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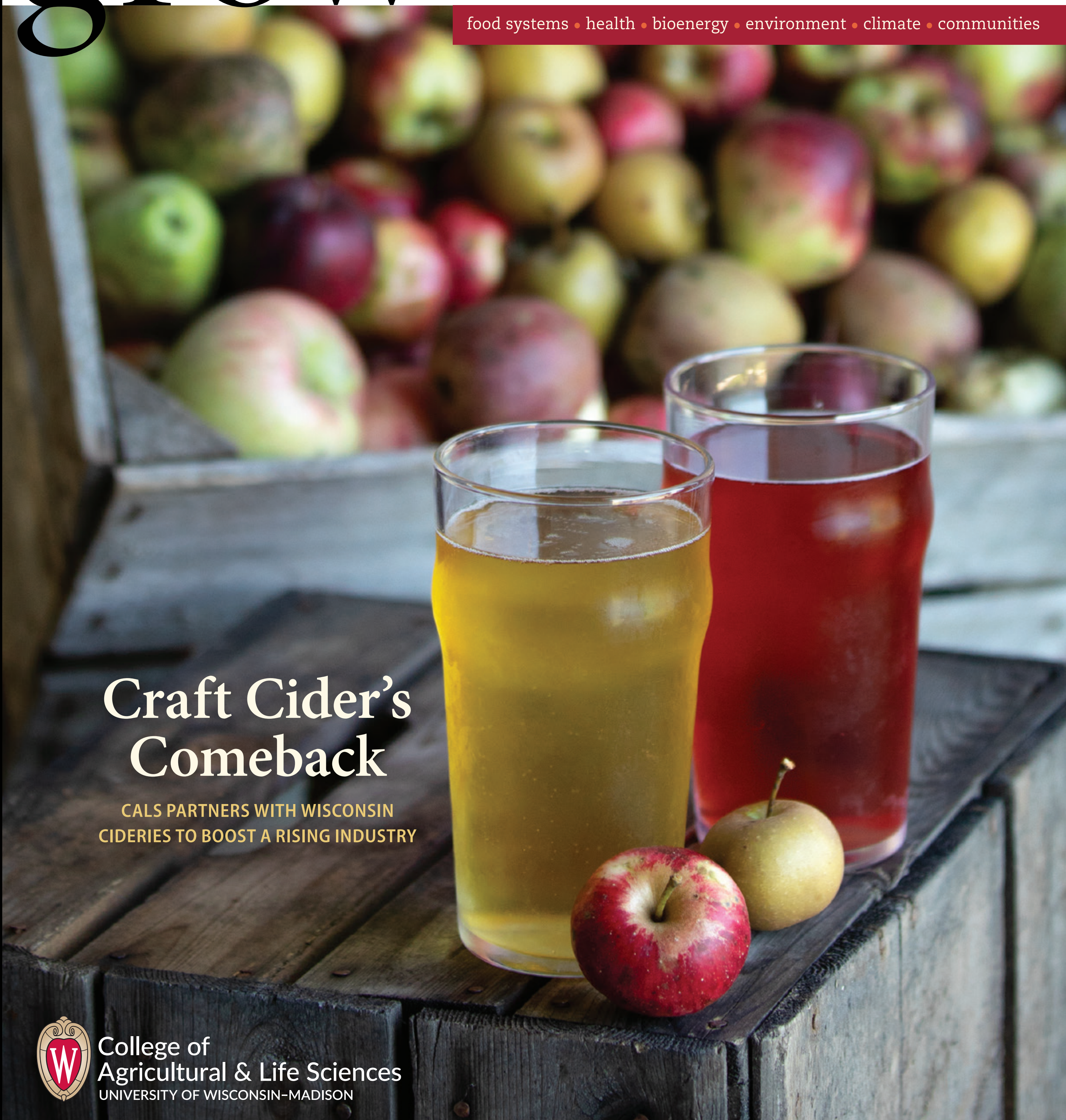
Wisconsin's Magazine for the Life Sciences • FALL 2018

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



Craft Cider's Comeback

CALS PARTNERS WITH WISCONSIN CIDERIES TO BOOST A RISING INDUSTRY

College of Agricultural & Life Sciences
UNIVERSITY OF WISCONSIN–MADISON

THE CHARCOALATOR'S TALE • WILDLIFE RESPOND TO A WARMING WORLD • VAMPIRE BATS ON THE RUN

Morning sunshine filters through fall foliage on Observatory Hill just northeast of the Soils Building and King Hall.

Volume 12, Issue 1 • Fall 2018

grow

Wisconsin's Magazine for the Life Sciences

FEATURES

DEPARTMENTS

ON THE COVER: Two types of craft cider, made by Brix Cider of Barneveld, Wis., and a wide variety of cider apples are seen on display at Albion Prairie Farm in the town of Albion, Wis., just east of Stoughton. The farm boasts more than 100 varieties of apples, many of which Brix uses in its products.

Photo by Michael P. King

Dean Kate VandenBosch

A Redesign for Success

In my message last fall, I mentioned that a team of CALS faculty and staff was working on recommendations for organizational changes within the college. In December, the CALS Organizational Redesign Committee submitted its report, and since then we have been working closely with our academic departments to find the best course to take.

You might be wondering why we are exploring alternative ways to organize CALS. Funding for higher education is changing. As state and federal support of public universities declines, tuition takes on a greater share of the costs, and students and their families want to know that they're getting an excellent education in exchange for their investment. At CALS, we want to exceed their expectations. My goal for the Organizational Redesign effort (**orgredesign.cals.wisc.edu**) is to configure CALS in a way that ensures a bright future for our college, the students we teach, and the people we serve through our research and outreach.

Experts tell us that today's students will likely work in a long series of short-term professional roles. To succeed in this "gig economy," our students must learn to be superb communicators who can work in diverse, team-based settings. CALS can help them gain these skills by offering collaborative and interdisciplinary academic programs that draw on many perspectives, including the biological and social sciences.

> "No matter what changes we undergo, we will stay true to our signature strengths."

By making our majors more broadly integrative and more closely tied to grand, global challenges, we can better prepare our students for postgraduate opportunities and at the same time grow our enrollments strategically. Recent trends show a decline in interest in some of our academic programs. A modernized structure in which majors with small audiences are repackaged into more interdisciplinary programs can help us counter these trends. So can improvements in our efforts to recruit and retain students. We can reach out to UW undergrads earlier in their campus careers. We can standardize, streamline, and expand our advising services as well as out-of-classroom and capstone experiences. All of these initiatives are in the works.

Changes to academic programs and majors are only in the discussion and planning stages at this point. It will be at least two years before we start admitting students into any new programs and longer before any current majors are closed. And all current students who have declared majors will be able to complete their studies in the fields they have chosen.

Also as a part of our redesign efforts, we are exploring partnerships within CALS that will make us more efficient and return the most on our investments. Soon, discussions with department chairs, faculty, and staff will lead to specific plans for newly merged departments or departmental collaborations that will enhance our academic programs, improve student experiences, and better support and invigorate our research and outreach missions.

I believe that these changes will strengthen our key external partnerships, which inspire and sustain us (and many of which involve our alumni). And no matter what changes we undergo, we will stay true to our signature strengths. CALS will continue to engage in cutting-edge science, support Wisconsin agriculture through applied research and outreach, and offer students a world-class education, including hands-on research and internships.

But only the best organizational structure will allow us to move forward and continue to serve our students and Wisconsin's communities in new and better ways. I will do all that I can to keep you, our alumni and friends, well informed as we pursue these goals.

grow

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College of Agricultural & Life Sciences
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UWMadisonCALS

Five things everyone should know about . . .

Vampire Bats

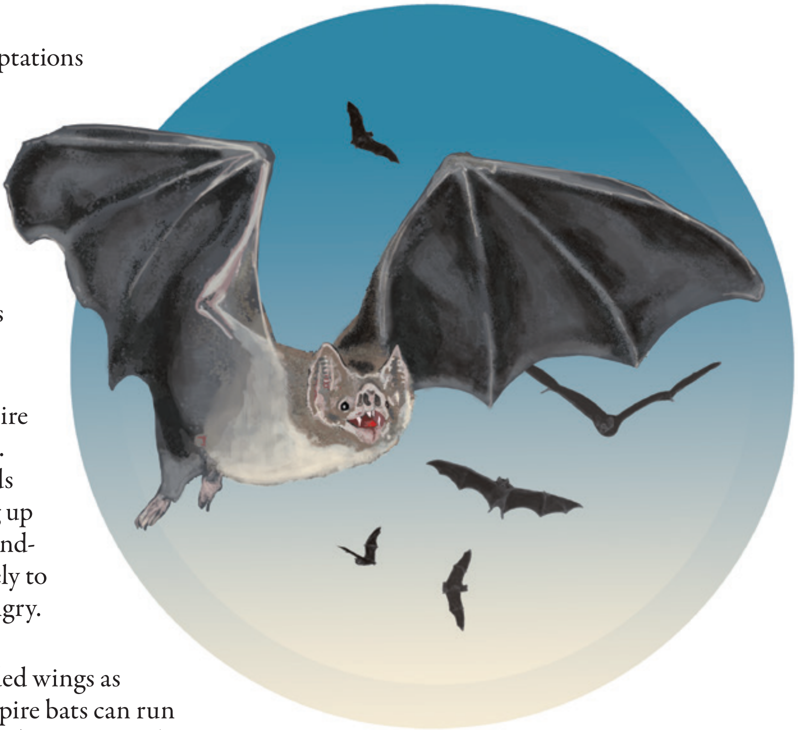
By Amy Wray PhDx'20

1 **There are no vampire bats in Transylvania.** Bram Stoker's 1897 novel *Dracula* popularized the connection between Eastern European vampires and bats. But Old World vampire folklore was well established before the discovery of actual vampire bats, all of which reside only in South and Central America. Out of nearly 1,400 bat species, only three are blood feeding, or hematophagous: the common vampire bat (*Desmodus rotundus*), the hairy-legged vampire bat (*Diphylla ecaudata*), and the white-winged vampire bat (*Diaemous youngi*). Several other bat species with "vampire" in their names, such as the greater false vampire bat (*Megaderma lyra*) and the spectral bat (*Vampyrum spectrum*), are actually carnivores that eat frogs, birds, and even other bats.

2 **They are highly skilled hunters** and use a variety of adaptations to find their food. Vampire bats are the only mammals known to use infrared radiation to locate areas with high blood volume on their target prey, and they have highly sensitive hearing that can differentiate between the breathing patterns of individuals. Because these bats can consume more than half of their own body weight in a single meal, they also have specially adapted stomach linings to allow for urination within two minutes of feeding.

3 **Social status matters to vampire bats.** Common vampire bats will starve to death if they go three days without food. To hedge their bets, female bats develop strong social bonds via reciprocal blood meal sharing (also known as throwing up in a friend's mouth). Vampire bats keep track of these "friendships," and those that share more with others are more likely to receive help in the future. Bats that don't share are left hungry.

4 **Vampire bats are impressive athletes.** Using their folded wings as an appendage to propel themselves forward, common vampire bats can run on the ground as a strategy for attacking unsuspecting prey (usually cattle). They are excellent jumpers, capable of leaping into flight by catapulting themselves as high as three feet. Scientists have studied the movements of common vampire bats by analyzing videos of them running on tiny treadmills, and these findings may someday help inspire robot design.



The common vampire bat (*Desmodus rotundus*).

5 **These bats don't suck.** Instead, they use their razor-sharp teeth to make an incision in the skin and then proceed to lap up the blood like a kitten. Chemicals in their saliva prevent clotting so the blood of their unsuspecting prey continues to flow freely. Some of these substances, cleverly referred to as "draculin" and "desmoteplase," have been isolated from bat saliva and are being tested as potential remedies for stroke and heart attack victims.

Amy Wray is a doctoral student in wildlife ecology. Her master's thesis focused on the feeding habits and pathogens of common vampire bats in Guatemala. Currently, Wray is using next-generation DNA sequencing and other methods to study the diets of insect-eating bats in Wisconsin. The findings will help her assess the extent to which bats feed on agricultural pests and how the spread of diseases such as white-nose syndrome may impact the utility of bats in pest control.

Illustration by Danielle Lamberson Philipp

On Henry Mall

News from around the college

So Long, Science House

A humble but storied building with many CALS connections leaves a lasting legacy

Not long ago, an unassuming house stood at 1645 Linden Drive. Clearly in its twilight years, white paint had worn away from its wooden siding, and ivy smothered its nameplate. A series of renovations had morphed the building into a mishmash of architecture, dwarfed by the modern redbrick giants nearby. Its official university name was simply its address.

Known to many as Science House, the building was the elder resident of its campus neighborhood. Just shy of 150 years old, it was once home to grand people and grand ideas. The building is gone now, but its long history weaves an intriguing thread through the origins of CALS, ghost lore, a statehouse ravaged by fire, an artist, and outer space.

A doorway stands ajar in the brick-walled basement.

Formerly known as the Farm Superintendent's House, UW Experimental Farm Residence, and the Artist-in-Residence House, Science House was demolished in August to make way for a multimillion dollar update to Babcock Hall, including a renovation of the Babcock Hall Dairy Plant and a three-story addition for the Center for Dairy Research (see page 9). Despite its age, the building was not eligible for listing on the National Register of Historic Places because of past remodeling projects and a relocation.

"Unfortunately, the ability of the building to tell its story was so compromised that it no longer met the eligibility criteria set by the National Park Service," says **Daniel Einstein**, historic and cultural resources manager at the UW–Madison Division of Facilities Planning and Management.

THE FOUNDATION

When Science House was built in 1868, the University of Wisconsin (now UW–Madison) had only three instructional buildings: North, South, and University (now Bascom) Halls. The Morrill Land-Grant Act had passed in 1862, and UW, Ripon College, and Lawrence University all competed to be the state's land-grant institution. Tipping the scales in Madison's favor was a pledge by Dane County to purchase 200 acres of land for an experimental farm. It would be the seed for the College of Agriculture, now CALS. The first two buildings on the farm were a barn (now the Horse Barn at 520 Elm Drive) and a farmhouse that eventually became Science House.

Though it seemed abundantly ordinary at first glance, Science House was designed by prominent Madison architect **August Kutzbock**. It was perhaps the final project of the German immigrant's life, as his career was in precipitous decline. He had designed several Madison landmarks, including Gates of Heaven Synagogue and the Pierce House (now Mansion Hill Inn). A decade before the university farmhouse project, he was chosen as the architect for Wisconsin's third state Capitol building, the second built in Madison. Nearing the final stages of construction, he sparred with politicians over the size and design of the Capitol's dome. Kutzbock resigned from the project and, for a fresh start, moved to California, where he fell seriously ill.

