). The fellowships foster an interdisciplinary community that creates content fusing science and art.

Hubert, who is pursuing a Ph.D in genetics, says her artistic interests and passion for scientific research are fueled by her experiences living with her own genetic condition — experiences she hopes can help fill gaps in scientific knowledge. Hubert has established herself as a leader in disability advocacy within STEM, creating accessible lab equipment and advocating for inclusive and accessible practices, some features of which can be found in this exhibit. Hubert works in the lab of genetics professor Deneen Wellik PhD’95, who provided consultation for the project.

Tang, a mural artist in the cellular and molecular biology Ph.D. program, uses her background in education to create public art that helps viewers lead their own process of discovery. She believes art can connect people to content they might otherwise find unapproachable. Tang is a student in the lab of Wilmara Salgado-Pabón PhD’08, an associate professor in the UW School of Veterinary Medicine, who Tang credits for providing freedom and encouragement for interdisciplinary pursuits.

Genetic Symphonies invites the public into an experience where science and art converge and artistic tools encourage public connection with scientific concepts. The exhibit is moving around the UW campus during the 2023–24 academic year.

—Andrew Hanus
Emissaries of Science

Through organized outreach, CALS graduate students bring the wonders of insects, plants, and genetics to kids and families.

By Susan Lampert Smith BS’82
Participants in a Wisconsin Bumble Bee Brigade event observe and collect data for submission to the citizen science project. The event was hosted by the Insect Ambassadors, an outreach group led by CALS graduate students.

Photo by ROMULO UEDA
It’s a summer evening in early July, and the sun is sinking into Lake Mendota. Along University Bay, the windows of campus buildings bathe in a golden glow. But across the water, a spectacle of a different kind is beginning to twinkle among the trees on Picnic Point.

First one, then two, then dozens of fireflies wink and blink into action. And based on the oohs and aahs coming from a small crowd armed with nets and petri dishes, you’d think it’s a Fourth of July fireworks show. Instead, it’s Firefly Night, an event organized by a group of entomology graduate students called the Insect Ambassadors.

“I got one!” exclaims 4-year-old Zongyi Shen as she hands over her wiggly prize to Eliza Pessereau, a master’s student in entomology and agroecology. Zongyi’s firefly is measured, photographed, and documented for the Firefly Atlas citizen science project. Next, Zongyi, the daughter of UW engineering graduate student Weijun Shen and his wife, Qing Xu, carefully lifts the petri dish lid and releases her flashing friend back into the evening sky.
Firefly Night is one of seven Community Science events the Insect Ambassadors coordinated for summer 2023 with funding from the Lakeshore Nature Preserve. The insect-centric events introduce kids and families to citizen science programs that monitor monarch butterfly larvae, bumble bees, and dragonflies or focus on garden pests and beneficials.

Pessereau is not the only ambassador on-site on this particular evening. Ph.D. student Jade Kochanski BS’16, MS’20, who works with Pessereau in the lab of entomology professor Claudio Gratton, mingles among the participants. Kochanski is studying bumble bees for her doctoral research, but she has a side interest in fireflies. Celeste Huff BS’20 is also on hand. She’s a master’s student in entomology who works in the lab of Leslie Holland, an assistant professor and extension specialist in plant pathology. Huff spent the past summer studying pollinators in the cranberry bogs of central Wisconsin.

All three graduate students have gathered on Picnic Point alongside 20 other people ranging in age from preschoolers to seniors. They’re waiting for the summer sunlight to fully fade so the “stars” of the evening can begin to flash.

As they cool their heels, Kochanski talks up the tiny celebrities. There are about 2,000 species of fireflies in the world, she explains, and about 24 of them are found in Wisconsin. These insects are typically referred to as fireflies in the northern U.S., but down South, they’re more likely to be called lightning bugs. And there are many other names for this fascinating member of the beetle family: candle flies, firebobs, firebugs, jack-o-lanterns, lamp bugs, peeni wallies, and will-o’-the-wisps, depending on your region of the country. (Read more in “Five Things Everyone Should Know About Fireflies,” Grow, summer 2018.)

According to Kochanski, when we spot a firefly on a Wisconsin summer evening, we’re only glimpsing a short phase of its one- to two-year life cycle. The insects spend a week or two flying around, flashing their lights to attract mates. The eggs they lay will mature for about a week and then spend a year or two in the soil as larvae and pupae, phases during which they also emit light (hence, yet another name for these insects: glowworms).

“No all the adults light up, but all the larvae do,” Kochanski explains.

