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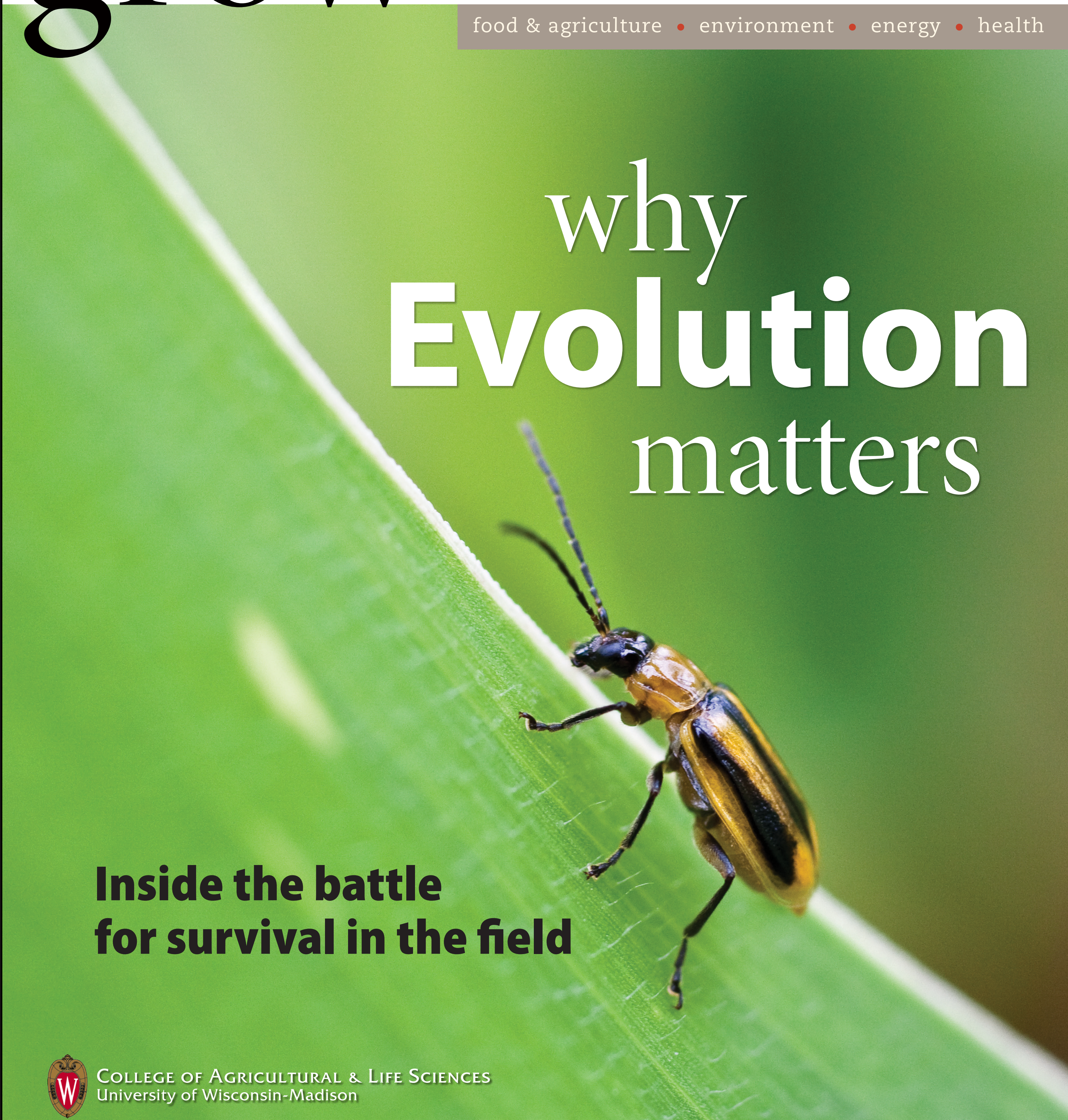
Wisconsin's Magazine for the Life Sciences • Fall 2009

food & agriculture • environment • energy • health



why Evolution matters

Inside the battle for survival in the field

College of Agricultural & Life Sciences
University of Wisconsin-Madison

UNCORKING WISCONSIN'S WINE INDUSTRY • ANTS: THE ORIGINAL FARMERS • ENERGY PIONEERS

Volume 3, Issue 1 • Fall 2009

SHELL GAME: A group of Wisconsin middle-school students brave a rain shower to examine a turtle during a wildlife summer camp at CALS' Kemp Natural Resources Station in northern Wisconsin. Read more about the station on page 9.