He returned to Madison in 1867 and had difficulty finding work. Accustomed to designing grander buildings, Kutzbock accepted a modest $50 commission to draw up the architectural plans for Science House. Before construction was complete, he drowned himself in the waters of Lake Mendota off Picnic Point. Adherents of the paranormal say an occasional mist drifting from the point toward downtown Madison is Kutzbock's spirit. The third Capitol — along with its dome designed by another architect — would ultimately perish in a fire in 1904, necessitating the construction of today's iconic statehouse.

EARLY OCCUPANTS

Science House was originally a farmhouse situated just east of the Horse Barn, where, at the time, it

View a gallery of Science House photos at **grow.cals.wisc.edu/science-house** housed the experimental farm's superintendent and laborers. When **William Arnon (W.A.) Henry** was hired by the university as an agriculture professor in 1880, he rented the house for $200 per year. The College of Agriculture was founded in 1889 with Henry (the namesake for historic Henry Mall) as its first dean. At his direction in 1901, Science House was moved a short distance to a new lot at 438 Farm Place, where it stood (most recently with a Linden Drive address) until its demolition.

After the move, **George Colvin (G.C.) Humphrey**, longtime chair of the animal husbandry department, took occupancy until his retirement in 1942, often welcoming Farm and Industry Short Course students to his home for social events. Humphrey was part of the team of scientists that conducted the groundbreaking "single-grain experiment" from 1907 to 1911, determining that cows were healthier when they ate only corn instead of wheat, oats, or a combination of the three. The team's work led to the development of the field of nutritional science.

Various professors and units used Science House until 1962. The north side of the house was then remodeled to provide a studio for UW artist-in-residence **Aaron Bohrod**. False "half-timbering" trim was added to match the Tudor Revival architectural style of the Stock Pavilion next door. A steady flow of science-oriented occupants used the building after Bohrod's retirement, including personnel from landscape architecture from 1974 to 1981 and food science from 1982 to 1991. The building was again renovated in 1993 to house the Center for Environmental Awareness.

SCIENCE OUTREACH

The building became known as Science House around 1998, when it welcomed the Rapid-Cycling Brassica Collection (RCBC) and Wisconsin Fast Plants, which was started in the 1980s by plant pathology emeritus professor **Paul H. Williams** PhD'62; his wife, **Coe Williams**, who served as the program's manager; and project coordinator **Jane Scharer**. Needing research tools for improving disease resistance in vegetables, Paul Williams bred "rapid-cycling" *Brassica rapa* plants to drastically shorten their life cycles. After many years of work, he reduced the plant's life cycle from six months to just five weeks. Five weeks was short enough to fit into a school lesson plan — or a space mission.

Fast Plants were first used in space research on the Russian space station Mir. NASA then took the plants on space shuttle Columbia in 1997, where they were the first plants to produce viable offspring in space. Then they went to the International Space Station, where they are still used in research. More than 75,000 teachers and 5 million children around the world experiment with Fast Plants in their schools each year. The program moved to Russell Laboratories when Science House was vacated in 2016.

The Delta Program in Research, Teaching and Learning was also a recent occupant, as was Place-Based Opportunities for Sustainable Outcomes and High-Hopes, a CALS-led project funded by a $4.7 million USDA-NIFA grant to help prepare Native American students for bioenergy and sustainability-related studies and careers.

"We wanted to use the building as a science outreach center on campus for a variety of programs," says **Dan Lauffer**, a longtime RCBC and Fast Plants employee. "We ran a hands-on Saturday Science Program for families and hosted meetings for the Madison Aquatic Gardening Club and Friends of the Lakeshore Nature Preserve."

Although this building with many names no longer graces the campus landscape, the contributions of its tenants to science, agriculture, and community will always stand as part of the UW legacy.

—Michael P. King

Science House viewed from the northwest.

The north room, which served as an artist-in-residence studio after extensive remodeling.

Photos by Michael P. King

Deer Disease Reservoirs

The first-ever discovery of prions in soil and water near Wisconsin mineral licks points toward another transmission route for chronic wasting disease

Chronic wasting disease (CWD) is a progressive illness that causes severe weight loss and eventually death in deer and elk. The disease has been detected in nearly half of the lower 48 states. Scientists have known for decades that CWD is caused by prions, malformed versions of proteins normally found in the central nervous system of deer and elk. It's also known that prions spread through direct contact among animals.

"This is the first time that anyone has demonstrated the existence of prions in naturally contaminated soil."

However, experts have long speculated that prions can also accumulate in the environment, and a recent study has confirmed their suspicions. For the first time, CALS researchers have detected prions in soil and water samples taken from sites where deer congregate. Their findings suggest that environmental reservoirs of prions could serve as additional transmission routes for CWD.

The study, led by **Michael Samuel**, an emeritus professor of wildlife ecology, and **Joel Pedersen**, a professor of soil science, searched for prions at mineral licks — areas where deer seek out essential nutrients and minerals — in the CWD endemic area across south-central Wisconsin. Out of 11 sites, nine had detectable levels of the disease-causing proteins, which have an abnormal or "misfolded" structure. Prions were found both in soil and in water from the sites as well as in nearby fecal samples from one site. Environmental reservoirs of prions are not expected to pose a health hazard to humans but could be a potential source of transmission to other animals.

"This is the first time that anyone has demonstrated the existence of prions in naturally contaminated soil," says Pedersen.

In Wisconsin, CWD is concentrated in southwestern and southeastern counties. More than 30 percent of adult male deer are infected in portions of Iowa County, according to the Department of Natural Resources. It is unknown whether humans can contract CWD from eating infected meat, but the World Health Organization has recommended that people avoid consuming it. No cases of human transmission have been reported.

The study, which was funded by the U.S. Geological Survey with support from the National Science Foundation, was published in May 2018 in the journal *PLOS ONE*. Samuel and Pedersen worked with colleagues in the Department of Forest and Wildlife Ecology and the Molecular and Environmental Toxicology Center at the UW School of Medicine and Public Health.

Environmental prions have previously been shown to infect deer in heavily contaminated experimental enclosures of deer. In 2009, researchers in Colorado also identified prions in untreated water entering a water treatment plant.

In Wisconsin, chronic wasting disease is concentrated among white-tailed deer in southwestern and southeastern counties.

Photo by Scott Bauer, USDA Agricultural Research Service

The prions were detected using a technique that amplifies the small amount of misfolded proteins isolated from soil or water samples. The prions are then added to a pool of properly folded proteins from mice engineered to produce them. The diseased folding state is transmitted to properly folded proteins, increasing the number of diseased prions and facilitating measurement.

It is not clear whether the quantity of soil-dwelling prions detected in the current study are sufficient to infect deer.

"Although we are able to detect prions, quantifying the amount present is still difficult using this technique," says Pedersen. Previous research by the Pedersen lab has demonstrated that soil-bound prions are more effective than free prions at infecting hamsters.

"It's a great advance for trying to understand how this disease transmits in the environment," says **Rodrigo Morales**, a professor of neurology and prion researcher at the University of Texas Health Science Center at Houston who was not affiliated with the study. "It explains what could be the main source of (transmission)."

Samuel says the significance of prion-contaminated environments in the spread and persistence of CWD among free-ranging deer remains unknown.

"We know it can occur, but we just don't know how it occurs in the wild, or how important it is relative to deer contacting each other," says Samuel.

Ten of the mineral lick sites tested in the study were artificial, and one was natural. Nine of the 11 sites were on private land and were tested with permission of the landowners.

"We manage most diseases by trying to interrupt their spread; having CWD concentrated at animal licks means that's going to be difficult," says **Don Waller**, a professor of botany and environmental studies at UW–Madison who investigates Wisconsin's deer herds. He was not involved in the study.

"It's not easy to test for CWD, but this result suggests we should be looking for hot spots of CWD prions in the environment and doing all we can to cover them up so animals can't get to them," Waller says. "We may also want to do more testing in other animal species to see which may be vulnerable to CWD infection."

—Eric Hamilton

An architectural rendering of Babcock Hall as it will look when the renovation and expansion are complete.

Zimmerman Architectural Studios

A 'WHEY' BETTER BABCOCK

The Babcock Hall renovation and expansion has begun! The major construction project, which broke ground in July 2018, will modernize the building's dairy plant and augment the Center for Dairy Research (CDR) with a new three-story addition.

When the dust clears in late 2020, the dairy plant will boast a new ice cream maker; more freezer and cooler space; an improved raw milk receiving bay; and new piping, pumps, and valves to more efficiently move milk and milk products around the plant.

The CDR addition will occupy the space formerly filled by Science House (see page 6). It will include state-of-the-art space for research, instruction, and small-scale production that will allow the center to expand the product development services it offers to the state's cheese industry. The facility's new equipment will make it easier for CDR staff to work with companies developing all kinds of new dairy-based foods. This includes alternative dairy products, such as whey, and fermented dairy products, such as specialty yogurts.

Funding for the project, which will cost $47 million, comes from donors, the state of Wisconsin, and UW–Madison. The donors, who primarily represent the state's cheese industry, raised more than $18 million. The project would not have been possible without them.

Learn more about the Babcock Hall improvements at **babcockhall.cals.wisc.edu**.

Resistance Is Not Futile

CALS plant pathologists have developed a soybean plant that staves off stem rot and defies drought

If there's anything that could be called the archenemy of Midwestern soybean producers, it just might be Sclerotinia stem rot. Once thought of as only a sporadic problem in the region, the disease has become a recurring and widespread threat.

Sclerotinia stem rot is perhaps better known as white mold, a name derived from the fine, pale filaments that spread over infected stems, leaves, and pods. The disease thrives under wet and cool conditions. That's when the fungus that causes it, *Sclerotinia sclerotiorum*, tends to persist — especially when plants are flowering. And when it peaks, it can be an absolute scourge to soybean fields with high yield potential.

Severe infection with white mold weakens the plants. They begin to grow askew, wilt, and die, leading to much lower than optimal yields. Between 2010 and 2014, white mold cost U.S. farmers $1.2 billion in losses. But a solution to this problem may soon be on the way.

By identifying and targeting specific genes that regulate the soybean response to *S. sclerotiorum*, a team of researchers in the Department of Plant Pathology has generated plants with increased resistance to white mold. And, as an added bonus, the plants show greater tolerance to drought.

Photo by Damon Smith

Characteristic white mold symptoms include white, cottony mycelium on the stem of soybean plants, as seen in this photo taken at an experimental plot at UW–Madison's Hancock Agricultural Research Station.

"We've made significant progress in understanding how *S. sclerotiorum* hijacks plant defenses and causes disease," says **Mehdi Kabbage**, assistant professor of plant pathology and leader of the research team. "We've uncovered some promising genetic targets for increasing resistance in soybeans."

The team includes associate professor and extension specialist **Damon Smith** and research associate **Ashish Ranjan**. Their work is built on previous studies showing that certain molecules, called reactive oxygen species (ROS), play a key role in regulating how plants respond to attacking pathogens.

At low levels, ROS act as helpful signaling molecules, part of the communication system that controls the basic functions of plant cells. But at high levels, the molecules become toxic. "The plant cell recognizes this particular threshold and basically commits suicide, which is to the advantage of the pathogen," says Kabbage.

Prior work has established that ROS are produced by enzymes called NADPH oxidases. The researchers focused their initial investigation on the underlying mechanisms of this process. They found that specific soybean NADPH oxidases are activated following infection with *S. sclerotiorum*, resulting in the production of damaging ROS levels. "So it appears that the fungus may be hijacking the soybean ROS machinery to its benefit by modulating the expression of NADPH oxidases in the host plant," Kabbage says.

Next, the team used a gene-silencing technique in the lab to inhibit the activity of NADPH oxidase genes in soybean plants. They found that the modified plants produced less potentially damaging ROS following *S. sclerotiorum* infection and showed a remarkable level of disease resistance compared to control plants.

The researchers also discovered, quite by happenstance, that the modified plants could withstand long periods without water. "When we were done doing our work with these plants, and they were in pots waiting to be cleaned, we noticed that the silenced plants were staying green longer, even after we stopped watering them for days," Kabbage says. "And it made sense. A lot of stresses like drought and cold also induce ROS, eventually causing plants to die. So if you can delay the plant from reaching that toxic threshold, it makes sense that you would get tolerance to other ROS-inducing stresses."

Because the plants with silenced genes displayed such significant and useful traits, the research team generated stable transgenic versions that will be tested in the field against a broad range of stresses. They first have to go through the excruciating process of increasing seed quantities, generation by generation, until they have enough plants to conduct trials. Their target is the 2019 field season.

Photo by Michael P. King

"We've invested a lot of money over the years to develop something just like this," says **Robert Karls** BS'91, executive director of the Wisconsin Soybean Marketing Board, which provided funding for the current project and prior soybean research at CALS. "We're excited because we're going to be able to offer a new tool for growers to help them produce beans more efficiently and help their bottom line."

A great deal of science has gone into developing ways to manage white mold, from more effective crop rotation methods to better tillage and planting practices to improved irrigation management. There are also soybean varieties with moderate genetic resistance to the pathogen. But this is the first time that a genetic tool has been developed to establish or enhance white mold resistance in soybean germplasm. For this accomplishment, the researchers were named finalists for the 2017 Wisconsin Alumni Research Foundation Innovation Award. And given that white mold can infect more than 400 other plant species, including lettuce, sunflower, and potato, the method for creating the resistant plant may have applications beyond soybeans in the future.

—Nik Hawkins

Healthy soybean plants flower in a field at the Marshfield Agricultural Research Station near Marshfield, Wis., in July 2018.

This study was funded by the Wisconsin Soybean Marketing Board and the North Central Soybean Research Group.

Awards and Honors

A FUTURE FULL AND BRIGHT
Marin Skidmore, a doctoral student in the Department of Agricultural and Applied Economics, is one of 12 UW–Madison students who were awarded grants from the Fulbright U.S. Student Program for study or research abroad in the 2018–2019 academic year.

CREAM OF THE CROP SCIENTISTS
Agronomy professor **Shawn Kaeppler** BS'87 was named president-elect of the Crop Science Society of America, an organization with more than 5,000 members dedicated to the conservation and wise use of natural resources in producing food, feed, fiber, fuel, and pharmaceutical crops.

EXCELLENCE IN PLANT PATHOLOGY
Two plant pathology faculty were recognized by the American Phytopathological Society. Associate Professor **Amanda Gevens** received the Excellence in Extension Award, and Professor and Chair **Patricia McManus** received the Lee M. Hutchins Award for her work on diseases of perennial fruit plants.

COMMITMENT TO STUDENT LEARNING
John Parrish, a professor of animal sciences for 29 years, received the 2018 Distinguished Teaching Award by the American Society of Animal Science. The award recognizes excellence in teaching animal science courses and investment in students.

Number Crunching | 103

THAT'S HOW MANY INCOMING FIRST-YEAR STUDENTS ENROLLED IN THE INAUGURAL COURSE FOR CALS QUICKSTART. The new program helps undergrads get a summer jump on their coursework, participate in early academic and career planning, join a community of peer scholars, and make the most of their time at UW.