After the introduction, Kochanski hands out guide sheets from the Firefly Atlas with visual depictions of the flash patterns that identify the different species most likely to be seen in Wisconsin. The flashes range from warm amber to yellow green to neon green-blue, and the patterns they present can be described with terms such as crescendo flash (building, then ending abruptly) and flash-train (a multiple flash sequence that repeats), and by the intervals between flashes. And many species engage in what’s known as “flash dialogue” between males and females, a sort of disco version of a mating dance.

“On a warm night, they’ll blink faster than a cool night because of the chemistry involved,” Kochanski says.

At the end of the night, the Insect Ambassadors collect forms and ship them off to the Firefly Atlas, a citizen science project that tracks the health of this popular yet dwindling species.
The Insect Ambassadors don’t stop with fireflies. Later in the summer, they will host another community science event at the Lakeshore Preserve where participants collect data to be submitted to the Wisconsin Bumble Bee Brigade, another citizen science project that tracks the health of the state’s native pollinators. The Lakeshore Preserve events occur during summer, when Wisconsin’s insects are easier to find, but the Insect Ambassadors plan events throughout the school year, presenting in classrooms from elementary schools to high school Advanced Placement biology courses.

The Ambassadors may look like serious, adult scholars, but they bubble with the same wonder for nature as 4-year-old Zongyi.

“I’ve always been a bug nut,” Huff says. “I was the dirty kid; I was the 9-year-old out in the field with a guidebook, trying to identify flowers and bugs.”

So, yes, Firefly Night on Picnic Point is a search for insects flashing their mating signs, but it also helps the bug people find one another.

At a S.T.E.A.M. Saturday science event at the Monona Public Library in August, plant pathology Ph.D. student Evan Lozano uses a whiteboard to walk a young child through a series of questions about how best to care for a tomato plant. (S.T.E.A.M. stands for science, technology, engineering, art, and math.) Like Huff, the Insect Ambassador, Lozano works in the Holland lab. But this event is coordinated by a different group of graduate students called What’s Eating My Plants? (WEMP).

“Would you feed a tomato a cup of coffee?” Lozano asks.

“No!” the little girl responds.

“How about a can of soda?”

“Noooo!”

After deciding together that water and sunshine are the best things for tomato plants, Lozano explains that a plant can develop something called blossom end rot when it gets too thirsty. Without adequate water, the plant can’t move calcium to the fruit, causing the far end to soften and start to decay. Lozano tells the little girl, “You need calcium for strong bones, and plants need it, too.”

At a nearby table, another WEMP member, Miette Hennessy, who is studying fungal genetics in soil microbial communities for her doctoral work, helps youngsters paint tomatoes while engaging in a spirited discussion with one of the parents in attendance about the HBO streaming series The Last of Us. The premise of the show involves a fungus that turns people into zombies. To the father, Hennessy describes the real-world inspiration: a “suicide fungus” called Ophiocordyceps, which infects ants and sends chemical signals that instruct it to climb to the top of the plant. Then the fungus kills the ant and sends a stalk up through its head, which showers spores on other ants and continues the cycle.
Like the Insect Ambassadors, WEMP brings the wonders of the life sciences to many communities. These plant pathology graduate students look to increase scientific accessibility and literacy through outreach, especially for underserved communities and underrepresented K-12 students. And they have cultivated some novel ways for teaching about plants — and what kills them. They recently unveiled a new instructional aide perfect for educating kids about garden plants during Wisconsin’s long winters: Legos.

The children who attended the next S.T.E.A.M. Saturday in Monona, held in December, were the first to try making Lego models of tomatoes. They used red and green plastic bricks to build healthy tomatoes and red, brown, and yellow bricks to make a tomato suffering from blossom end rot.

The tomato models were designed by Brian Hudelson MS’89, PhD’90, director of the Plant Disease Diagnostics Clinic at CALS, using BrickLink Studio 2.0. The software allows him to model plants in 3D and then analyze the Lego bricks needed for the project. He’s worked out models of other diseases, such as cedar apple rust, corn smut, downy mildew, and silver leaf, but not all the bricks are commercially available, so he’s trying to create them on a 3D printer.

Before the Lego models existed, the WEMP students taught the course by making papier-mâché tomatoes that the kids could paint to emulate the mushy, black blossom end characteristic of diseased tomatoes.

The WEMP students coordinate a number of family science nights and participate in the Saturday Science events at the Discovery Building on the UW campus. During the COVID-19 epidemic, WEMP students produced a series of YouTube videos designed to teach science lessons at home. One at-home activity features coloring pages with plant vascular structures that complement an episode of The Magic School Bus, an animated children’s television series. The effort was lauded by the American Phytopathological Society.