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Wisconsin's Magazine for the Life Sciences

EVOLUTION *at CALS*

Departments

ON THE COVER: A western corn rootworm beetle rests on a corn leaf in a Wisconsin field.
Photo by Wolfgang Hoffmann

Dean Molly Jahn

A Chance Worth Taking

A person is only supposed to get one once-in-a-lifetime opportunity. In my professional life, I've been fortunate enough to have at least three.

The first came when I received a federal grant to pursue my graduate studies at the Massachusetts Institute of Technology and later at Cornell University. Everything that followed in my career has flowed from that support.

The second came when I was asked to serve as CALS dean. I recognized this as a chance to become part of an institution that makes a profound and daily impact on lives in Wisconsin and throughout the world. Having witnessed the accomplishments of this community firsthand, I can tell you that CALS earns its sterling national reputation every day with the intelligence and innovative spirit of its faculty, staff, students and alumni.

It's because of that national respect for CALS that I have been given another of those once-in-a-lifetime opportunities. I have accepted an

Our college's tradition of contributing to national leadership in agriculture is a long and proud one, and I am humbled to inherit that legacy.

appointment as deputy undersecretary for research, education and economics for the U.S. Department of Agriculture, a role that will allow me to participate in the conversation about our national priorities related to food, agriculture, health and natural resources.

Our college's tradition of contributing to national leadership in agriculture is a long and proud one, and I am humbled to inherit that legacy. I will be joining a team charged with bringing transformative change to an agency that funds more than $2 billion of research activities annually and is interconnected deeply with land-grant institutions such as UW-Madison. I believe I can help spark that change by bringing forward ideas that have found success in CALS and Wisconsin.

Chancellor Martin has granted me a one-year leave from my duties as dean to take on this new assignment. But I head to Washington knowing that CALS is in good hands. I am delighted to announce that the chancellor has appointed Irwin Goldman, our wonderful vice-dean, as interim dean. Irwin will guide the college with wisdom, compassion and humor, and I am certain that CALS will move ahead at full speed under his leadership.

Thank you for your support for the college and for me as I take on this new adventure. It is the wisdom and spirit of this community that has opened this door, and I hope that we can all walk through it together.

grow

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College of Agricultural & Life Sciences
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Brushing up on History

New Ag Hall artworks have deep roots.

At the tail end of the Great Depression, CALS Dean Chris Christensen reached out to well-known regional artist John Steuart Curry with an extraordinary offer. As the university's first artist-in-residence, Curry would be given a $4,000 annual salary, a studio and a mission: to awaken the artistic spirits of Wisconsin's rural citizens.

To position an artist on the ag college's faculty was bold and innovative. Christensen himself described it as "one of the most interesting experiments … that has been by any institution of higher learning in the country." And while the artist-in-residence program is now administered elsewhere on campus, current dean Molly Jahn says Christensen's idea is still very much alive.

"The concept is that science is deeply connected with the visual arts," says Jahn. "We've been making strategic moves to try to recapture that idea and show the integration of the arts and sciences."

As one recent example, Jahn used an Ag Hall remodeling project to revive a connection to one of Curry's outreach efforts as artist-in-residence. When the building's lobby was renovated this summer, she had the formal portraits that hung in the rotunda replaced by paintings from the Wisconsin Regional Art Program, which Curry created in 1940 to encourage the creative impulses of farmers and rural citizens, Now administered by the UW Division of Continuing Studies, WRAP sponsors workshops and exhibits for non-professional artists throughout the state, including an annual exhibit of Wisconsin's most notable rural art at the UW's Memorial Union.

Five paintings from WRAP's statewide exhibit were hoisted into the freshly painted and lighted lobby in October. The selected pieces—painted by artists Jenna Eichberger of Black River Falls, William Balthazor of Oconomowoc, Jake Stephens of Prairie du Chien, Jack Dennis of Cross Plains and Sandra Cashman of Slinger—offer a flavor of Wisconsin's natural environment, including landscapes of farms, a snow-covered field and even the state's most famous golf course.

In the lobby of Ag Hall, a student catches up on homework underneath a painting of a barn, one of five works from the Wisconsin Regional Art Program that hang in the lobby.

The paintings will hang in Ag Hall for a year, and new artistic works from WRAP artists will be selected each fall.

"It's really a wonderfully appropriate addition to our flagship building," says Jahn. "The paintings remind us that the science we do is constantly reflected in and even influenced by visual images."