More at **cals.wisc.edu/quickstart**

Photo by Michael P. King

classAct

Ciara Michel

Beekeeping for Livelihood in Uganda

Photo by Michael P. King

Not many UW students can say they've led a beekeeping operation in Uganda. In fact, there may be only three, and **Ciara Michel** BSx'19 is one of them. A senior majoring in microbiology, Michel and two of her peer undergraduates spent four weeks in Uganda in the summer of 2017 managing The Apiary Project, which benefits communities affected by civil war in Uganda.

Many factors prodded Michel to travel to Uganda, including her passion for global health, her aim to better understand international partnerships, and her desire for experiences beyond the academics of the global health certificate she's pursuing. The journey itself was coordinated through GlobeMed, a UW student group that raised money to sponsor a grassroots organization in northern Uganda called Children of Peace Uganda (CPU).

With GlobeMed's support, CPU expanded its efforts to teach residents of Lira, Uganda, and the surrounding region the technical side of beekeeping and the particulars of selling honey to local markets. Many of the city's residents have endured decades of hardship since the Lord's Resistance Army (LRA) rebelled against the Ugandan government from 1987 to 2006. Michel helped advise children born in captivity, former abducted child soldiers, and women who were kidnapped by the LRA to serve as the wives of soldiers.

So far, the project has reached 169 households. The residents use the beekeeping income for food, medical bills, school fees, livestock, and apiary expansion.

"Beneficiaries are able to fly solo after being supported with supplies and training," Michel says. "They continue producing honey and expanding each year, making it a sustainable project."

Michel also took steps to ensure that CPU's work in Lira continues. Through interviews with residents, she identified priorities for the next apiary team. One primary goal is to budget for better hives.

"The original hive — the 'local' or 'log hive' — was hard to transport and wasn't as efficient as the more expensive Kenyan 'top-bar hive,'" Michel says. "It's newer technology that has a screen that you pull out; it's safer and produces more honey."

Michel's trip abroad expanded her horizons and made her want to learn more. After returning from Uganda, she started working toward a certificate in African studies.

"The biggest eye-opener was seeing how disproportionate wealth and health are around the world," Michel says. "Everyone should experience global health work; it's so different in person than in a classroom. I am more conscious of my identity and privilege, and I am more passionate about making a difference and getting involved in grassroots organizations."

Michel plans on returning to Uganda to work with CPU, see friends she's made, and explore more of the country.

—Stephanie Hoff BSx'20

Photo courtesy of Ciara Michel

These Kenyan "top-bar hives" in Lira, Uganda, are safer and more productive than older "local hives" built from hollow logs.

MALI

CALS Researcher Offers Hands-On Training at Gamou Farms

A native of Mali, **Thierno Diallo** takes great pride in his Fulani heritage. The West African ethnic group is well known for its tradition of raising livestock. Diallo's family didn't own cattle, but being immersed in the Fulani people's pastoral ways made him long for a life in agriculture.

That's precisely the life Diallo pursued. He studied agronomy for six years in Russia and interned on three farms in Normandy, France, before working for 12 years at three dairies in Wisconsin. In 2007, he took on his current role as a corn researcher with professor **Joe Lauer** in the CALS Department of Agronomy and decided shortly after that he wanted to use his skills and knowledge to give back to the agricultural community in Mali. To that end, in 2012, just outside Mali's capital city of Bamako, he founded Gamou Organic Farms.

According to Diallo, you can learn about farming from books and lectures, but you can't truly appreciate it until you've done the manual labor. Gamou Farms tries to bridge this gap between knowledge and experience for Malian students by immersing them in both the research and day-to-day operations associated with agriculture.

"When I worked on farms, you would get up and do just about the same thing every day," Diallo says. "So even if you don't want to learn, something is going to stick. And if you really want to, and you love what you're doing, there's no limit to how much you can learn."

Diallo manages Gamou Farms largely from abroad and returns to Mali for a month every summer. At any given time, local students can be found on the farm driving tractors, feeding cows, repairing fences, and administering vaccines to livestock, among other tasks. Also, by serving as a platform for Diallo's research with the agronomy department, the farm provides scientific training for students while advancing agriculture in Mali.

Today, Gamou Farms is pursuing two major projects. The first involves fonio (*Digitaria exilis*), a common West African grain crop that is adapted to dry areas and resistant to weeds. Fonio is drought tolerant, doesn't require much fertilizer, and is one of the world's fastest growing cereals, so it could play a vital role in enhancing food security and nutrition in Mali. However, at the end of the season, the seeds shatter, causing a 30–50 percent yield loss.

Sara Patterson PhD'98, a professor in the CALS Department of Horticulture, is working with researchers from the University of Bamako, the Institut d'Economie Rurale Cinzana, and the University of Georgia to find a solution to the seed shattering. Their aim is to develop better fonio varieties that won't bend at the stem (lodge) and will retain seeds at maturity. The resulting bump in yield would mean an enhanced food source for West African people and more income for fonio producers.

Gamou Farms provides a place for crossbreeding and selection among the collected samples, followed by the multiplication and dissemination of the new and better varieties to the local population. Diallo has extracted DNA samples in Mali and brought them to a CALS lab for further study. Students assist with DNA extraction, sequencing, and field data collection.

The farms' second project focuses on dairy. The goal is to create a new breed of cattle by crossbreeding local, disease-resistant N'Dama with "super milker" Holsteins. For that purpose, Diallo took 13 Holstein embryos with him on his July 2018 trip to the farm.

"When those embryos get transferred into my cattle back home, many vets, technicians, and students will be involved, so they can see and learn about this technology," Diallo says. "Gamou Farms is like an incubator, a place where students will come to learn and transfer technologies I've learned throughout my career and all that I have available to me here in the U.S today. These students are future leaders, farmers, researchers, and decision makers. If we consistently train many of them each and every year, we will raise the production level across the board."

—Andrew Pearce

Photos courtesy of Thierno Diallo

Top: Abai Mounkoro (right), a cattle herder at Gamou Organic Farms, teaches trainee Seydou Doucoure how to use a wire stretcher to rebuild and repair fences.

Bottom: Thierno Diallo at work at Gamou Organic Farms.

The Muscle Demystifier

Adam Kuchnia is using diagnostic imaging to enhance our understanding of human muscles and explore better treatments for muscle-wasting diseases

Interview by Nicole Sweeney Etter

AS A WRESTLER AT THE UNIVERSITY OF WISCONSIN–LA CROSSE, Adam Kuchnia lost a lot of pounds so he could compete in a particular weight class. And that didn't always lead to the best nutritional choices.

"I started to notice how good and bad nutrition felt when I was competing and the outcomes of poor nutrition," says Kuchnia, who is now an assistant professor in the Department of Nutritional Sciences. "When I was eating poorly, whether it was too few calories or a lot of fast food, I saw my energy levels decline. My performance declined drastically — I didn't have any energy to compete at the level that I was capable of competing at because I wasn't following the proper nutrition prescription. So that really snowballed into wondering how nutrition, specifically protein, changes the body and affects the way we move, perform, and think."

It was a wake-up call that would inspire Kuchnia to shift his career focus from exercise science to nutritional sciences. And even after he hung up his collegiate wrestling shoes, he continued to stay active and look for ways to enhance his own fitness. "I was always into exercise and always had this interest in trying to maintain and build muscle," he explains. "My interest in proteins, amino acids, athletics, and performance really pushed me into clinical nutrition. I wanted to get a deeper understanding of how nutrition impacts your body at a cellular level."

Now Kuchnia's research lab is focused on developing imaging techniques to more accurately evaluate muscle as it responds to aging and disease and how to best treat muscle wasting.

WHAT IS IT ABOUT MUSCLE THAT FASCINATES YOU?

It's important for everything. You need muscle to build an immune response when you're sick. It's important for movement, for function. To be healthy, you have to have an adequate amount of muscle — and healthy muscle to boot. It's just paramount. And yet, knowing how important muscle is to health and wellness and mobility, we still don't have good objective markers to characterize it.

WHY IS IT IMPORTANT TO CHARACTERIZE MUSCLE IN AGING AND DISEASE?

We're looking at how we can characterize muscle quantity and, more importantly, muscle quality. Currently, clinicians and nutrition professionals are subjectively palpating muscle, and it's not as accurate as I think this sort of assessment needs to be.

We also look at muscle to diagnose malnutrition, and we're still using some of the same techniques to assess nutrition that people used to observe illness over 1,800 years ago — looking at the fat pads under the eyes, ribs, clavicles, shoulders. We're trying to say something about nutritional status just by looking and touching; and nutrition professionals, clinicians, and physicians are forced to use this visual inspection because there's nothing better. Someone might seem nourished just by looking at them because you may not see any obvious muscle degradation, but if you get advanced imaging data, you might actually see signs of muscle loss.

There's so much imaging and technology that's available now that I think we can get a better, more accurate picture of what's going on inside the muscle. Essentially, we are trying to come up with an imaging-based biomarker of muscle quality that can be used to appraise and guide therapeutic intervention. Utilizing more invasive procedures, such as MRI, CT, DXA (which measures muscle mass and bone density), and biopsy, we hope to develop noninvasive and inexpensive methods that can objectively characterize changes in muscle. All of this can be used to improve functional status, independence, quality of life, and mortality.

WHY IS IT IMPORTANT TO LOOK AT MUSCLE QUALITY AS WELL AS QUANTITY?

Muscle quality is still a vague term; we're still trying to figure out what that means. Back in the late 1990s, early 2000s, researchers were looking at older people and saw their muscle quantity had gone down a little, but their physical function had dropped drastically. What is accounting for this discrepancy? Today there is good evidence that a loss of muscle quality precedes loss of muscle quantity.

Adam Kuchnia stands in front of a projected 3D image of human torso muscles created from dozens of cross-sectional CT scans.

Photo by Michael P. King

ARE THERE PARTICULAR POPULATIONS THAT WOULD ESPECIALLY BENEFIT FROM THIS TYPE OF MUSCLE ASSESSMENT?

It's very important for everybody but especially for people who are hospitalized. When people go into the hospital, they're immobile. They have an immediate inflammatory response that leads to muscle loss. Then, when you add in disease that leads to muscle wasting, such as critical illness or cancer, the effects are catastrophic. If we can identify these changes in muscle earlier, we can intervene earlier.

SO ONCE WE CAN BETTER CHARACTERIZE MUSCLE DECLINE, WHAT CAN WE DO ABOUT IT?

We can intervene in many different ways, but I'm focused on nutritional intervention, specifically protein and amino acids. When people are going through cancer or are in the ICU and are having this huge inflammatory response, we don't really know the right levels or types of proteins and amino acids to give them. If we give them too much, we could be harming them. But if we give them the right amount and type, we could help increase protein synthesis, reduce protein breakdown, and reduce muscle wasting. We're trying to improve patient outcomes so they get out of the hospital sooner, and so, when they leave, they have a quality of life that's meaningful for them.

WHEN DOES AGE-RELATED MUSCLE LOSS START TO HAPPEN? IS THERE ANYTHING WE CAN DO TO LESSEN ITS AFFECTS?

Sarcopenia, which is what we call age-related muscle loss, starts to happen in mid-adulthood. We lose roughly 3 to 8 percent of our muscle mass per decade after the age of 30, and that increases substantially as you hit 60. But that's just muscle quantity. I'm trying to look at muscle quality. How much is actually active, functional muscle?

Even the healthiest people we know lose muscle as they age, but you can definitely slow down the process with proper nutrition, regular exercise, and an overall healthy lifestyle.

WHAT'S NEXT FOR YOUR LAB?

I've been here less than a year, so the next thing is growing my lab, really carving out the physical space and hiring the right students and lab assistants. Then it's trying to get to the bottom of these muscle-wasting syndromes. There are so many questions there.

YOU'RE A PRODUCT OF THE UW SYSTEM. WHAT'S IT LIKE TO BE BACK AT A UW CAMPUS AS A FACULTY MEMBER?

It's pretty special. I grew up in Twin Lakes, did my undergrad degree at UW–La Crosse, and then went to UW–Stout for my master's degree. I feel like I have a responsibility to the state of Wisconsin to give back. We talk a lot about the Wisconsin Idea here — giving back not only to the university but to the community at large. I really like that my research can help benefit the place where I grew up.

After I finished my doctorate at the University of Minnesota, I was willing to go anywhere from coast to coast, but I was very lucky when this position opened up. It's a phenomenal department. I couldn't be happier here.

Craft Cider's Comeback

UW's Center for Integrated Agricultural Systems partners with local cider makers to support the state's burgeoning craft cider industry

By Nicole Miller MS'06

Photos by Michael P. King

A row of cider apple trees in the orchard at Albion Prairie Farm, located just east of Stoughton, Wis.

Opposite page: Hard cider samples are set out during a tasting at Heritage Tavern in Madison, Wis.

A lot of cider apple trees — the kind that produce fruit for hard apple cider — aren't easy to come by. Most of them are old European or American heirloom varieties that aren't readily available for commercial purchase. And you can't just grow the trees you want by planting seeds from your favorite apple. No two apple seeds are alike; each contains a unique mix of genetic material.

To propagate artisanal cider trees, you often have to graft.

That's exactly what 50 people opted to do on a Saturday afternoon last spring as participants in the inaugural Hard Cider Apple Grafting Workshop hosted by the UW–Madison Center for Integrated Agricultural Systems (CIAS). Crowded around tables in a basement room in Moore Hall, they learned eagerly about grafting while awaiting the opportunity to try their own hands at the ancient technique.

Grafting is both a science and an art. Which is why a set of experts, including **Amaya Atucha**, a CALS and Extension fruit crop specialist, was on hand to explain and show how it works. Grafting involves taking a small branch from the tree you want to propagate (a scion) and connecting it to the bottom portion of a different apple tree (the rootstock). It must be done in such a way that the vascular systems of the two trees connect and fuse, "so they heal up together and become one unit," says Atucha. It takes just a few precise cuts with a grafting knife and something to secure the bond.

"For the first cut, your goal is to get an inch-long, gradual angle across the base of the branch," explains **Matt Raboin** MS'10 of Brix Cider, located near Barneveld, Wisconsin, as he demonstrates the cut to the attentive group. "You want a nice flat, straight surface."

Next, he cuts a little flap into the base of the branch. He repeats the cuts on the rootstock and then brings the scion and rootstock together, slipping one flap over the other, and gives a push.

"Basically, it's a puzzle; you're fitting these two pieces together," notes **Marie Raboin** MS'10, while showing how to secure the juncture with a wrap of stretchy tape. Marie and Matt, a married couple, co-own Brix Cider.

At this point, workshop participants are set loose to try the technique, known as the "whip and tongue" approach to grafting. Each selects an assortment of scions, grabs some rootstock, and then hunkers down to practice the cuts. It's a messy, mesmerizing scene: A room full of enthusiastic, knife-wielding, novice grafters in deep concentration amid a jumble of branches, roots, and dirt.

"It's like an adult kindergarten room, but instead of construction paper and scissors everywhere, there are branches and roots and grafting knives," says CIAS associate director **Michelle Miller** BS'83, who organized the event as part of the center's broader efforts to support Wisconsin's craft cider industry.