Max Chibuogwu, a doctoral student who studies fungal diseases of corn in the lab of plant pathology professor and extension specialist Damon Smith, attended the Monona library event wearing the “Badger Crop Doc” khaki uniform, part of his work with the extension service that diagnoses Wisconsin crop diseases. Chibuogwu, who is from Nigeria, said he particularly enjoyed participating in a Juneteenth Day festival where WEMP students handed out seeds for cowpeas and taught children about food crops that originated in Africa.

WEMP students are known for their passionate outreach to families of color, says Amanda Gevens, chair of the plant pathology department, in nominating WEMP for the CALS Equity and Diversity Award. She notes that they produce lesson plans in Spanish and English and have held events for the Latino Youth Summit, Centro Hispano, and “Expanding Your Horizons,” a day on campus for middle school students to learn more about science, technology, engineering, and math research.
Darwin Day
A Celebration of Curiosity

Jassim Al-Oboudi, a Ph.D. student in microbiology, recalls a flash of inspiration from his childhood. He was watching a PBS documentary at home, in Los Angeles.

“I remember being 7 or 8 and learning about supermassive black holes and deciding right there and then I wanted to be a scientist,” he says. “Here was something so amazing, and it actually exists in the world. I remember it really opening my mind and grabbing my attention.”

Today, Al-Oboudi is one of the graduate students from Wisconsin Evolution (also known as the J.F. Crow Institute for the Study of Evolution) who are exposing the next generation of kids to the life-changing stuff of science. The group organized the annual Darwin Day festivities to mark the mid-February birthday of Charles Darwin, the 19th-century naturalist known for major contributions to evolutionary biology — and to celebrate intellectual curiosity.

This year, the events were held at the Discovery Building on the UW campus and included science activities for kids and an art show on the theme of variation. After several years of events that were partly or fully virtual due to the pandemic, Al-Oboudi says it was great to get back to in-person events. Younger children are drawn to the hands-on and tactile science experiences, he says, while teens tend to gravitate to science that relates to their everyday life and topics they care about, such as climate change. And it’s fun to see kids show up excited for science, he says.

“We’re showing them that the natural world is sometimes stranger than fiction,” he says. “In fact, it gets weirder the farther you get into the wild world of science. I’m a scientist, and I see things every day that surprise me.”

Ana Cristina Fulladolsa Palma, who co-founded the What’s Eating My Plants? graduate student outreach group with Alejandra Huerta, works with grade school students during a Science Night event in March 2014.

Faculty Support for WEMP

Faculty advisors in the Department of Plant Pathology are vital to WEMP’s efforts. Their labs provide resources for WEMP programs, such as supplies, cultures, and other materials. They also offer guidance and time. In addition to the previously mentioned Gevens, Holland, and Smith, CALS professors Caitlyn Allen and Medhi Kabbage and CSU plant pathology professor Amy Charkowski BS’93 help graduate students make WEMP a success.

WEMP was founded in 2012 by then-doctoral student Alejandra Huerta PhD’15. The daughter of farm workers who moved between California’s Central Valley and Mexico, Huerta is passionate about reaching children of color and exposing them to the science of agriculture.

“When I was growing up, I saw the labor part of agriculture, not the science,” she says, adding that she was strongly discouraged from studying science. She remembers having a rough transition between sunny California, where she had earned undergraduate degrees, and frigid Madison. She had failed her preliminary exams and was questioning her future.

“I had never been in a place where I was the only dark-haired individual in the room,” Huerta says. She also felt discouraged from pursuing extracurricular work when she was supposed to be concentrating on her research. That all changed one day when she was eating lunch at the Babcock Dairy Store, and a tall Black man walked in, trailed by about 20 kids of color. The man was Tom Browne, who is now senior assistant dean for climate and engagement at CALS. He introduced Huerta to opportunities to engage with children about science.

Her first events were a long way from the bespoke Lego sets of today’s WEMP. Huerta remembers scrounging dead plants that had been discarded in plant pathology labs and begging colleagues for samples that kids could examine under a microscope.

“Finally, my good friend [fellow grad student Ana Cristina Fulladolsa Palma PhD’15] asked me, ‘What are you doing with all this stuff? Can I come?’ ” Huerta recalls. “So, a one-person thing became a two-person thing. She got excited, too, and we started inviting others to join us.”
Huerta says she named What’s Eating My Plants? with an eye toward what would appeal to children. It appealed to the American Phytopathological Society, too. The organization gave the WEMP team a grant to buy a microscope and other supplies, which meant they could quit begging for materials and scavenging from the lab trash.

Huerta is now an assistant professor at North Carolina State University (NCSU), where she leads a research team that focuses on how bacterial plant pathogens compete against other organisms. She started the position after doing postdoctoral studies at Colorado State University (CSU). Fulladolsa Palma, who grew up in Guatemala, is now on the faculty at CSU, where she is a plant disease diagnostician and assistant professor.