—Michael Penn

A Whole New Can of Beans

CALS helps state growers scale up for organic processing.

Graduate student Nicholas Goeser tests nitrogen levels in a field of organic snap beans at Arlington Research Station.

Nick George senses opportunity. With sales of organic foods outpacing the market for conventional vegetables, the executive secretary of the Midwest Food Processors Association sees a niche for Wisconsin's processing industry: canning and freezing organic veggies.

"When you see something get wheels, you want to be part of that," George says.

The vision makes sense. Wisconsin ranks among the nation's leaders for processed snap beans, sweet corn, peas, cucumbers and carrots, and it has more certified organic growers than any state except California. But one thing Wisconsin doesn't yet have is a vast quantity of organic vegetables to keep the packing lines running. While the state grows more than 200,000 acres of processing vegetables, organic production was just 348 acres by a 2005 estimate.

"We have to be able to figure out organic production on a large scale," says Mike Bandli, an economic development consultant with the Wisconsin Department of Agriculture, Trade and Consumer Protection. "If we don't, the likelihood is that organic commercial-scale vegetable production will move out of the state and out of the region."

To help avoid that fate, a team of CALS researchers have been studying the challenges of large-scale organic production. Spearheaded by horticulture professors Jed Colquhoun PhD'00 and A.J. Bussan PhD'97 and graduate student Heidi Johnson, the group includes experts in soil science, entomology, plant pathology, agricultural engineering and economics, as well as state and industry officials.

The researchers say they can't count on simply scaling up techniques used on smaller-acreage fresh-market operations. "For example, we didn't think hand weeding was feasible when you're talking about several thousand acres of vegetables," Bussan says. Organic fertilizers present another challenge, both because of their cost and high phosphorus content.

Instead, the researchers are taking an integrated systems approach, looking at complementary practices to accomplish multiple goals. One aspect they are studying is the use of legume cover crops to add nutrients and control pests. For example, one strategy is to plant sweet corn into alfalfa, which continues to grow between the rows of corn, suppressing weeds and providing nitrogen.

Colquhoun notes that Wisconsin does have some advantages that favor large-scale organic production. The state's bitterly cold winters help suppress pests that are problems in more temperate regions, and its livestock industry provides an ample supply of organic fertilizer.

"Even though our organic vegetable production has been small scale, we learn from the experience of those growers," Colquhoun says. "(We can) take the knowledge learned in smaller-scale production and look at the feasibility of scaling it up."

—Bob Mitchell BS'76

The New Pollinators

THERE ARE STILL NO GOOD ANSWERS about the mysterious disease killing millions of European honeybees—the chief pollinator of some $15 billion in agricultural crops. But at least there may be an alternative. A new CALS research project suggests that native bees may be able to assume much of, if not all, of the imported European bee's workload. "What people don't really think about (is that) there are 4,000 species of native bees in North America," says entomology graduate student Hannah Gaines who collected more than 100 native bee species from 15 Wisconsin cranberry bogs during the past two summers. With associate entomology professor Claudio Gratton, she is now working to evaluate what kinds of surrounding landscapes best support native bees, which could help farmers create native bee habitat and reduce their dependence on rented honeybee hives.

Drop in the Bucket

Rain keeps the grass green—even when it's dry.

At CALS' O.J. Noer turfgrass research facility, Doug Soldat is saving up for a not-so-rainy day.

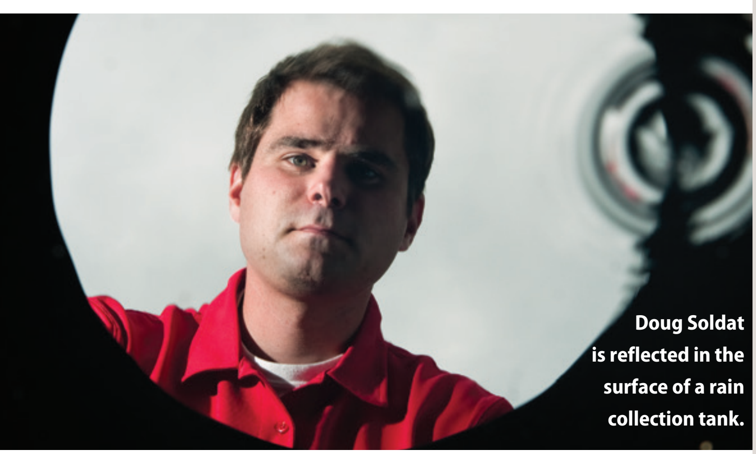
With the help of graduate student Brad DeBels BS'07, Soldat, a professor of soil science, built two huge tanks to collect stormwater from the facility's 7,000-square-foot roof and divert it into the soil—a concept similar to the rain barrels that many homeowners use, but on a massive scale. While consumer-grade rain barrels typically hold 50 gallons and can overflow quickly in heavy storms, Soldat's tanks each capture 4,000 gallons of water, which trickles back into the soil through underground lines.