Hard cider, a traditional drink of early America, has been making a comeback in recent years — in Wisconsin and around the nation. Among those who want to participate in this renaissance, including hobbyists and entrepreneurs, there's an eagerness to learn how to graft and to procure cider apple trees.

"At the workshop, we were sharing scions from some unusual, cider-specific apple varieties that are hard to find," Miller says. "There's a lot of interest in that."

Over the past few years, CIAS has been partnering with Wisconsin cider businesses, including Brix Cider, The Cider Farm near Hollandale, and others, to assess and address the needs and challenges of the state's burgeoning cider industry. Together they have been working to help rediscover and rebuild some of the cider knowledge that was lost in

Above: Paul Whitaker, of Wausau, Wis., lines up his graft junction during a cider apple grafting workshop hosted by the Center for Integrated Agricultural Systems at D.C. Smith Greenhouse on the UW–Madison campus.

Left: Workshop participants practice making their own grafts.

the past, including information about which trees grow well in the state and what their apples taste like in cider form.

"In France and England, they've been making cider for hundreds of years," Miller says. "They've figured out the best apples for their region for growing and producing tasty cider, and there are certain flavor profiles associated with certain areas. We don't know that yet for Wisconsin. So we're in the process of figuring out what trees work best in our area."

CIAS, along with several farmer-participants, is about to embark on a new collaborative project to explore opportunities to expand markets and increase profitability for cider businesses. At the same time, the project will establish a professional guild for Wisconsin's cider growers, creating a network of growers who can help support one another.

"We hope not just to grow our own business but to grow the industry as a whole, with a focus on family farms, regional flavors, sustainability, craft, and quality," Matt Raboin says.

CIDER'S HISTORICAL UPS AND DOWNS

During America's early years, hard cider was a popular beverage. Originally, for lack of refrigeration, all cider was hard cider (unless it was consumed within a few days of pressing). Left sitting at room temperature, apple juice ferments into cider within a couple of weeks as naturally occurring yeasts convert the sugars into alcohol. And that was a very good thing at the time.

Thanks to the alcohol it contained, hard cider was among the safest beverages around. The level of alcohol — from 3–4 percent for a cider fermented from wild yeast — helped kill pathogenic bacteria, making it a relatively sanitary option compared to the various untreated or unpasteurized beverages available at the time.

Cider's popularity began to wane — and beer's began to wax — during industrialization, as more people moved to cities, where it was easier to ship and store grain. But if beer cut into cider consumption, the temperance movement and prohibition chopped it down. Literally. During prohibition, many individuals cut down their cider trees. Likewise, to stay afloat, many cider businesses razed their orchards, replacing their trees with rows of sweet table apples — the kind you eat. Many prized, cider-specific varieties were lost.

Now, almost 100 years later, cider is experiencing a revival. Between 2011 and 2015, hard cider was the fastest growing alcoholic beverage category in the United States, with sales expanding from \$89.9 million to \$326.9 million, thanks primarily to the growth in sales of mass market ciders produced by large beer companies. More recently, there's been a shift from mass-market ciders to craft ciders, similar to how consumers transitioned away from mass-market lagers to craft beer. Craft ciders now account for 25 percent of overall cider sales and have been experiencing double-digit growth for a number of years — a trend that looks like it will continue.

There are now around 800 cideries in the U.S., twice as many as there were three years ago. Wisconsin currently has 18 cideries, according to the Cyder Market website. Most of them are relatively new, established in the past decade or so, and most grow some of their own apples.

CIAS got into cider-focused work in 2016, when Brix Cider's Matt Raboin, who was a part-time staff member at CIAS at the time, embarked on a project to assess the needs and challenges of cider businesses in Wisconsin and nearby states. The project was close to Raboin's heart, as he and Marie were already working toward their Brix Cider dream. It was not the first CIAS project related to apples.

Founded in 1989, the CALS-based center focuses on sustainable agriculture research for small- and medium-sized farms. It specializes in using a participatory approach, bringing together farmers, academics, and others across many professions and disciplines to work side by side to develop research projects and educational programs that address farmers' needs.

In the early 2000s, CIAS led an effort known as the Eco-Apple Project to help farmers ramp up their insect and disease monitoring programs and reduce their use of pesticides. The program spun off into a private-sector enterprise and continues to this day. The center also runs the university's Midwest School for Beginning Apple Growers, an intensive three-day education program for people interested in starting an apple orchard business that attracts around 30 to 40 attendees each year.

The CIAS cider needs assessment project, funded in part by the David S. Bourne Foundation, compiled information from 44 cider businesses from around the region and identified a list of challenges. It quickly turned into something of a research agenda for the center. Cider businesses reported facing issues related to financing, marketing, and distribution. At the same time, they were eager for information about what cider apple varieties work best for the region.

The latter concern was particularly relevant for the Raboins, who were in the midst of trying to decide which trees to graft and plant in the Brix Cider orchard.

"There are literally thousands of possible varieties out there. It's overwhelming," Matt Raboin says. "We didn't have the data to say, 'These five varieties are the best ones, so we are going to grow these five.' So we've planted over 100 varieties that we are trying out. Our orchard is kind of a living experiment."

This need for information inspired the Raboins to embark on a research project to assess 40 promising cider varieties, work that CIAS later continued.

SEARCH FOR THE TASTIEST CIDER APPLES

Brix Cider's home orchard is located in the rolling hills of Iowa County, just south of Barneveld. The Raboins live in an old farmhouse on the six-acre property along with their two young children and two dogs. They also lease a space in Mount Horeb, Wisconsin, where they plan to house their production facility and a tasting room beginning in early 2019.

They planted their first graftings back in 2014 and now have around 1,000 trees on the property representing more than 100 varieties. Eventually, they hope to expand to a total of about 2,000 trees.

"I think a lot of the intent with the orchard is really to preserve and promote these old American varieties of apples," Marie Raboin says. "We're in America, and there's a really strong cider heritage here. So we'll grow some English and French varieties, but we're really focusing on American cider varieties."

Even 2,000 trees won't be enough for all the cider the Raboins want to make. Brix Cider's business model involves procuring local apples from other sources: abandoned orchards, wild trees, and the ugly or odd-looking (but perfectly edible) leftovers from pick-your-own orchards that would otherwise go to waste. The Raboins are particularly excited about their orchard series, a line of ciders featuring the apples gathered from individual orchards.

Photo by Matt Sweeny

In the orchard at The Cider Farm, Deirdre Birmingham and John Biondi display some of their fine ciders and apple brandy on a charred-oak barrel used for aging.

Madison area chefs, from left, Daniel Bonnano of A Pig in a Fur Coat, Joe Cloute of Heritage Catering, and Sean Fogarty of Steenbock's on Orchard, taste commercially available hard cider at Heritage Tavern in Madison, Wis.

"Our business model is to partner with other orchards and create a market for underutilized fruit, because there are so many apples around that just don't get harvested," Marie Raboin says. "It's a way to utilize the resources that are available and, I think, a way to help build a better community."

In 2016, the Raboins received a Farmer Rancher Grant from the USDA's Sustainable Agriculture Research and Education program to assess 40 cider apple varieties for their characteristics. They gathered the apples (about a half bushel of each variety); pressed the juice and analyzed it for sugar, acidity, and tannins; fermented the juice into single-variety ciders; conducted a taste analysis; and then posted the results on Brix Cider's website.

Matt and Marie Raboin of Brix Cider harvest apples from a tree at Albion Prairie Farm.

After that, Matt Raboin decided to write a grant proposal for CIAS to assess another 40 varieties. "We thought it would be better to try to incorporate other growers who have more experience, folks like **Deirdre** [**Birmingham** PhD'96] from The Cider Farm, and also get the university involved," he says. "So there's a team with more research skills, analytical experience, and expertise to take over this work."

Not long after the new grant was secured, Matt Raboin left CIAS to ramp up his efforts with Brix Cider. Miller took over coordinating the project, and the Raboins opted to stay involved as farmer-participants.

The grant, along with additional support from the David S. Bourne Foundation, tapped several UW experts to help. **Nick Smith**, a fermentation expert in the Department of Food Science, made the ciders and tested their chemical makeup. **Julie Dawson**, an assistant professor of horticulture with expertise in participatory sensory analysis, led four tasting evaluations of the single-variety ciders.

At these events, which were run like blind taste tests, participants were asked to evaluate selections of the 40 ciders for various characteristics, including appearance, sweetness, bitterness, acidity, mouthfeel, flavor intensity, and overall performance.

Whereas mass-market ciders tend to be on the sweet side, craft ciders can be dry or off-dry. They come across as light and refreshing, with a crisp, appley flavor. Some have nice bubbles. Others can be reminiscent of a dry white wine, such as a sauvignon blanc.

This makes sense because cider is often made like a wine, using wine yeast. And, like wines, ciders can contain tannins, bitter-tasting compounds found in certain plants.

"[Tannins help] give structure, complexity, and mouthfeel to the beverage," explains Birmingham. Her orchard, The Cider Farm, specializes in English and French varieties that are high in tannins. The tagline for The Cider Farm's products is "cider refreshment, wine complexity."

"Just like there are fine wines, we consider our ciders to be fine ciders," she says. "We do use tart table apples as a base, but blending in the tannic apples makes all the difference."

Birmingham, along with **John Biondi**, established The Cider Farm in 2003 on a lovely piece of property near Hollandale, Wisconsin, about a 15-minute drive from Brix Cider. They have about 10,000 trees and 4,000 graftings in the nursery, and they plan to expand their orchard to as many as 25,000 trees. And they are doing all of it organically. (Read more about Birmingham in our "In the Field" series on alumni entrepreneurs on page 34.)

Birmingham and Biondi, who will open a tasting room and production space in Madison in the coming months, are active farmer-participants in CIAS cider projects; they contributed their scion and expertise to the grafting workshop as well as their apples and palates to the single-variety evaluation.

"[We were] particularly interested in the results of the focus group cider tastings as a way to get a better feel for market preferences among craft cider customers," says Birmingham.

Overall, traditional English and French varieties tended to rate well in the evaluations, as did some of the popular American heirloom varieties. A few wild varieties also stood out, including the Bergere apple, a variety the Raboins discovered in an abandoned field. It turned out to be the most bitter of the bunch.

"The guy who was picking with us that day, his name was Bergere. He's the one who found the tree, so it's called the Bergere," explains Matt Raboin.

Between the two single-variety projects, cider hobbyists and businesses now have information about 80 cider varieties, data that can help them decide which trees to grow and which apples to try blending into a cider.

This information already proved useful last spring when it was time to decide which scions Brix Cider and The Cider Farm should bring to the CIAS-hosted grafting workshop for participants to take home and, ideally, help further propagate down the line.

"We selected trees that ranked high or looked like they had a lot of promise for flavor and for building a terroir of hard cider in our region," Miller says.

A BOOSTER FOR THE CIDER INDUSTRY

CIAS is now involved in a new cider-focused project, along with partners at Michigan State University, Washington State University, and the University of Vermont, to understand and tackle issues related to the sales, marketing, and distribution of hard cider products. With funding from an Agriculture and Food Research Initiative (AFRI) grant from the USDA National Institute of Food and Agriculture, the project aims to assess obstacles to profitability and identify opportunities for market expansion.

And there certainly seem to be opportunities out there. Nationally, the market is largely millennials and baby boomers; each group drinks about one-third of the cider consumed. "That's who's drinking cider right now. So there's interest in how to expand to [other] cohorts," Miller says.

In Wisconsin, she notes, there appears to be a relatively untapped market among tourists visiting traditional apple-growing regions, such as Door County and the Bayfield area. While these regions already have local cider producers, there may be room for more. The state is also conveniently located next to a national cider hot spot: Chicago.

"So we're near this high-volume market where there's a real preference for artisan ciders," Miller says.

That said, it probably isn't wise for entrepreneurs to jump in without considering the local market — and where they would fit into it. "At this point, the market is crowded in such a way that you really need to have a plan," notes The Cider Farm's Biondi, a longtime entrepreneur. "What part of the value chain are you going to compete in? How are you going to differentiate yourself?"

CIAS is also cautious about encouraging people to start new cider businesses because the economics aren't well understood. The new AFRI-funded project is designed to shed light on this topic, notes Miller. At the same time, Wisconsin stands to benefit by interacting with the three partner institutions, which are located in states with more established cider industries.

"Just by participating, we think we can learn a lot that we can share with growers here in Wisconsin," says Miller.

Brix Cider and The Cider Farm provided letters of support for the new CIAS grant and are serving as advisers. They will be involved in various aspects of the project, including a Wisconsin-specific effort to create a network for the state's cider businesses for sharing information and resources and working together to advance the state's craft cider industry.

It will be an organization for existing cider makers — and hopefully some newcomers, too.

"We get emails all the time from folks that say, 'I'm so-and-so from this little town in Wisconsin, and I want to start a cidery, I want to plant a cider orchard,'" says Matt Raboin.

These are the folks that the Raboins, as well as Birmingham and Biondi, are happy to share their accumulated wisdom with (and their scions, in certain cases) — the ones who reach out to them through email, at presentations and workshops, and via the soon-to-be cider network. The big-picture goal is to make sure all Wisconsin-made craft ciders are top-notch.

"We find a lot of customers assume that they don't like cider. They say, 'Oh, I'm not a cider drinker,'" Matt Raboin explains. "But if we can convince them to try it, they often like it. So it's important that other cider makers make good cider — so that people's first experience is a good one, and they'll want to try other ciders on the shelf." g

online extra

FRUITFUL OUTREACH

UW Fruit Team supports Wisconsin apple growers

Managing an apple orchard isn't the romantic endeavor some might imagine. There's a lot to do. Thankfully, Wisconsin's commercial growers have the UW Fruit Team to turn to for help and guidance.

READ MORE AT **GROW.CALS.WISC.EDU**

CLIMATE CHANGE IN MICROCOSM

By Caroline Schneider MS'11

Research in a state wildlife area is revealing how wild animals are struggling with and adapting to an environment in flux

Photos by Michael P. King (2)

Jon Pauli is perched in the passenger seat of a mud-spattered Ford F-250. His ceramic mug brims with coffee as graduate student **Evan Wilson** guides the truck, loaded with equipment, over the rough roads of the Sandhill Wildlife Area. A spill is just one big jostle away, but Pauli prefers things this way — a sign of his coffee devotion. He jokes about how his wife once tortured him for weeks when she unknowingly bought decaffeinated beans.

But Pauli's love for coffee seems lukewarm compared to his passion for his work as an associate professor of forest and wildlife ecology. He radiates enthusiasm — along with an abundance of laughter and a smattering of swear words — as he expounds upon conservation biology, Sandhill, and the research his lab is pursuing.