Other WEMP alums can be found from the University of British Columbia, where Corri Hamilton PhD’22 is a postdoctoral researcher, to the Puerto Rican Agricultural Extension Service, where Sofia Macchiavelli Giron PhD’21 is an assistant extension agent. Tina Wu, who is university relations coordinator with the National Society of Minorities in Agriculture, Natural Resources, and Related Sciences, says her WEMP involvement improved her leadership and communication skills and helped her learn how to approach science outreach through a lens of diversity, equity, and inclusion.

Huerta says she is leveraging the newfound privilege of her faculty position to broaden the reach of the university to include communities often excluded from STEM. This includes working with Latinx students through NCSU’s Juntos college access program. In her case, getting kids excited about science helped turn her own academic career around. She still remembers the first group of kids she invited to UW’s Russell Labs, a group of middle schoolers who were on campus for the Latinx Summit.

“They would get very excited to see bacteria under the microscope or a nematode swimming,” she says. “We had plants that were engineered to fluoresce, and we’d turn off the lights and they’d be very impressed. You would hear, ‘Oh my gosh! Look at that!’ ”

And that was the spark she was looking to light.

Ostin Tu uses a magnifying glass to examine an insect on a flower during a Wisconsin Bumble Bee Brigade event hosted by the CALS Insect Ambassadors in summer 2023.

Photo by ROMULO UEDA

EXPLORE ONLINE
Insect Ambassadors
go.wisc.edu/insect-ambassadors
What’s Eating My Plants?
go.wisc.edu/wemp
Darwin Day
go.wisc.edu/darwin-day
Last year, the University of Wisconsin–Madison turned 175. The university has been celebrating this impressive milestone by hosting campus and statewide festivities and by highlighting UW’s most significant scientific advancements and other contributions to society (see 175.wisc.edu).

From UW’s very early days, the agricultural and life sciences have been at the heart of the institution’s enterprise. As the state’s land-grant public university (so designated in 1866), UW is charged with studying and teaching practical disciplines, such as agriculture, science, and engineering. The College of Agriculture (now the College of Agricultural and Life Sciences, or CALS) was established in 1889 to help support that mission. Over the past 135 years, the college’s faculty, staff, and students have made many groundbreaking discoveries that have changed the world for the better. So CALS is celebrating, too.

As part of the celebration, the past two issues of Grow have spotlighted various aspects of the college’s rich history, including the evolution of the university’s agriculture library and its Agricultural Research Station system. And the celebration continues here with a sampling (but by no means a complete list) of notable scientific breakthroughs stemming from CALS. These discoveries have made a lasting impact on the state, the nation, and the world, and they serve as models and guides for CALS as it looks to the future.
Super Silos

In the late 19th century, when dairy farming and cheesemaking were just taking root in Wisconsin, farmers weren’t sure about the best way to keep cows fed through the long, cold winters. A common form of animal feed growing in popularity in the U.S. at the time was silage. Composed of fermented hay, corn, or other plant materials, silage can be used all winter long if stored correctly. Two early CALS faculty members contributed greatly to the improvement and adoption of silos for this purpose.

In an early trial, in 1881, UW researchers started with a square-shaped structure. They built a stone cellar with cement walls on a UW research farm and filled it with corn and clover. When the silo was opened months later during winter, some moldy clover was discarded; but the corn fodder was in good shape, and the cows that ate it showed healthy weight gain.

William Henry, the first dean of the College of Agricultural and Life Sciences, who was involved in the study, advised farmers to utilize silos and shared details on silo-building methods and materials.

But square silos had their problems. Chiefly, the silage would go bad in the corners. F. H. King PhD 1910, a professor of agricultural physics (later called agricultural engineering, now biological systems engineering), became a big proponent of an alternative. He studied the merits of the cylindrical silo and conducted the initial engineering research on the structure. He reported that round silos prevent the spoilage seen in square silos, and they are easier to load and structurally stronger. Like Henry — and in keeping with the Wisconsin Idea to ensure university research helps the citizens of the state — King published the first-ever bulletin with instructions for how to build round wooden silos.

The King Silo, or Wisconsin Silo, as it came to be known, became ubiquitous across the rural landscape, allowing farmers to have planned, dependable animal rations throughout the year. Eventually, it became an iconic symbol of the dairy farm as virtually every farm in Wisconsin featured a red barn and a silo.
**Vitamins Unveiled**

In the early 1900s, a team of researchers at UW embarked on an important nutritional study to understand the basic components of a healthy diet. The team devised an experiment to feed groups of cows “purified foods” from single grains — oats, wheat, or corn — so each group of animals received a chemically balanced diet of the three macronutrients: protein, carbohydrates, and fat.