"In a three-month period we collected 19,000 gallons off the roof at the Noer center and sent it all to the turf—3,150 square feet of lawn," Soldat says. "We were able to use and infiltrate all of the rain that that fell on the center's rooftop."

Systems like this could make a dent in the amount of water pumped from wells and surface waters. The U.S. Environmental Protection Agency estimates that about a third of the water piped to a typical household is used outdoors, and half of that goes to water lawns and gardens.

But Soldat sees it as more than a way to water the lawn without turning on the tap. It's also a tool for infiltrating more stormwater, preventing runoff that floods and contaminates surface waters, and recharging rapidly depleting groundwater. "In one of our (plots), we put on three-and-a-half inches of water in four hours without any ponding because all of the water leached through the soil," says DeBels. "If you did that with overhead irrigation, you would be putting it on faster than soil could infiltrate. Your lawn would be a muddy mess."

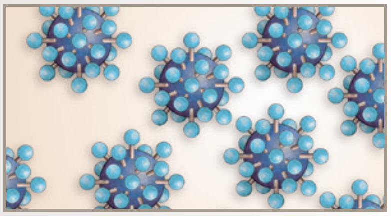
—Bob Mitchell BS'76



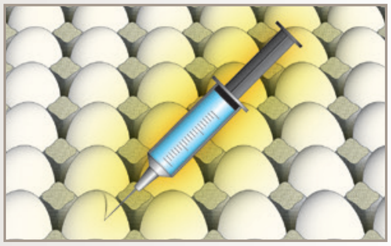
Doug Soldat is reflected in the surface of a rain collection tank.

how to make a flu vaccine

From your body's perspective, a flu shot looks a lot like an oncoming case of the flu. Made from weakened flu viruses, flu vaccines trigger our bodies to pump antibodies and immune cells into the bloodstream. This enables our bodies to mount a fast defense against real flu viruses. Producing the vaccines, however, is hardly so efficient. Current methods require five to six months of labor, a fair share of educated guesswork—and a good supply of eggs.



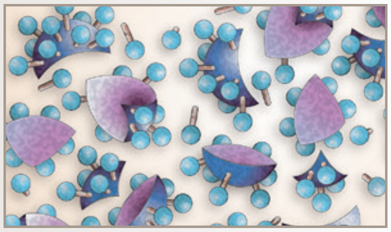
Pick a virus. Because vaccine production takes so long, public-health officials must predict problem flu strains nearly a year in advance. The U.S. Centers for Disease Control and Prevention then develops stocks of each virus and distributes them to vaccine makers. That's why there are two flu shots this year: production of the vaccine against H1N1 virus did not begin until the virus emerged as a pandemic in late spring.



Egg, meet virus. Tiny needles inject live viruses into fertilized chicken eggs. It takes about one egg to make one dose of vaccine, which means somewhere around 100 million eggs are needed to create seasonal flu vaccines. And that's one of the major limitations of the current process. If a strain of avian flu started infecting humans, for example, there might not be enough healthy chickens and healthy eggs to produce vaccines. Scientists are exploring new approaches that would replace this step with something faster and more reliable, such as engineered cells that could churn out virus-like proteins.

Keep the eggs warm. The eggs are incubated in ideal virus-growing conditions for a number of days, allowing each virus injected into an egg to reproduce hundreds of times over.

Crack 'em open. Big machines slice off the tops of the eggs and invert them to collect the fluid inside, which at this point is teeming with live viruses.



Kill the virus. Chemicals are used to deactivate the viruses and chop them into pieces. In the case of the seasonal flu vaccine, particles from three flu strains get mixed together at this point to create a vaccine that can guard against multiple varieties of flu.

Illustrations by H. Adam Steinberg

A Culprit in the Blood

Iron deficiency may be key to combating fetal alcohol syndrome.

In her lab, Susan Smith (top) and researchers Ana Garic-Stankovic and Marcos Hernandez inject chicken embryos with alcohol to model the effects of fetal alcohol spectrum disorder.