He shares his passion with two other forest and wildlife ecology professors: **Ben Zuckerberg** and **Zach Peery**. Their collective work explores one question: How do we protect species that are vulnerable to disruptions in their environment, such as climate change and land use? The three have formed a productive collaboration and, it seems, an easy camaraderie. It's not hard to imagine them walking into a pub together and leaving with a plan for their next great endeavor.

And Sandhill Wildlife Area, 9,000 fenced-in acres of state land set aside for research and hunting, is a perfect place for them to pursue their ideas. Situated just off a rural highway in west-central Wisconsin, the area is a bit unassuming at first, with an office and a dormitory next to a small paved parking lot. But once inside the fence, it's clear the area holds a diverse wealth of landscapes, plants, and animals.

Sandhill was named for the sandy ridges that roll gently across the property. Animals are abundant. On a quick ride through its marshes, flowages, and forests, one can glimpse swans and songbirds, ducks and deer. A closer look might reveal turtles, grouse, and porcupines, the animals at the center of Peery's, Zuckerberg's, and Pauli's work.

Rarely seen is the small herd of American bison that has called Sandhill home since **Wallace Grange** owned the land. Grange and his wife, Hazel, purchased Sandhill in the 1930s and spent more than two decades nurturing the land and running the area as a game farm. Upon his retirement in 1962, Grange sold the area to the state of Wisconsin, requiring that it be used as an education and demonstration area. Today it is managed by a team of Wisconsin Department of Natural Resources (DNR) biologists, technicians, foresters, and wildlife researchers.

An ideal setting for research, Sandhill offers years of data for scientists like Pauli, Zuckerberg, and Peery. **Lloyd Keith**, a retired forest and wildlife ecology faculty member, was studying the area's animals and weather conditions as early as the 1960s.

"We have long-term data on what this place used to look like, and we have data on what it looks like now," says Pauli. "It's not just the place that makes Sandhill special, it's all of the data we are drawing upon. Long-term field sites like this are pretty rare. They're really important to be able to understand ecological change."

Opposite page: Evan Wilson (left) and Jon Pauli weigh a porcupette in the Sandhill Wildlife Area near Babcock, Wis.

Porcupettes, or baby porcupines, are at the center of ongoing research into the impact of climate change on wildlife.

Photos by Evan Wilson

Snowshoe hares at Sandhill Wildlife Area are shown here against backdrops with snow cover and no snow cover. Researchers had proposed that early snow melt and less snow cover would lead to more hares being predated because they would be easier to spot against the now-brown background.

WITH YEARS OF ACCUMULATED data in hand, Pauli and Wilson are working to understand the relationship between climate change, snowshoe hares, carnivores, and porcupines (especially porcupettes, the delightful but rarely heard name for baby porcupines). Their project is, in essence, a time machine. They have pushed the Sandhill Wildlife Area back in time by reintroducing an animal that is no longer naturally present within its boundaries: snowshoe hares. By doing so, they can observe how the species, which evolved to survive snowy winters, is adapting to warmer winters and dwindling snow cover. Further, they can better understand how the effects ripple out into populations of other animals, such as porcupettes.

Sandhill is right at the edge of snowshoe hare habitat. As with many animals, hare populations go through rise-and-fall cycles, and these cycles have been associated with patterns in predator–prey relationships. Over the last 50 years or so, through multiple cycles, snowshoe hare numbers in Sandhill steadily decreased as the animals moved north. Eventually, they functionally disappeared from the area.

To study what happens to the hares with shorter winters and less snow, Wilson and Pauli had to reintroduce them. This involved a slow, laborious process of catching hares from other parts of the state and releasing them at Sandhill.

"We trapped hares north of here using baited traps put out at night," Wilson says. "The next morning, we'd come back and collect the hares — usually two or three per night. After about a month and a half of trapping, we brought the hares down here, radio-tagged them, and did a kind of soft release."

A soft release entails building an enclosure for the hares so they can acclimate to the area. The kennel-like structures provided food and shelter for two nights before the hares were fully released. Wilson eventually released 99 hares into Sandhill, just under his goal of 100. "Close enough," he jokes.

The hares were released in winter, when their seasonally changing coats matched the white snow cover. A late-winter snow melt offered a true test of the team's hypothesis. Researchers had proposed that early snow melt and less snow cover would lead to more hares being predated because they would be easier to spot against the now-brown background. And that's just what they found. During the first week of an early snow melt in March, 30 percent of the hares died. In comparison, in weeks when hares matched the surrounding snow, an average of 7 percent of the hares died.

"Not all the weeks were that extreme, but weekly survival is a short interval to be able to measure," says Wilson. "If you're experiencing enough mortality in a week for that to be an important number, that's telling."

It was experimental data to back up what Pauli and his colleagues had been hypothesizing for some time — shorter winters are directly related to the survival of snowshoe hares. But if snow is melting earlier, why don't the hares' coats just turn to brown earlier?

"Molting is predominantly driven by solar cycles," explains Pauli. "They're cueing into photoperiod [day length] to change from white to brown. But snow isn't cued in on photoperiod. Snow is melting earlier and earlier in these areas, and we're seeing a mismatch of white animals on brown backgrounds. That's why this is a climate change story."

As warmer winters hit areas where snowshoe hares live and the hares' predation rates go up, other animals in the ecosystem will feel the effects as well. With fewer hares to eat, predators such as fishers and coyotes will turn to other possible prey, such as porcupettes, likely causing their numbers to decline as well. To better understand these relationships, Pauli and Wilson are currently investigating what killed the hares (using DNA found on the hares and prints found nearby) and monitoring porcupette populations in Sandhill. It's likely that the ripple effects of losing hares will be felt widely in areas of warming winters.

So what can be done? That's another question that Pauli and Wilson are working to answer. And they have some suggestions. They have found that patches of high-quality, dense habitat are important for hares to survive. Historical data suggest the same — some of the last areas where Keith, their predecessor, recorded hares were large patches of aspens, alders, and low-lying conifers.

"These areas are ideal," Wilson says. "They give the hares hiding spots, thermal cover, and food resources all in one spot. Animals that have those areas available to them had higher survival."

Having a possible solution or recommendation to at least slow the decline of hare populations is exciting for Pauli. "When we talk about climate change, land managers aren't always offered tools to manage it," he says. "But Evan's work shows that there may be habitat management techniques that people could employ to buffer the effects of climate change and promote species like snowshoe hares. We're not just telling you bad news; we're also trying to provide you with tools to promote this species on the landscape if that's what you want to do."

As Wilson's time in the field came to an end in summer 2018, he continued to tease out the different aspects of his work and create a clearer picture of what he found at Sandhill. That picture will help other researchers and may guide land managers looking for ways to mitigate the effects of climate change on different species.

A WARMING CLIMATE ALSO POSES challenges to the ruffed grouse. It's possible the thick-feathered, brown and gray game birds could benefit from some of the same habitat management concepts that Wilson and Pauli suggest. Like snowshoe hares, ruffed grouse have adapted to cold winters and snow cover, and they have undergone extensive study in the Sandhill area historically. Ben Zuckerberg and graduate student **Amy Shipley** want to understand how changing winters might affect the birds.

Zuckerberg has been modeling changes in grouse populations (which experience cycles much like those of snowshoe hares) for several years, and Shipley came onboard to investigate the mechanism of those population trends. Sandhill was, again, the ideal place to study what the birds were doing during winter and how they might respond to less snow.

"Ruffed grouse is a really interesting indicator species," Zuckerberg explains. "They get through the winter, but it's definitely a bottleneck in terms of their populations. Populations have been declining, especially those around the southern boundary of their range. Sandhill is at that boundary."

Like snowshoe hares, ruffed grouse are vulnerable to the loss of snow cover. They burrow under snow in winter to keep warm and, it is surmised, to avoid predators. Scientists have documented a 7–10 percent loss of snow cover per decade in areas of the Upper Midwest, which means that this important refuge is disappearing. Not surprisingly, a DNR report on grouse at Sandhill found that winters with low amounts of snow meant fewer birds the following spring.

To better understand why, Shipley undertook a project to track grouse with radio transmitters through three winter seasons. She tagged about 20 birds each year, hoping they would reveal which roost sites grouse were using at Sandhill and how their behavior and survival rates were responding to less snow cover.

Shipley looked closely at physiological stress in Sandhill's grouse. Chronic stress in the winter can lead to reproduction declines the next season — an indicator of poor fitness. Shipley collected samples of droppings from which she measured levels of the stress hormone corticosterone.

> "Ruffed grouse is a really interesting indicator species. Populations have been declining, especially those around the southern boundary of their range. Sandhill is at that boundary."

"We found a strong relationship between stress and temperature," she says. "The colder it was outside, the more stressed the grouse were because it takes more energy to keep warm. When the birds were able to burrow in the snow, though, that relationship went away. Birds that were in snow burrows were a lot less stressed."

Photo by Angela Walker

Amy Shipley holds a ruffed grouse with a radio-tracking tag.

Because snow cover is so important to grouse, managing habitat in a way that maintains snow cover could go a long way in protecting them and encouraging populations of grouse in areas where numbers are declining. For instance, grouse sometimes roost under low branches of spruce trees and under the cover of fallen trees. Conifers and complex understories in forests can also maintain snow and provide warmer areas for the birds. As Shipley continues her work, she plans to identify more strategies to optimize grouse roosting and survival. It's a similar story to what Pauli and Wilson see with hares.

"Grouse are an important sentinel of climate change, in particular the loss of snow cover throughout the Upper Midwest," Zuckerberg says. "We need to think about whether there are aspects of habitat management that will allow animals to continue to use their adaptations to snow cover to survive."

HABITAT MANAGEMENT MAY BE ONE way to protect another vulnerable animal — the turtle. Turtles are one of the most endangered groups of reptiles. Zach Peery and graduate student **Nathan Byer** are trying to understand how environmental changes are affecting three freshwater turtle species in Wisconsin: Blanding's turtles, snapping turtles, and painted turtles. Blanding's turtles are globally endangered, and snapping and painted turtles, while more common, are also declining in locales throughout their North American range.

For more than 20 years, Wisconsin DNR wildlife biologist **Dick Thiel** captured, marked, and released turtles at Sandhill. He accumulated a large data set, and Peery and Byer are contributing to it by radio-tracking turtles. They're also using the historical information to study what happens to turtle populations in response to environmental disturbances. It's an ideal site, then, for evaluating early warning signs and long-term impacts of climate change on turtle populations.

"The long lives of turtles make them very sensitive to environmental change, particularly if those changes reduce adult survival," explains Byer. "So most of our research focuses on integrating local studies and statewide monitoring to predict responses of Wisconsin turtles to climate and land use changes."

On a cloudy fall day, Byer sets out on a gravel road at Sandhill to release a Blanding's turtle riding in the back of his SUV. Easily identified by its yellow chin and throat and the pale speckles on its upper shell, the Blanding's turtle is docile and semi-aquatic. Driving just behind the bison enclosure, Byer points down at the road and says that in spring this is a popular nesting site for the turtles. It's hard to imagine the gravel and dirt being a suitable area to dig a nest, but he says they find spots where the material is loose.

Blanding's turtles are interesting animals to study for several reasons. They are long-lived, sometimes reaching up to 70 or 80 years, and they don't reproduce until around age 15 or 16. When they do reproduce, they practice "natal philopatry" — that is, they return to where they were born to nest. Also, females lay their eggs and leave. They have no knowledge of the fate of their offspring or how well the nest fared.

"We've found in our work that there is a friction between what's good for the mother when nesting and what's good for the offspring," says Byer. "Because this is a long-lived species, it's usually better for the mothers to be selfish. For instance, they tend to nest in areas close to woods. This may not help the nests survive, but it does seem to reduce the risk of predation for the mothers. And because they're cold-blooded, they are often more interested in maintaining a comfortable body temperature than picking an optimal nesting site."

By studying nesting sites and turtle numbers in Sandhill, Byer is continuing work

Nathan Byer demonstrates the radio-tracking technology used to locate turtles at the Sandhill Wildlife Area.

started by a former graduate student in Peery's lab, **Brendan Reid** PhD'15. The goal is to determine what factors are influencing population size, age, and distribution in the area. There are a number of suspects, many of which are related to changing climate and how humans make use of the land.

"After turtles spend the winter underwater, the males set out to find females to mate with. During that time, they're hopping between wetlands," explains Byer. "Changes in climate could cause some of those wetlands to dry up and disappear, and land use change can affect the distribution of wetlands. Both make it harder for turtles to move between populations."

PHOTOS BY BEN VINCENT (2)

"We are seeing more young turtles returning to recently restored habitats, indicating that hatchlings from those areas are surviving to adulthood."

Land use poses other problems for turtles. Reid's genetic work shows that agricultural lands form barriers for turtles, stopping them from dispersing and mixing with other populations, and that urbanization reduces the number of wetlands and nesting areas they need to survive. As roads are built through turtle habitats, females have to travel farther and through more populated areas to find suitable nesting sites. This puts them at higher risk for death from predators and automobiles. As evidence of this, Reid's research has found sex ratios skewed toward males and low genetic diversity in areas with many roads.

Warming temperatures also threaten turtle populations. Turtles have temperature-dependent sex determination — the temperature of the eggs during a particular point in development dictates the sex of the offspring. The difference of just a degree or two can flip the switch. With warmer temperatures, more females will be born, skewing sex ratios, reducing population growth rates, and contributing to the loss of genetic variation.

"They may find ways to change their nesting behaviors to account for temperature changes," says Byer. "They could start nesting earlier in the season or nest under more cover so the nests are cooler. But that may be a trade-off for the mother if it puts her more at risk. There is a lot of uncertainty regarding how, say, nesting in a more shaded area may have indirect effects on the nesting turtle."

Habitat management could solve some of the problems freshwater turtles face in Wisconsin. Efforts to protect wetland areas could reduce the distances turtles need to travel during mating season. Land managers could provide nesting turtles with areas of loose dirt and gravel far from roads and close to woods. Despite the many threats Blanding's turtles face, work from Peery's lab suggests that the Sandhill population is increasing in response to nesting and wetland habitat restoration.

"DNR employees have been restoring prairie and oak savannah at Sandhill since the 1990s. We have discovered that these areas are good for nesting Blanding's turtles," says Byer. "We are seeing more young turtles returning to recently restored habitats, indicating that hatchlings from those areas are surviving to adulthood."

In addition to tracking the turtles, Byer is taking samples of their blood for a genetic study. He plans to compare their genetic makeup with that of turtles in other areas of the state. If genetic differences are related to climate conditions, this could be evidence of adaptation to climate change.

"We are incorporating information from both long-term nesting and population monitoring efforts at Sandhill with more recent statewide genetic sampling to develop sound conservation strategies," explains Byer. "Integrating multiple data sources is important for accurate predictions in an uncertain future."

THE UNKNOWNS ASSOCIATED WITH environmental change and the randomness of fieldwork both present many challenges for research at Sandhill. But addressing those challenges can be rewarding for wildlife ecologists. Jon Pauli, still precariously balancing his coffee mug in the passenger seat of the jostling truck as the tour of Sandhill comes to an end, explains why. It seems that unpredictability — a characteristic that defines the animals he studies, the landscapes they live in, and even the research process itself — is one of the things he loves.