The corn-fed cows were healthy. But cows receiving the oat- and wheat-based diets exhibited blindness, stunted growth, and stillborn births. These findings told the researchers there was something essential in the corn-based diet that wasn’t present in the others. The results, published in 1911, left a big question unanswered: What was the critical component missing from the oat- and wheat-based diets?

Enter UW biochemist Elmer McCollum, who had been hired to help analyze the samples for the purified foods experiment. He decided to pursue this question and brought on Marguerite Davis as a researcher — originally as an unpaid volunteer — to conduct the experiments using rats as a model organism.

They started out by replicating the cow study in rats, which yielded the same results. Next, they began adding supplemental components to the two deficient diets — such as fats in the form of milk fat, lard, or olive oil — to find what could make a diet complete.

The rats given the milk-fat supplement grew, while rats that ate olive oil or lard continued to be sick and stunted. Milk fat clearly gave the rats some kind of health benefit. Next, the researchers extracted fat-soluble compounds from milk fat and added them to the olive oil and lard. The rats consuming this fortified oil and lard turned out just as healthy as the milk-fat-fed rodents.

Davis and McCollum published their findings in 1913. Their coauthorship on this study is significant because, at the time, women were often excluded from professional societies and denied credit for their discoveries. Davis’s work in this area is just one example of the important and often underappreciated contributions women made to the nutritional sciences in the early 20th century.

The scientific tandem went on to call their extracted fat-soluble compounds “fat-soluble A,” later renamed vitamin A. They had isolated the very first vitamin.

Next, Davis and McCollum identified leafy greens as another source of vitamin A. This explains why the corn-fed cows and rats thrived: The corn rations had been processed with grains, stems, and leaves.

The biological method of analysis Davis and McCollum employed — the combined use of diets and animals — made UW a pioneer in the discovery of dietary essential minerals for animals and humans. This body of work opened the door to the discovery of other vitamins, the foods that contain them, and their role in human health and nutrition.

Later CALS research in this area led to the eradication of numerous vitamin deficiency diseases in many parts of the world. For example, biochemistry professor Conrad Elvehjem’s work on vitamin B-3 in the 1930s contributed to a cure for pellagra, a deadly, nutrition-related disease that reached epidemic proportions in the U.S. in the first half of the 20th century. And before this, in 1923, biochemistry professor Harry Steenbock devised a way to fortify foods with vitamin D through exposure to ultraviolet light. The innovation helped nearly eliminate rickets by the mid-1940s and launched a long history of groundbreaking vitamin D research at CALS.

At Lear’s Pharmacy in Ansonia, Conn., owner Arnon Lear makes a sale to a customer who came to him for advice on vitamins. This common scene, from 1958, would not have been possible without the groundbreaking vitamin research that took place at CALS.

**Photo by Jack Stock courtesy of the University of Wisconsin-Madison Archives**
Warfarin, the Wonder Drug

In 1933, Ed Carlson, a farmer from Deer Park, Wisconsin, drove 200 miles to Madison to figure out what was killing his cows. They were suffering from a known sickness called sweet clover disease, which causes uncontrollable bleeding in animals and was a persistent problem for cattle herds across the northern U.S. at the time. But the root cause of the condition remained a mystery.

After finding the office of the state veterinarian closed — it was a Saturday — Carlson ended up at the laboratory of UW–Madison biochemist Karl Paul Link BS 1922, MS 1923, PhD 1925, a coincidence that altered the trajectory of Link’s career. Sweet clover disease was already linked to moldy hay. For the unfortunate cows that ate this bad hay, their blood would not clot, and they would hemorrhage to death. Link set out to find the chemical culprit.

Link’s research team determined the chemical structure and then synthesized the compound in 1940. The Wisconsin Alumni Research Foundation (WARF) quickly patented this molecule, which scientists had named “dicumarol.” In 1941, dicumarol entered human trials as a blood thinner to treat blood clots and prevent strokes at the Wisconsin General Hospital and the Mayo Clinic.

Subsequently, Link and others in his lab synthesized more than 100 compounds structurally related to dicumarol. Each of these analogs had a slight difference in chemical makeup, but all produced some kind of anticoagulant effects. Link and his collaborators began exploring which of these analogs was best suited for practical use.

One analog, number 42, showed commercial promise. In particular, it made a great candidate for rodent control. Link named the compound warfarin — in honor of WARF — and it was patented in 1947 by Link and graduate students Miyoshi Ikawa and Mark A. Stahmann. It entered the market in 1948 as a rat poison.

Meanwhile, research continued to identify which of the analogs was the safest and most effective to use as a blood thinner in human patients. The result was surprising: It turned out to be analog 42 (warfarin) again, which worked even better than dicumarol. A water-soluble version, known as warfarin sodium, was approved for human use in 1954 and went on the market under the brand name Coumadin.