After decades of exploring the damage that alcohol causes to human fetuses, Susan M. Smith PhD'87, a professor of nutritional science, is finally growing hopeful that the biggest cause of preventable brain damage among American newborns may be tamed.

Fetal alcohol spectrum disorder (FASD), the current name for alcohol's ravages on the developing brain, impairs both behavior and intelligence in children. While the severity of FASD typically increases with heavier drinking during pregnancy, even a few drinks can create damage in a developing baby.

Smith's optimism does not reflect any reduction in the rate of FASD, which affects 2 to 5 percent of American newborns. Rather it emerges from the growing understanding of exactly how a mother's drinking causes the cells in her child's brain to commit suicide during a period when they should be growing and networking.

In the latest of many landmark studies to emerge from Smith's lab, graduate student Echoleah Rufer has found that in rats, the combination of alcohol and a low level of iron multiplies the damage expected from either factor alone. Although the iron level in the study was not low enough to constitute anemia, it is found in 22 percent of American women of child-bearing age.

Smith says she began to wonder if iron was implicated in fetal alcohol problems several years ago. "We noticed that FASD often grows more severe with successive pregnancies, and we realized it sounded as if the women were being depleted of a protective factor." Iron was a key suspect, because women lose so much iron during menstruation and pregnancy. Iron deficiencies also cause learning and behavioral problems in children.

In 2007, Smith won a Merit Award from the National Institutes of Health, which gave her 10 years of research support and a perfect opportunity to explore the link further. The recent research found that either alcohol exposure or iron deficiency alone could impede learning, but the combination caused a significant increase in brain cell death, which resulted in a five-fold decrease in the learning ability of the newborn rats. The destructive synergy could reflect the need for iron in chemicals that carry signals among nerve cells or in the reactions that cells use to process energy.

If the findings are supported by further research, Smith says screening for subtle iron deficiencies could become a standard part of prenatal care. "If an adequate level of iron is essential to brain development in all developing children, then we should identify a strategy to ensure that all pregnant women have this level of iron." She adds that a nutritional approach would likely be more effective at mitigating FASD than the current alternative, which is urging women not to drink while pregnant. Reports in the press sometimes give the impression that moderate drinking during pregnancy can be safe, which makes abstinence an uphill battle, Smith says.

"We cannot say there is a safe limit, and we do not know who is more or less susceptible," she says. "A woman is playing Russian roulette if she drinks during pregnancy."

—David Tenenbaum

Nobel Example

UW-Madison's Khorana Scholars got a chance this summer to present their work to a pretty significant visitor. Former CALS professor Har Gobind Khorana, who won a Nobel Prize in 1968 for research that helped crack the genetic code, met with students in the program that bears his name while in town for the biochemistry department's annual Steenbock Symposium. The Khorana program pairs students from Indian universities with UW-Madison faculty to work on summer research projects, part of an effort to foster greater collaboration between UW-Madison and Khorana's home country. "Khorana is an icon to Indian scientists," says biochemist Aseem Ansari, one of the program's co-founders. "For (the Khorana Scholars), it was an incredible experience to meet him."

Blight Future

Gene sequence may offer new hints for combating plant pathogen.

As farmers and gardeners battled with an outbreak of late blight this summer, scientists were taking on the disease on another front: its genetics. An international team of researchers announced completion of the genome of *Phytophthora infestans*, the organism that causes the disease, potentially pointing to more effective ways to deal with the pathogen.

Best known as the cause of the 19th century crop failure that sparked the Irish Potato Famine, late blight remains a serious threat to potato and tomato crops. This summer's outbreak—the first in Wisconsin since 2002—was contained quickly, but only after farmers spent time and money on treatments to ward off the disease.

The sequencing project found that the mold responsible for late blight contains almost four times as many genes as close relatives, which may be key to its lethal capacity. "This pathogen has an exquisite ability to adapt and change, and that's what makes it so dangerous," says Chad Nusbaum, an MIT scientist who led the study. Much of the extra material comprises repeated strings of DNA, allowing the pathogen to pick up and lose traits quickly, he says.

Helping unravel all of that DNA was David Schwartz, a UW-Madison professor of chemistry and genetics and the inventor of optical mapping sequencing technology. Optical mapping complements traditional, letter-by-letter sequencing by providing a broader view of how segments of DNA fit together in a full genome.