"We work in places where you're constantly dealing with problems and proven wrong," says Pauli with a laugh. "You start to embrace the things you can't control, and you start to accept that you need those things to answer your questions. I mean, I didn't know it was going to freaking snow in April here this year. But that helped us understand our work and the animals even more."

Controlled Burn

Thea Whitman digs into questions of soil, carbon, and biochar that could determine the ultimate trajectory of climate change

BY ERIK NESS

In a small utility room in UW–Madison's Animal Science Building, the world's smallest and most precise forest fire is burning. The fuel today: 100 grams of white pine. The chips sit inside a steel tube enclosed in an oven-sized electrical furnace. In a few short hours, this woody mix of organic molecules will be pyrolyzed, reduced almost entirely to an essential grid of carbon. You'd call it charcoal, but assistant professor of soil science **Thea Whitman** calls it pyrogenic organic matter, or biochar.

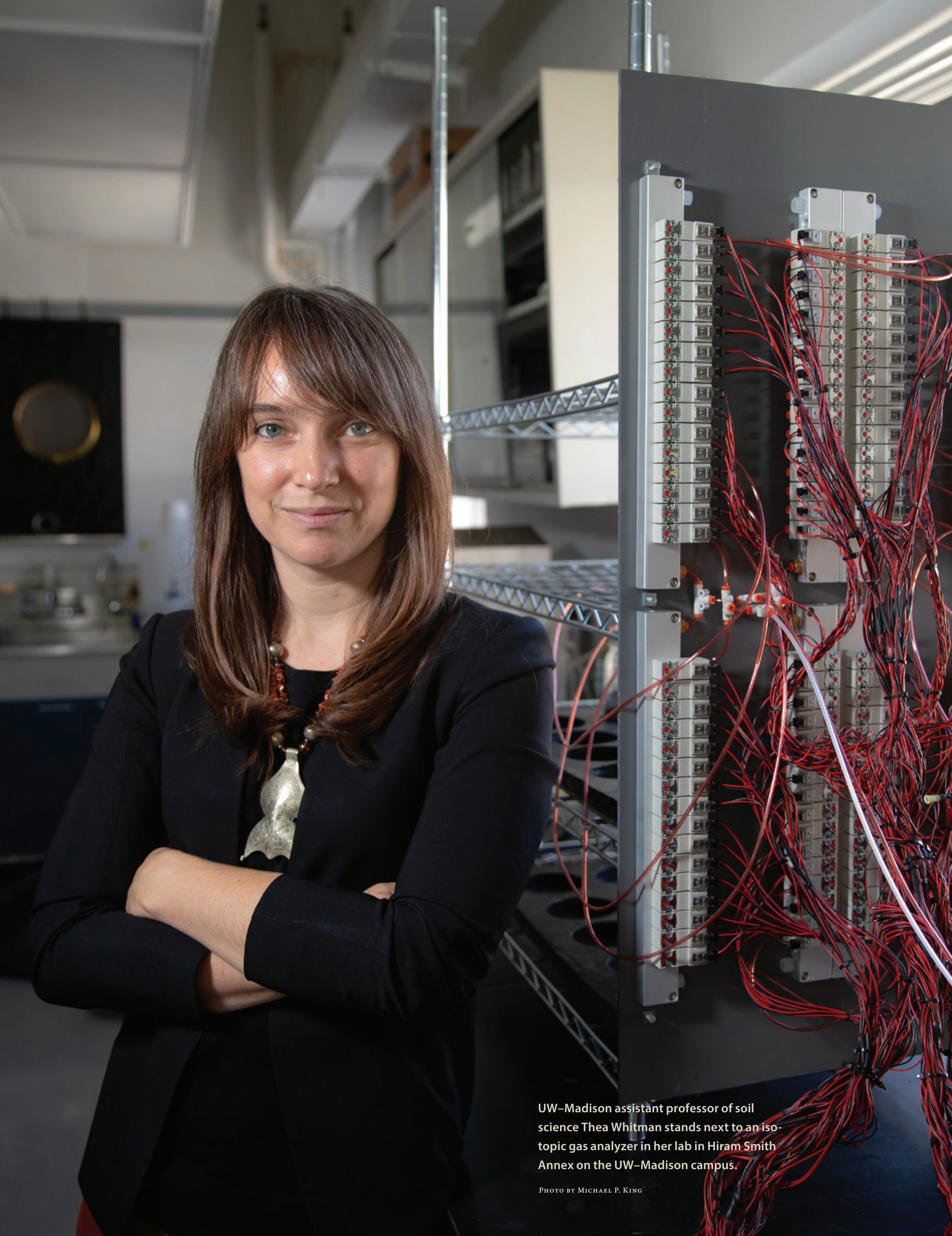
Burning wood is sometimes pleasantly chaotic and sometimes a terrifying force of nature, but for this fire, Whitman and first-year Ph.D. student **Nayela Zeba** seek absolute control. Biochar may have a big role to play in understanding — and even combatting — climate change. But not without control.

The furnace, dubbed the Charcoalator, was custom-built by Whitman's colleague and former labmate, **Akio Enders**, who drove through a February snowstorm to deliver it from Cornell University. Argon flows steadily through the chamber, the neutral gas crowding out any oxygen that would tip combustion out of control. A digital thermal controller raises the temperature by 5 degrees Celsius per minute until it reaches the desired temperature — usually between 300 and 600 degrees (572 and 1,112 degrees Fahrenheit) — then holds it for three hours. Water cooling halts the charring process and prevents spontaneous combustion when opening the chamber.

Every soil scientist knows the challenge of keeping things clean. In her primary lab, Whitman has a "very clean room" and a "pretty clean room." The Charcoalator, however, is inescapably dirty; by design, it's housed in a different building altogether. The grinding and sifting of char has only been happening for a few weeks, but already a fine black dust lingers. Zeba has resigned herself to an all-black wardrobe — only the face mask and lab coat are white — for the days she bakes the biochar.

While fire has a homogenizing impact on biological materials, not paying enough attention to the differences has led to some inconsistency in the way that we study and talk about biochar. The Charcoalator — and the techniques being refined by Zeba — are designed to bring some rigor to Whitman's work in the field. "If you look at these chars under a scanning electron microscope, it looks like plant cell structure; you can still see the microstructure inside of a plant," says Whitman. "Which means that different biomass will give it different properties. By being really consistent about the way we produce it, we can be more scientific."

Escalating fire seasons and a growing interest in producing energy from agricultural biomass have spurred soil scientists and climate change advocates to look more closely at the role of carbon in soil. It's the very basis of life on Earth. It's a



UW–Madison assistant professor of soil science Thea Whitman stands next to an isotopic gas analyzer in her lab in Hiram Smith Annex on the UW–Madison campus.

Photo by Michael P. King

critical component of some of the most important greenhouse gases. There is twice as much carbon stored in soil as there is in the atmosphere. And yet we're still not entirely clear on the myriad ways that carbon moves through and influences Earth's biogeochemistry. How is it that carbon in a corn stalk will be returned to the organic mix of the soil inside of a year while it can remain stable in biochar for centuries? Can we use this to benefit agriculture and to fight climate change?

These very big questions have some very small answers: microbes. "How is [the char] being perceived by the microbes?" asks Zeba. "How are they metabolizing it? What microbes are doing it? Because it's something very odd that you wouldn't expect, but microbes can do everything."

Photo by Michael P. King

Ph.D. student Nayela Zeba places a stirring paddle in the Charcoalator, which is loaded with eastern white pine biomass ready to be pyrolized.

JUST A HANDFUL

"There are more microbes in a handful of soil than there are people on Earth," says Whitman. "That's one of my favorite go-to facts."

She situates her lab's work at the nexus of soil biogeochemistry, microbial ecology, and global environmental change, but Whitman came late to both soils and microbiology. As an undergraduate at Queens University in Kingston, Ontario, she focused on biology and the environment. Not until her final year did she take a soils class.

Soils integrated her interests in climate change and carbon, so she looked into the field for grad school. Not long after that, she saw "that microbes were basically controlling everything that I was interested in, and I realized I should probably engage with them."

As both a teacher and an investigator, Whitman's exploration of microbes begins with picturing the soil environment. With billions of organisms per tablespoon, it's easy to imagine the soil as an unbroken panoply of life. Yet zoom in, and you'll find a crazy-quilt universe. There are massive sand grains and tiny grains of clay. Bacteria themselves vary in size by several orders of magnitude. Moisture clings to some particles, while other areas are parched. Bacteria and fungi may teem around a leaf particle while millimeters away there is so little food and moisture that the bacteria have formed dormant spores that may not awaken for decades.

"Think about how dynamic the water environment is in soil," Whitman says. Soil can be dry as any desert; then a simple, soaking rain flips the switch. "Bacteria in the soil are still effectively aquatic organisms, living in films of water. I think it's kind of an extreme environment. I'm not the first person to make that argument."

Their ability to adapt to a range of extreme environments gives bacteria a gee-whiz, trivia-question level of fame, and over the course of 3.7 billion years, they've leveraged that talent into an almost absurd level of diversity. No food? Scavenge energy from heat, light, or even sulfur. No oxygen? Go anaerobic. No water? Go dormant. Adapting to these extremes, over billions of years, bacteria have "discovered" some of the most important chemistry on the planet. Some of our most significant discoveries — from antibiotics to the nitrogen cycle that fuels agriculture — are microbial innovations.

As masters of adaptation, bacteria are the most abundant organisms in soil, with a rich and necessary complement of fungi, viruses, archaea, and single-cell protists. Worms, mites, springtails, and all manner of insects are the giants that round out the census.

By one estimate, soils contain a quarter of the world's biodiversity. Just picture it: 9 billion organisms, from perhaps 10,000 species, existing together in a single tablespoon. And yet, according to some theorists, it's possible that most of these bacteria are only really perceiving organisms that are 20 micrometers away. "Soils are among the most diverse environments with the most different types of organisms," says Whitman. "The question is: Why?"

One of her favorite exam questions asks students to write the autobiography of a microbe. The same essential question governs her lab's work. "How do we better understand soil microhabitats effectively?" she asks. "Coming back to that is really essential for us as scientists — understanding and asking good questions about that environment. If you don't reality-check yourself every so often, you can easily go off on paths that don't necessarily make sense."

FROM COMPOST TO BIOCHAR

Growing up in a scientific family in rural Nova Scotia, Whitman was the composter. "That was one of my chores at home," she says. When her municipality began providing compost pickup while she was in high school, it fit with her emerging ideas about the human quest for sustainability. And when her graduate education turned toward soils, her initial plan was to try to calculate the global carbon impact of composting versus not composting.

Instead, Whitman discovered the burgeoning field of biochar. Dark, carbon-rich soils in the Amazon had been observed and cataloged over the last 150 years, but it wasn't until the latter part of the 20th century that scientists began to understand that these uncharacteristically rich soils had been deliberately created by prehistoric peoples. Unlike the contemporary "slash-and-burn" agriculture often blamed for destroying rainforests, these people had used "char-and-burn" methods instead. By accident or by design, they lit controlled fires that produced relatively more char and less ash and then worked the charred organic matter back into the ground.

In 2008 Whitman joined the lab of Cornell University's **Johannes Lehmann**, who had helped uncover the origin of this "terra preta," or dark earth. His lab, broadly interested in nutrient cycling in soil, was exploring the potential of biochar for contemporary agriculture.

Soil is a carbon storehouse, but it's also a major carbon producer. Under the right conditions, soil microbes can take apart almost any organic thing inside of a year, releasing that carbon as carbon dioxide or methane.

That cycle changes when organic matter is burned under the conditions mimicked by the Charcoalator: oxygen deprived, between 300 and 600 degrees Celsius. Most organic molecules are vaporized away, leaving a lattice of almost pure carbon.

So take corn stover — the rough-hewn leavings of a harvested cornfield — and plow it back into the soil. Inside of a year, it will be almost completely decomposed, the carbon cycle complete. But char that carbon properly, and it lasts significantly longer. "It's not sequestered permanently," explains Whitman. "But you're talking decades, hundreds of years, thousands of years in residence times."

In other words, pre-Columbian subsistence farming offers our carbon-challenged economy the precious commodity of time, a buffer — compounded yearly — in which to store our dangerous carbon surplus.

In the best-case biofuel scenario, biochar production would be a triple play. First, it could produce energy from the initial process. Second, as a soil amendment, it would sequester soil carbon and improve soil quality. Last, by preventing anaerobic decomposition, it could prevent the even more threatening emissions of methane and nitrous oxide — greenhouse gases many times more powerful than carbon dioxide.

"Biochar sits at the nexus of all these really interesting areas — some of our most pressing global issues," says Whitman. Climate change, food security, biofuel and bioenergy systems, stabilizing carbon, deforestation, and even women's issues because, in many cultures, the women gather the fuel and tend the cooking fires. "It's really interesting, and it's also certainly complex," she says. "There are definitely systems in which biochar makes sense." The goal right now is to continue to identify and better understand those systems.

Is it going to make sense in the high-input industrial agriculture of North America? Not necessarily. Transporting biomass and then biochar all

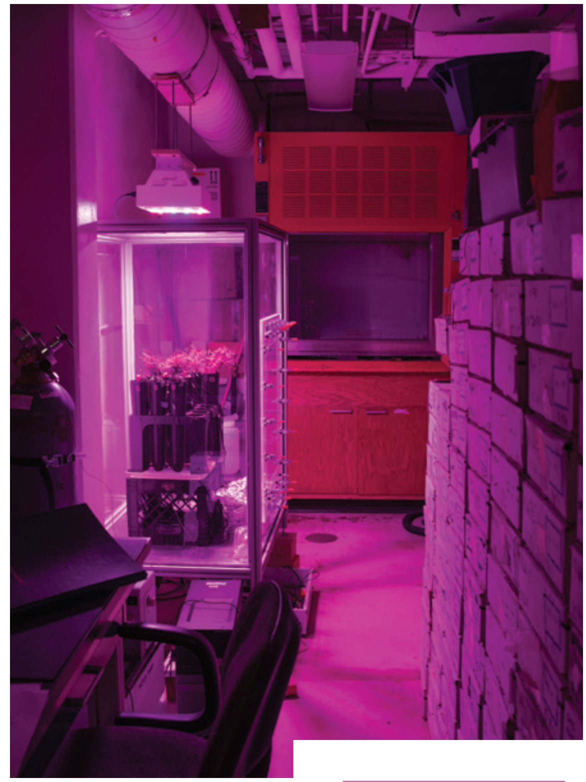


Photo by Michael P. King

This custom-built, automatically controlled growth chamber is being used to grow plants with a carbon-13 enriched atmosphere. The plants will be pyrolyzed in the Charcoalator and used in soil incubations, where the team will determine which microbes consume the charred organic matter.