In 1955, word got out that President Dwight D. Eisenhower had been given Coumadin following a heart attack. This contributed to the adoption and popularity of the drug. In short order, warfarin became both the most widely used rat poison and the most widely prescribed blood thinner (Coumadin) in the world.

While new types of anticoagulants have been gaining in popularity over the past decade or so, Coumadin remains one of the most common treatments for blood clots to this day. Experts estimate that around 100 million prescriptions for Coumadin are still issued globally each year.

More CALS Discoveries

The scientific breakthroughs highlighted here are just a sampling of the many major advancements stemming from CALS. For a short primer on the history of the college, including a more comprehensive list of its notable achievements, visit calswisc.edu/history.
Synthesis of the First Gene

Today it’s possible for researchers to place an online order for a custom strand of DNA — with next-day delivery. So, it might be hard to imagine a time when we didn’t understand the genetic code or how the information coded in DNA works (via messenger RNA, or mRNA) to produce the proteins in our bodies.

But that was still the situation in 1960 when Har Gobind Khorana joined UW–Madison to serve as codirector of the Institute for Enzyme Research and a faculty member in the Department of Biochemistry. While at UW, he conducted research that helped crack the genetic code, revealing the biological instructions that tell living cells what to do (i.e., what proteins to make) to perform the vital functions for survival.

As a first step, Khorana used nucleotides — the building blocks of genetic material — to create short strands of mRNA. He then looked at the proteins produced from these mRNA strands, focusing on how the order of the specific nucleotides can influence what proteins are produced. The order was a type of informational code, it turned out, dictating the type of protein formed, and he was able to figure out its meaning. For this work, completed during his tenure at UW, Khorana shared the Nobel Prize for physiology or medicine in 1968.

From there, the rest of the puzzle was relatively straightforward: This same type of code is reflected in DNA, which serves as the long-term storage of genetic information. While still at Wisconsin, Khorana began his work to synthesize the first artificial gene made of DNA.

He left Madison in 1970 to join the Massachusetts Institute of Technology, and, shortly thereafter, Khorana and his colleagues announced that they had synthesized two genes crucial to protein building — the world’s very first synthetic genes. This pioneering work, started at UW, has revolutionized biotechnology. Early on, researchers could only make short strands of DNA, but science has advanced to the point today where entire genomes — the full genetic blueprint for a living organism — can be assembled from scratch. Custom-designed pieces of DNA are widely used in research labs, and they have played a role in countless advances in medical, agricultural, and basic research.
A Compendium of Colds

The common cold is nature’s most ubiquitous human pathogen. In a given year, adults often endure two to four infections, while schoolchildren can catch as many as 10. Cold viruses are responsible for millions of illnesses each year at an estimated annual cost of more than $40 billion in the U.S. alone.

In 2009, a multi-institutional team of researchers led by Ann Palmenberg, a biochemistry professor and affiliated faculty at UW’s Institute for Molecular Virology, reported the genome sequences for all 99 known strains of the cold virus, providing for the first time a detailed genetic blueprint for the virus, including information about its structure and how it operates. The sequenced cold viruses were collected from human noses worldwide. This work shed light on the organism’s evolution as well as its vulnerabilities, revealing pressure points that could lead to new antiviral drugs and other approaches to prevent or mediate infection.

Palmenberg’s team went on to develop a method for propagating rhinovirus C, a “missing link” cold virus first identified in 2006 that is associated with severe respiratory infections in children, especially those with asthma. The method enabled further discoveries by the team, including the identification of the 3D structure of the virus and the revelation of peptides that might block it from causing disease.

Over the years, Palmenberg’s viral genome and physical structure research has led to the creation of new antivirals, vaccines, and high-demand research reagents used in thousands of labs around the world.

To recognize the impact of her work, in 2020, Palmenberg was named a fellow of the National Academy of Inventors, an honor that acknowledges innovators who have made an impact on quality of life, economic development, and the welfare of society.
Milestones are a great time to reflect on the past — and also to chart a course for the future. The faculty, staff, and students of CALS today are looking ahead for the next high-impact discoveries that will position society for a better tomorrow.

Last fall, CALS leaders hosted two “visioning sessions” focused on research priorities. These interactive discussions brought together the college community to identify research areas where CALS is strategically positioned to solve grand challenges. In particular, participants were asked to consider the broad areas of sustainable agriculture and the life sciences, and then identify where the college has multidisciplinary teams that can work to solve some of the major problems of the world.

“We held these sessions to help inform the college’s strategic hiring, our infrastructure investments, and our fundraising efforts,” says CALS Dean Glenda Gillaspy. “We had great participation over the two sessions and received a lot of innovative ideas for research priorities. We also talked about [the spaces we need] to help us improve our research impact.”

In the realm of sustainable agriculture, these discussions identified three areas of focus: decarbonizing food production systems; creating systems for water sustainability; and developing innovative agronomic systems. In the life sciences, identified strengths revolved around human health: feeding the world through synthetic biology; promoting healthy aging through gut microbiome and nutrition; and preventing vector-borne diseases.

Earlier in 2023, the college completed a facilities master plan, which includes an analysis of current infrastructure and guidance for the future. The plan recommends consolidating research space, including building new multidisciplinary research hub facilities.

“We’ll be constructing big buildings that accommodate multiple departments and are designed to promote transdisciplinary research and discovery,” says Gillaspy. “It’ll be a new look for CALS, something different. It’s the way of the future.”

CALS Research Priorities

**Sustainable Agriculture**
- Decarbonizing food production systems
- Creating systems for water sustainability
- Developing innovative agronomic systems

**Health through Life Sciences**
- Feeding the world through synthetic biology
- Promoting healthy aging through gut microbiome and nutrition
- Preventing vector-borne diseases
For William Campbell MS’54, PhD’57, the path to a Nobel Prize started with a fluke — specifically, a sheep liver fluke. During a school trip to an agricultural show in rural Northern Ireland when he was 14, Campbell happened to read a pamphlet advertising a new drug for treating livestock infected with a parasitic flatworm commonly called a fluke. He remembers thinking how remarkable it was that one small pill could make such a difference for animal health.

A few years later, Campbell was a promising biology student at Trinity College in Dublin with a dual interest in veterinary and human medicine. His undergraduate adviser happened to be in touch with UW veterinary science professor Arlie Todd, who was looking for talented graduate students just as Campbell was in search of a postgraduation direction. At the time, the Department of Veterinary Science was part of CALS; it has since evolved into the Comparative Biomedical Sciences Graduate Program, now housed in the UW School of Veterinary Medicine. The program had acquired an international reputation for research and graduate training, and it became Campbell’s destination.

Supported by a Fulbright travel grant, Campbell set sail for the U.S. on the Britannic in January 1953. In Madison, he moved into the Knapp House, which gathered graduate students from various disciplines to live in the former governor’s mansion near Lake Mendota. In the lab, he worked closely with both Todd and veterinary science and zoology professor Chester Herrick to study giant liver flukes in sheep and deer. Todd then coaxed a reluctant Campbell to consider applying his skills in the pharmaceutical industry. With some misgivings, Campbell accepted a job at Merck and moved to Rahway, New Jersey.

“I only wanted to work on science for the sake of science and not for utility, but [at Merck] I discovered the tremendous joy and excitement of doing something that might actually be useful,” Campbell says. He stayed with the company for 33 years.

Campbell was an unusual industry scientist for his time. In addition to his assigned work, he regularly pursued independent projects that led to journal publications, invitations to academic conferences, and a fellowship in South and Central America usually reserved for university-affiliated scientists. One of those independent projects led to the discovery of a method to cryogenically freeze certain types of worms for as long as 10 years without killing them.

In 1975, Campbell joined a team that was conducting research on cattle roundworms. That team eventually developed ivermectin, widely considered a wonder drug of modern veterinary science. In addition to treating cattle and horses, ivermectin was the first convenient and widely used treatment to prevent heartworm in dogs.

Fluke Fighter

William Campbell’s achievements in parasitology have made the world healthier for people and animals. They’ve also earned him a Nobel Prize and the UW Distinguished Alumni Award.

By SANDRA BARNIDGE

Photo by KATHLEEN D’AMICO
Campbell’s interdisciplinary background helped him hypothesize another use for ivermectin: as a treatment for onchocerciasis, or river blindness. Caused by a parasitic worm and spread by blackflies, river disease was the second-leading cause of blindness worldwide before the 1980s.

“I was in a position to propose that there were reasons why [ivermectin] might work in river blindness, and I passed that word up the line,” Campbell says.

Clinical investigators proved his hunch correct, and Merck executives made the unusual decision to make the drug available to all who needed it for the prevention of river blindness. This, together with the dedicated work of several nongovernmental organizations, resulted in the eradication of the disease in many of the affected countries in South America and Africa.

The significant, ongoing impact of ivermectin led to Campbell sharing a Nobel Prize in physiology or medicine in 2015. He was invited to the White House to meet President Barack Obama, who gave Campbell a small stuffed toy in the shape of a heartworm.

Campbell’s achievements also earned him the Distinguished Alumni Award from the Wisconsin Alumni Association (WAA) in 2023. The WAA’s highest honor, it celebrates prestigious UW graduates for their professional achievements, contributions to society, and support of the university over the course of their career or lifetime. Campbell will receive his award during a ceremony on April 12.