Photo by Ellen Whitman

Thea Whitman collects soil samples at a severely burned site in Canada's Wood Buffalo National Park in June 2016. The samples were later analyzed to characterize the area's soil and microbial communities.

over the landscape would probably negate the carbon benefit. But if the baseline scenario is simply letting that biomass rot in an anaerobic heap, then maybe it would make sense.

While earning her master's degree, Whitman looked at low-tech cook stoves and did simple incubation studies measuring how quickly char decomposes compared to the original biomass. It's not 100 percent stable in the first year. And sometimes the char appears to prime the soil's metabolism, ramping up the carbon cycle. "If you're adding biochar to soil to sequester carbon and it's actually increasing decomposition rates of your existing soil carbon, that's a problem," she says.

She dug deeper, looking for nuances. Learning how and under what environmental conditions the char persists led to deeper questions. "Really understanding the mechanisms that are driving the carbon cycle is important for predicting in which systems you will see which effects and over what time scales."

Photo by Thea Whitman

A burn site in Canada's Wood Buffalo National Park where Thea and Ellen Whitman and their colleagues collected samples for analysis in June 2016.

Microbes were clearly a huge part of this, but Whitman ran into a problem: Because carbon is such a fundamental biological building block, it was hard to delineate the biochar carbon from that already in the soil.

As she was banging her head against a wall of chemical equations, she hit upon some sleight of hand, a way to use carbon-13 isotopes to tag the carbon. Building on a technique that could delineate two sources, Whitman devised a way to separate three carbon sources — soil, char, and plants. "I think this works," she recalls thinking as she hurried down the hall to whiteboard it for a colleague. "The idea is so simple, really, that it's really just like three equations."

Like its better-known radioactive cousin carbon-14, carbon-13 is a rare variant of the element that makes up less than 1 percent of natural carbon. The extra neutron allows it to be detected by sensitive equipment. By growing biomass in a carbon-13-enriched atmosphere, Whitman could char and then mix it with soil. A gas analyzer could then measure what portion of the respired carbon dioxide came from existing soil carbon and which came from char.

The more carbon-13 in the system, the more powerful the tool. For example, in higher proportions, the carbon-13 would get built into the bacterial DNA. If you extract the DNA using standard techniques and then put it into an ultracentrifuge — that's 200,000 times the force of gravity for four days — the extra neutron makes the DNA physically heavier, and it sinks to the bottom.

"What's cool is we can say conclusively this organism took up that carbon," Whitman says. "There's not really another way to say that."

The knowledge doesn't come cheaply. In June, the first jack pine seedling entered the lab's new carbon-13 greenhouse. Whitman's back-of-the-envelope calculation suggests that 100 liters of carbon-13, costing about $8,000, will produce only about 54 grams of jack pine destined for the Charcoalator.

SIBLING HARMONY

Thea is not the only Whitman daughter whose work is catching fire. Her younger sister, Ellen, is a Ph.D. candidate at the University of Alberta and a fire research assistant with the Canadian Forest Service. Interested in wildland fires and their interface with cities, Ellen began studying urban planning but eventually jumped into spatial analysis and the examination of things from an ecological angle.

"Being interested in science just had to do with growing up in our family," says Ellen. Science fairs were a big deal, and when things got slow, their mom pulled out a microscope and pond water. "Thea knew early on that she was interested in the biological side of things," adds Ellen. "She was mostly interested in climate change and carbon and the more global effects."

Ellen's and Thea's worlds converged with a series of lightning strikes in the far north during the summer of 2014. That year, the Northwest Territories, following an extended drought, experienced what official reports designated "a truly exceptional fire season." Nearly 400 fires burned a record 13,100 square miles. The fires dipped southward into Wood Buffalo National Park, which straddles the border between the Northwest Territories and Alberta.

Thea was generally aware of the big fire season, and then she learned that Ellen would be conducting extensive field research among the burns. "A lot of the questions that we're asking in a biochar context can also be asked in a fire-affected ecosystem context," she says. And the boreal forests of Canada are a massive account on Earth's carbon ledger. With Ellen focused on questions at the square-kilometer level, what if Thea paired that with findings from the microscopic end of the spectrum?

Ellen ran the first field season, with Thea joining in 2016. Hitching rides on inactive fire choppers, they were able to access areas deep in the park. It's not exceptionally hilly, though the karst landscape — barren, rocky, and porous — includes sinkholes. A UNESCO World Heritage site, it is home to a huge salt flat, the world's largest inland river delta, and wild buffalo everywhere.

Most important, the boreal forest contains lots of spruce, jack pine, and aspen. It's far enough north that the trees are not giants, but the region is rich in peat-forming wetlands. Overall the ecosystem stores immense amounts of carbon — an estimated two to three times as much carbon as stored by tropical forests.

As a fire-adapted ecosystem, fire is to be expected. But more intense fire seasons suggest both the possible impacts of climate change and a substantial enough release of carbon to fuel climate change.

It's hard to imagine that a changing fire regime won't shift ecosystem types. "An ecosystem that is adapted to a 100- or 150-year fire return interval is just not going to persist unchanged if that interval goes down to 20 years," says Thea. It's also important in terms of climate feedback cycles. "Understanding and predicting how fires will affect those carbon stocks is really important."

A recent meta-analysis published in *Nature* looks at how changes in fire frequency affect soil carbon stocks. The authors predict that, overall, more frequent fires will decrease soil carbon stores. But different ecosystems behave differently, and the paper suggests that a moderately increased fire frequency might actually increase carbon storage in boreal forests.

Forest fires, of course, result in an immediate and major loss of carbon. But what remains is transformed into biochar, a relatively more stable form. Could there actually be a sweet spot where an increase in boreal forest fires would help our carbon balance? Whitman is skeptical. "Much more research needs to be done to be able to predict this conclusively."

ANALYZER 'X'

For now, the challenge of climate change makes it easy to stay focused on the story of carbon. "There is no question that it is occurring; there is no question that the effects are going to be severe," she says. "It's a huge concern in my day-to-day life. It feels like one of the biggest, if not *the* biggest, challenge of our time."

At least the quantum leaps happening in microbiology are helping delineate carbon-cycle challenges. Whitman is pairing the explosion in genetic decoding and related statistical techniques with her own bespoke tools.

In addition to the Charcoalator and her carbon-13 growth chamber, in the corner of her lab's "very clean room" sits a curious pairing of a $50,000 isotopic gas analyzer and a collection of Mason jars. The jars and the analyzer are connected by a jumble of red tubing, valves, circuit boards, and the custom software of postdoc **Timothy Berry**. The still-unnamed system — Berry and Whitman agree that a generic acronym is unacceptable — will streamline the carbon-13 work. By incubating various soil types and microbial communities with the tagged carbon, they'll be able to gather far more detailed data on biochar interactions.

PHOTO BY MICHAEL P. KING

Glass jars of soil are connected to an isotopic gas analyzer in Thea Whitman's lab.

It's an exciting time to be a microbiologist, yet Whitman cautions that, amid the data deluge, we need to be modest about our limited ability as humans to pick out and think about stories. "In a paper, you interpret your data as a story," she says. But recall those billions of microbial citizens in her proverbial handful of soil. "There's also a million other narratives in there that we're not pulling out," she says. Even as we augment our analytical powers with artificial intelligence, there are still too many narratives. "I think we're still going to be limited by the human brain." g

in the field

BY STEPHANIE HOFF BSx'20

KEN MCINTYRE BS'92

Ken McIntyre's degree in forest science and interest in business dovetailed perfectly when, in 2006, he agreed to co-own and develop Chippewa River Forest Management (CRFM) in Cornell, Wisconsin. "My passion is production," McIntyre says. "I love the feeling of satisfaction when we're cranking out the number of loads of wood that I know we're capable of." When his business partner passed away in 2009, McIntyre faced some tough decisions on his own. Because the woodchips his company was producing no longer met the specifications of the mill he was using, McIntyre sold the logging equipment to focus solely on wood chipping. But rather than continuing to rely on other companies to supply the wood he needed, in 2011, he launched Lake States Timber LLC, a logging company that supplies half of the logs that CRFM needs. "I take pride in knowing that every load of wood sold is coming from a sustainably well-managed forest." The two companies have 20 employees and full-time contractors, including foresters, administrative assistants, equipment operators, and truck drivers. They produce around 3,000 semi loads of wood per year.

CHRISTY MCKENZIE BS'04

Christy McKenzie is a prime example of what the Wisconsin Idea is all about. In fact, the age-old UW philosophy of working for the benefit of all Wisconsin citizens inspired her to launch Pasture & Plenty. The meal pickup and delivery service — with a specialty market, deli, and demonstration kitchen — in Madison, Wisconsin, gives the community access to healthy, locally sourced meals suited for busy schedules. McKenzie brings more than 15 years of professional experience in food, advertising, and consumer research to this endeavor. She has had many roles related to food, from demonstration chef and recipe editor to marketing specialist with Allrecipes.com to launching Mad Local Food Group in southwestern Wisconsin. She is now director of account management for a major digital promotions company, but she has always focused on how people connect with food solutions. "CALS gave me a foundation in systems thinking, in communication and community engagement, which have been threads through my life and career," says McKenzie, who earned her degree in community and environmental sociology (formerly rural sociology). "My work at the university gave me a broad perspective," says McKenzie. "I studied food, community development, and culture and identity, never imagining I would work to develop an international online community with Allrecipes." With Pasture & Plenty, McKenzie brings what she has learned back to work in Wisconsin, creating new paths to market for local ranchers and food producers.

BRIAN WALSH BS'83

Brian Walsh's interest in molecular biology stems from his experience collecting critters in the woods and ponds as a child. Years later, he earned a degree in bacteriology from UW–Madison. His first job was working for a company that made starter cultures for the cheese industry, and it was, as Walsh describes it, "very Wisconsin." Today, Walsh owns Fotodyne Incorporated, a life science equipment manufacturing business. He is also the co-founder of Waukesha County Green Team, a nonprofit organization that promotes environmental sustainability. In April 2018, Walsh returned from 15 months of service as a Peace Corps volunteer at a research center in Guadalajara, Mexico, where he delivered seminars to researchers and students about technology commercialization, served as a mentor on a business startup team, and participated in the business development process. "Interestingly, many things I have learned in volunteer activities have circled back to provide fresh ideas, approaches, and direction to my professional work," Walsh says. "Now, I am using my entrepreneurial background in a nonprofit organization called WiSys Technology Foundation. We encourage faculty, staff, alumni, and students at UW's four-year comprehensive campuses and two-year colleges to innovate by offering technology transfer services such as patenting and licensing."

ENTERPRISING ALUMNI

Many CALS graduates go on to launch small businesses, patent new products, and found successful companies, among other entrepreneurial endeavors. This special "In the Field" series tells their stories. Look for more profiles of innovative alumni in the next issue.

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

Alumni making their mark as ENTREPRENEURS

LAUREN BS'12 and KYLE BS'11 RUDERSDORF

Lauren and Kyle Rudersdorf met at UW–Madison, where they each arrived with a love of the outdoors, a concern for the environment, and a desire to work outside. Neither Kyle nor Lauren considered a career in farming separately, but together, it felt possible. Their goal was to create a small, diverse farm that connected people to their food, so in 2013, they rented some family land in Brodhead, Wisconsin, where Raleigh's Hillside Farm was born. "CALS really laid the foundation for everything we're doing and building today," Lauren says. "It gave us the knowledge of alternative methods of agriculture and taught us about the food system and the ways it was broken or could be improved upon. If we hadn't attended CALS, we never would have known that people could make a living growing vegetables, or have an impact doing so." Their farm is marketed through a community-supported agriculture (CSA) model, meaning it is supported by local consumers who purchase prepaid shares of what the farm produces. "Our members are endlessly supportive," Lauren says. "Seeing how our food transforms their lives is incredibly rewarding." The Rudersdorfs work as a team while keeping their separate domains. "The food is absolutely my favorite part of the work," says Lauren, a community and environmental sociology major. "I love eating it, creating amazing recipes with it, and getting other people excited about the bounty that is here in Wisconsin." She also produces the farm's weekly newsletter and authors a recipe blog. Kyle, a soil science major, enjoys growing, problem solving, and building something of his own. "He is really the workforce putting long hours in at our fields and making sure everything stays irrigated, weeded, and healthy," Lauren says.

KAZUTOSHI UENO BS'86

Kazutoshi Ueno grew up in Japan, where his passion for livestock and agriculture began at an early age. His father made a living importing chickens from Iowa, and Ueno still remembers Americans visiting his father at the chicken house when he was a young child. Meeting Americans made him interested in studying abroad in the U.S., and eventually Ueno went to UW–Madison to major in agricultural and applied economics. "For Japanese people, 'Wisconsin' creates an image of a dairy state," Ueno says. "When I speak with dairy farmers and let them know I went to UW, they immediately think I am a specialist." Ueno is the founder of eAnimal Company, a Japan-based business specializing in feed products designed to increase the health and performance of cows, pigs, chickens, and even fish. Ueno consults with clients across Japan on farm management and efficiency and sells essential nutrients through colostrum-derived products. Ueno imports the colostrum from the U.S., where it is more affordable and available in abundance. The products themselves deliver immune protection to livestock; because calves and piglets are born without immune protections, the products provide long-term health benefits for the animals. "The animals have to perform for the farmers to stay in business," Ueno says. "Ensuring that they are healthy and perform well is my role in this industry."

DEIRDRE BIRMINGHAM PhD'96

Deirdre Birmingham's connection to agriculture started with a love for horses and a plan to pursue equine medicine. Along the way, she discovered she was more interested in her agriculture classes and pursued a bachelor's degree in agricultural science instead. After earning a master's degree in agronomy, her desire to address poverty and hunger in developing countries led her to Africa, where she worked to improve the agricultural livelihoods of people living there. Later, she earned her joint Ph.D. in natural resources management and adult education at UW–Madison. Even with multiple degrees in agriculture, Birmingham never thought about having a farm. Yet, in 2002, she and her husband bought 166 acres of land that are now collectively called The Cider Farm. At the time, they didn't have a clear vision for their business — only that it would be organic and would produce a value-added product versus a raw commodity. They decided to grow English and French apples that yield fine ciders. Because these varieties were not commercially available, they hand-grafted the trees that would become the orchard. Today, their apples are also used in the production of apple brandy. To learn more about Birmingham and The Cider Farm, see "Craft Cider's Comeback" on page 16.

Catch up with…

Andy Fisher Farm and Industry Short Course (FISC) '99

For **Andy Fisher**, farming isn't just a way to make a living. It's a way of life. "I feel it's one of the most honest and honorable ways to live on this earth," he says.

A fourth-generation farmer, Fisher grew up on a dairy in Valders, Wisconsin. In January 2004, he co-founded Riverside Dairy LLC in nearby Reedsville. There, along with his business partners and their eight employees, Fisher manages almost 800 cattle (with around 400 milking cows) and farms about 750 acres of herd-feeding crops.