Campbell studies parasitic worms, but he also paints them. He completed Brass Bowl with Tapeworm Bouquet in 2015. Image courtesy of WILLIAM CAMPBELL

Since retiring from Merck, Campbell has kept busy as a university lecturer at Drew University in Madison, New Jersey. He is also an avid painter, mostly of parasitic worms, and he regularly donates artworks to the American Society of Parasitologists to auction off as fundraisers for student scholarships.

“I like parasites, even though I’ve spent most of my life trying to kill them,” he says. “I often compare them to flowers — there’s an almost endless variety in their structure and life cycle. It’s absolutely phenomenal.”

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Burkhardt Fund Supports Hands-On Experiences for Students

By GEORGE SPENCER

M ake “cool stuff.” That’s what Micah Robinson BS’23, MSx’25 wanted to do in the Biological Systems Engineering Shop. Thanks to the Martin and Kathleen Burkhardt Fund, that’s exactly what he did for two years as an undergraduate employee.

“When I applied, I went in, and I looked at all the machines in the shop, and I was like, ‘Wow, if I knew how to use them, I could do so many things — make things, fix things — the sky would be the limit,’” Robinson says. “Getting that work-study assistance has made me much more confident and boosted my problem-solving ability.”

UW alums Martin BS’60, MS’64 and Kathleen Burkhardt started the fund 27 years ago. Since then, the married couple’s contribution has helped many biological systems engineering (BSE) students gain real-world skills in machining, fabrication, and assembly — how to use lathes, mills, welding equipment, 3D printers, and computerized numerical control routers. The fund, which paid Robinson $7,000 in wages, is available to students in the BSE and nutritional sciences departments in CALS and to environmental textiles and design majors in the UW School of Human Ecology, where Kathleen earned her bachelor’s degree. It also supports an internship in Allen Centennial Garden.

Both Martin and Kathleen have agricultural roots in Wisconsin. Kathleen grew up on a farm south of Kewaunee, and Martin’s grandparents owned a Century Farm south of Plymouth, so the fund gives first preference to students from rural Wisconsin. The Burkhardts also prefer that its recipients earn the assistance through work or service rather than as a scholarship, a nod to Martin’s personal path through college.

Now he wants others to benefit as he did. “I probably got more out of working with machines and building fans and so forth there than I did in any engineering courses I took,” he recalls.

Kody Habeck BS’08, MS’11 has run the BSE shop since 2016. And he agrees with Martin — some things can only be learned through experience.

“A lot of students can design something that looks really nice on a computer, but they have a hard time putting manufacturing capabilities into that design,” says Habeck, who also teaches design classes in BSE. “They haven’t always thought through how they can actually make it.”

But Robinson has done the thinking and the hard work. Under Habeck’s supervision, he created — from scratch — a 20-inch-wide sheet metal roller with a hand crank that gets extra oomph thanks to a gearing mechanism he also developed. With the added force, the roller can bend sheet metal as thick as three-sixteenths of an inch. The resulting curved pieces can be used in machinery that chops corn stover (harvest remnants) or as parts of chopper snouts that shoot cut material into a wagon.

After completing the computer-assisted design, Robinson reviewed manufacturing tolerances with Habeck. Then he made all the parts himself; he purchased components and did all the welding and fabrication.

Robinson caught the engineering bug by watching his grandfather, a farmer from Black River Falls, Wisconsin, who loved buying and repairing old tractors. “It does kind of feel like I’ve come full circle,” says Robinson, who is now working on his master’s degree in BSE, “and I’m doing something that my family has done for generations.”

“If Micah wants to become a design engineer, having done this work-study will make him far better off than most other similar graduates,” Habeck says. “He understands how something works. That’s why we’re grateful to have had this Burkhardt fund for so many years.”
Day of the Badger returns on April 16–17! It’s a spirited day of giving that unites alumni, friends, and students to strengthen the university and ensure future generations enjoy the same level of educational excellence.

There are many ways you can make a difference, from giving to an area you’re passionate about and bolstering student scholarships to celebrating beloved traditions and sharing your pride in UW and CALS.

Find out more at dayofthebadger.org.
In 1945, professor of agricultural chemistry Karl Paul Link BS 1922, MS 1923, PhD 1925 stands in front of a poster advertising warfarin, a compound he and graduate student researchers Miyoshi Ikawa and Mark A. Stahmann developed and patented. Warfarin was first used for rodent control but later became a popular, life-saving clinical anticoagulant. Read about this world-changing CALS discovery and many others starting on page 28.

Photo by GARY SCHULZ courtesy of the UNIVERSITY OF WISCONSIN–MADISON ARCHIVES