Photo by Peggy Coffeen, Progressive Publishing

Andy Fisher stands by the 4,000-gallon bulk tank on his farm. Filling it to capacity on a daily basis is just one goal he has set and achieved.

Riverside uses research-proven methods to keep its cows comfortable and happy. As a result, the herd produces an impressive 10 million pounds of milk per year while maintaining high fertility rates and low white blood cell counts, a sign of healthy immune systems and good milk quality.

Fisher also makes caring for his community a high priority. He takes significant measures to reduce the environmental impact of his farm and volunteers for multiple organizations. His on- and off-farm achievements earned him the Wisconsin Outstanding Young Farmer award in 2018. Fisher says he tries to be a role model for his two sons, who help with the dairy, and would be proud to pass on his family tradition if they choose to carry farming into a fifth generation.

WHAT FACTORS DO YOU THINK CONTRIBUTE TO THE SUCCESS OF YOUR DAIRY FARM?

Retaining employees who are goal-driven and treat my farm like it is their own. Listening to their ideas and asking for their input. Giving them credit when credit is due. Educating both myself and my employees through reading and attending extension meetings. Maintaining solid relationships with my nutritionist, breeder, veterinarian, feed mill, and custom operators. These are all key to achieving success.

HOW DID YOUR TIME IN FISC PLAY A ROLE IN YOUR SUCCESS?

While attending FISC, I worked at the UW Dairy Cattle Center, mainly doing chores. But I also helped with some of the trials. I learned to appreciate research and analyzing data and saw that, although it can be tedious, it pays off in the end. We've done on-farm trials with synchronization programs, pre- and post-fresh cow care, cow comfort, herbicide programs, and inoculants to ascertain whether what we are doing is paying off. I need more than just the sales pitch as proof that the product I'm investing in is working.

HOW DO YOU INCORPORATE SUSTAINABILITY AND CONSERVATION ON YOUR FARM?

Recently, I participated in a program named SUSTAIN with Land O'Lakes, my milk cooperative. It assesses conservation and sustainability in dairy farming practices. A checklist asks a series of questions about milk production, manure management, energy and water usage, feed rations, and crop production. The information is reviewed again the following year to assess improvement. Land O'Lakes also uses the information to educate consumers about how the program's producers are working to reduce enteric greenhouse gas emissions by not using feed ingredients that have been identified as the greatest contributors.

I also work with a certified agronomist and follow a nutrient management plan for crop rotation and manure application spreading rates. On highly erodible soils, winter rye is planted as a cover crop, followed by no-till corn in spring. All of this helps keep the soil healthy and productive, and it reduces the runoff of fertilizer into nearby waterways.

—Nik Hawkins

FISC Photo

Farm and Industry Short Course students visit a greenhouse at Natural Beauty, a wholesale floral operation in Denmark, Wis., as part of the inaugural Agricultural Experience Tour in November 2017. An anonymous $50,000 gift will fund the tour for four more years.

Farm Tour Enriches FISC Experience

Since 1886, the Farm and Industry Short Course (FISC) has been drawing students to the UW–Madison campus for certificate-level education as they pursue careers in the agricultural industry. Now, thanks to donor support, they can go off campus for an experience as diverse as their career prospects.

From a goat's milk creamery to a wholesale flower grower, the stops along the inaugural Agricultural Experience Tour in November 2017 went far beyond the typical Wisconsin farm. The two-day bus trip rolled through the northeast quadrant of the state, allowing students to connect with each other, instructors, and FISC alumni now involved in successful businesses.

"We wanted to provide them with a shared experience to show the diversity of agriculture that exists within our state's borders," says **Cindy Fendrick**, FISC's assistant director. "We hoped they would begin to see how their short course education will serve them in their agricultural career paths."

William Zeimet FISC'18 of Cottage Grove, Wisconsin, who was a first-year student during the tour, had never seen a rotary milking parlor until the tour stopped at Pagel's Ponderosa, a 5,000-plus cow dairy operation in Kewaunee. Interested in becoming a dairy farmer, he found inspiration at Kampy Holsteins in the village of Brandon, meeting alumni **Darren** FISC'15 **and Derek** FISC'15 **Kamphuis**, who used their education to expand their family's farm.

"The cool thing was that the business plan they used to do the farm expansion, they put it together while in school here," says Zeimet. "It's a class that I could take next year. They were able to take what they learned home to the farm and apply it."

LaClare Family Creamery in Malone was memorable for **Joe Powalisz** FISC'18 of Manitowoc, Wisconsin. Students learned about the increasing demand for goat's milk cheeses and yogurts from the award-winning creamery and niche events, such as goat yoga. Powalisz was also impressed by the agritourism offerings for school groups and the public at Meuer Farm in Chilton.

"I think there's actually a market out there for ag education — not just in a classroom but on-site," says Powalisz. "It's important that people know where their food comes from."

Students also visited Natural Beauty, a wholesale floral operation in the village of Denmark that produces millions of plants annually; Knigge Farms, a dairy with a robotic milking system in Omro; and Pollack-Vu Dairy in Ripon.

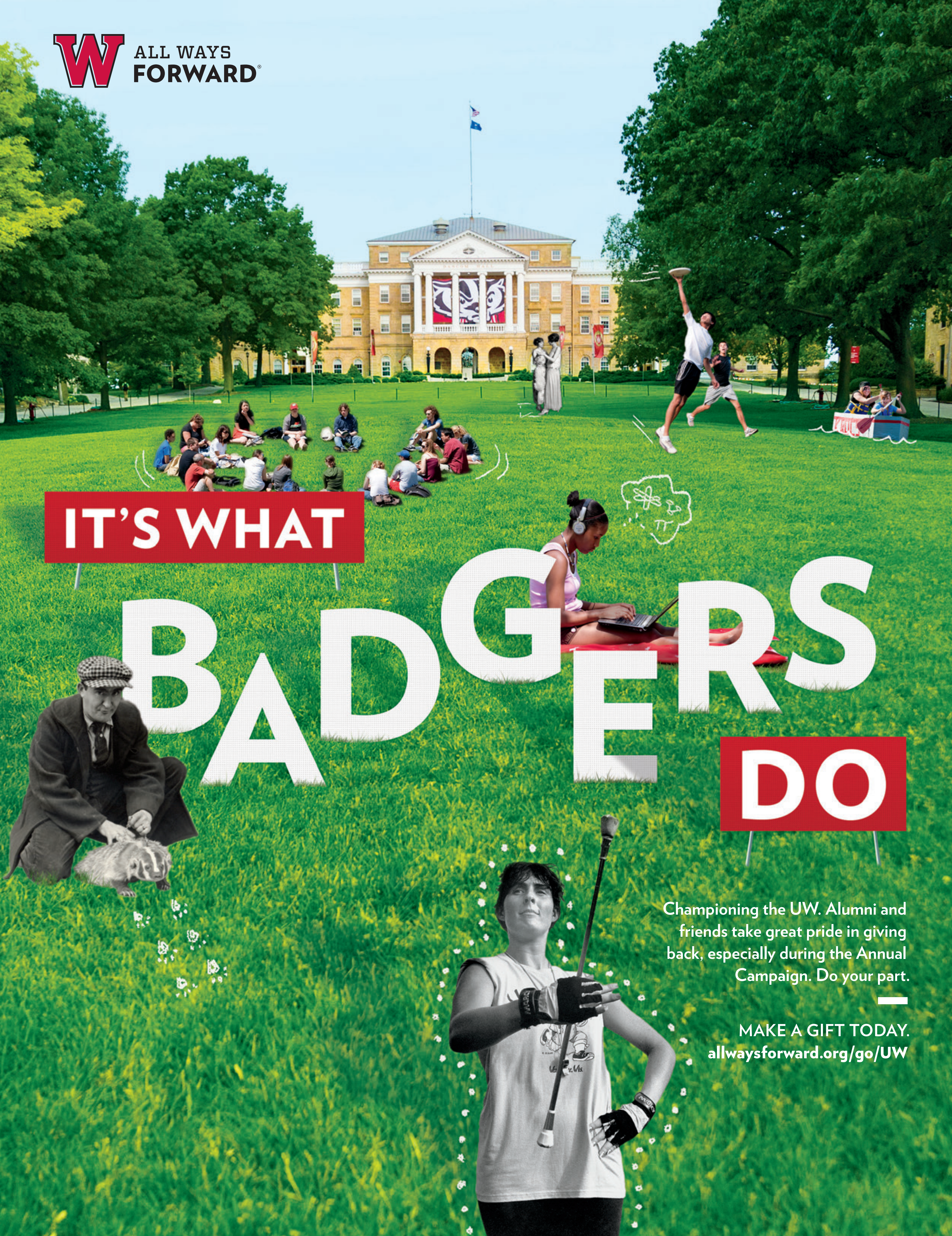
The tour was made possible by an anonymous $50,000 donation intended to provide diverse, out-of-classroom experiences for five years at no additional cost to the students. The 2018 tour, which will be in the north-central and Central Sands regions, is scheduled for November 3–4.

"I would just say thank you [to the donor] from the bottom of my heart, because it was an amazing trip, and I wouldn't have gotten an opportunity like that if it hadn't been for them," says **Cricket Cushman** FISC'18 of Mount Horeb, Wisconsin. "Just being able to see what else there is out there beyond my 'back 40,' I find that so amazing."

—Michael P. King

WOULD YOU LIKE TO HELP PROVIDE FUTURE FARM TOURS FOR SHORT COURSE STUDENTS?

Visit **supportuw.org/giveto/ExperienceTour** to make a gift to the Short Course Agricultural Experience Tour Fund. Thank you for your support!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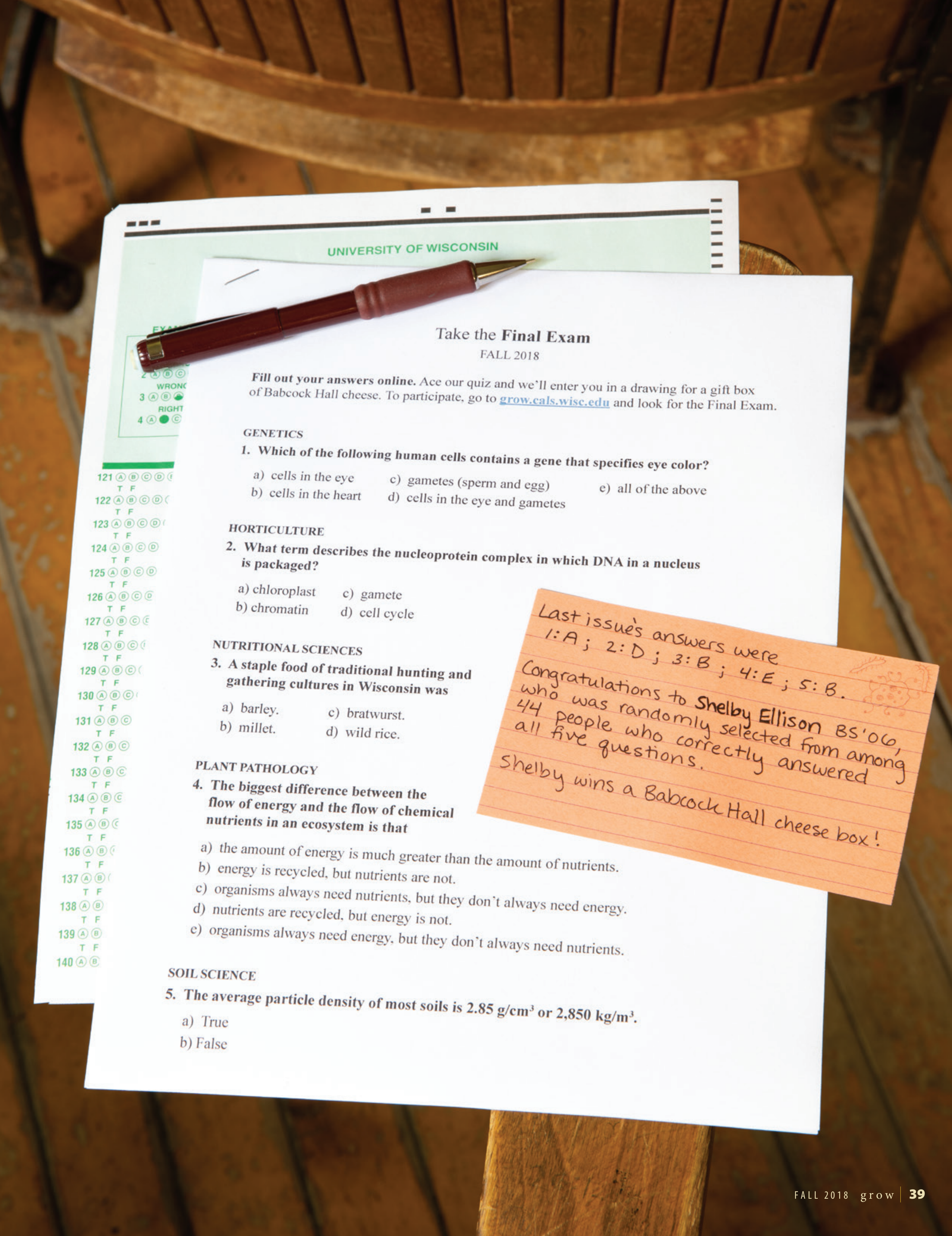

UNIVERSITY OF WISCONSIN

Take the **Final Exam**

FALL 2018

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

GENETICS

1. Which of the following human cells contains a gene that specifies eye color?

a) cells in the eye
b) cells in the heart
c) gametes (sperm and egg)
d) cells in the eye and gametes
e) all of the above

HORTICULTURE

2. What term describes the nucleoprotein complex in which DNA in a nucleus is packaged?

a) chloroplast
b) chromatin
c) gamete
d) cell cycle

NUTRITIONAL SCIENCES

3. A staple food of traditional hunting and gathering cultures in Wisconsin was

a) barley.
b) millet.
c) bratwurst.
d) wild rice.

PLANT PATHOLOGY

4. The biggest difference between the flow of energy and the flow of chemical nutrients in an ecosystem is that

a) the amount of energy is much greater than the amount of nutrients.
b) energy is recycled, but nutrients are not.
c) organisms always need nutrients, but they don't always need energy.
d) nutrients are recycled, but energy is not.
e) organisms always need energy, but they don't always need nutrients.

SOIL SCIENCE

5. The average particle density of most soils is 2.85 g/cm³ or 2,850 kg/m³.

a) True
b) False

Last issue's answers were
1: A ; 2: D ; 3: B ; 4: E ; 5: B.
Congratulations to **Shelby Ellison** BS'06, who was randomly selected from among 44 people who correctly answered all five questions.
Shelby wins a Babcock Hall cheese box!

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BLOOMING BUCKY

This striking statue, inspired by native prairies and wildflowers, "bloomed" on Henry Mall recently as part of a free public art event featuring 85 life-size Bucky Badgers. It was designed by artists Paula Hare and Diane Heatley.

Photo by Michael P. King