"We now have a comprehensive view of (the pathogen's) genome, revealing the unusual properties that drive its remarkable adaptability," says Nusbaum. "Hopefully, this knowledge can foster novel approaches to diagnose and respond to outbreaks."

—David Tenenbaum

Number Crunching

50 PERCENT OF CALS SENIORS COMPLETED a research project with a faculty member outside of course or program requirements before graduation, according to the 2008 National Survey of Student Engagement. That figure was highest among the eight UW-Madison colleges that educate undergraduates and exceeds the campus average by 18 percentage points.

tom steele MS'83 PhD'95

• **job** Superintendent, Kemp Natural Resources Station • **lab** 235 acres of old-growth forest, wetlands and pristine shoreline in the heart of Wisconsin's Northwoods • **what I do** Oversee research, instruction and outreach at CALS' only dedicated natural-resources research station

What's the most unique feature of your lab? The Kemp station was originally the summer estate of the Kemp family, which was donated to the university in the 1960s. We support some of the last remnants of old growth hemlock-hardwood forest in the Lake States.

How many people work in your lab? This year, the station will support more than 50 research projects, more than 15 field classes and a dozen outreach programs. All totaled, we will probably see more than 6,000 user days of research and instruction.

Is work 9-to-5 or 24/7? Definitely 24/7. This past summer, we hosted a team studying the spawning behavior of muskies. Muskies spawn at night, so they were working from dusk to dawn. At the same time, we had other researchers studying the impacts of forest management on bird populations, and they were up before the birds.

What's the view from your office window? Towering oaks, maples, hemlock and pines. Many times I have looked out the window to see white-tailed deer, red fox, black bear or wild turkey ambling by.

If you had to evacuate, what would you grab first? My dog Gus. She is a seven-year-old black lab that comes to work with me each day.

Eat out or brown bag? Neither, I live on the station and walk home for lunch each day.

Where do you get your best work done? In my office. The Kemp family donated many of the furnishings in the buildings, and so my office is furnished with some grand antiques.

What keeps you in Wisconsin? Ask anybody and they will tell you I have the best job in the entire university.

Doug Maxwell

A Lebanese plant researcher examines tomatoes during a research trip to Morocco, where an international group of scientists are working to breed disease-resistant plants.

LEBANON

Tomato Diplomacy in the Middle East

Doug Maxwell will never forget his 63rd birthday. He was in Cyprus, attending a meeting of Middle Eastern plant breeders who had come together to discuss a pernicious virus that was busily decimating the region's tomato crop. At the end of an exhausting, day-long strategy session, he joined plant experts from Israel, Lebanon, Egypt, Jordan, Morocco, Tunisia and the Palestinian National Authority in a small celebration.

"At the party, members of the Lebanese and Israeli groups were all dancing together," says Maxwell, an emeritus professor of plant pathology, of the 2004 meeting. "It set the stage for a really productive and exciting six years with this group."

The researchers' alliance has crossed more than just cultural and political borders. Since the start of the project, funded by the U.S. Agency for International Development, the group has collaborated to develop new tomato varieties that resist the virus, known as Tomato yellow leaf curl virus, and customize them for each nation's tastes. "The key was that each of these countries needed to develop germplasm specific for their local markets," says Maxwell, who retired from CALS in 2001 to devote himself full-time to international projects. In Lebanon, for instance, people like to scoop out the insides of large tomatoes and fill them with salad, putting hefty tomatoes in high demand. Consumers in Jordan, on the other hand, prefer round tomatoes that weigh only a few ounces.

The scientists succeeded in creating pre-commercial hybrids for four of the countries before the grant's completion earlier this year, and now it is up to local companies or national agricultural institutions to produce the seeds and market them to growers. The Middle Eastern scientists have secured additional funding to continue working together on similar tomato projects.

But tomatoes aren't the only thing that has grown from the partnership. Maxwell says the effort opened doors for collaboration between countries that often are embroiled in fierce political disagreements. The team occasionally shuffled the location of meetings to avoid regional military conflicts, and in one case, fighting broke out between Lebanon and Israel right before the group was scheduled to convene. "I was wondering to myself, 'What's going to happen when these two groups get together?'" says Maxwell. "They gave each other big hugs. It was very touching to me."

"That's an equally important achievement as the scientific part," he says. "(The project) was the mechanism that brought them together."

COLOMBIA

In Bogotá, Politics is Anything but Usual

While conducting research in his native Colombia this summer, Hernando Rojas PhD'05 found himself in a new, exhilarating position: talking into a camera on the set of a national television news program.

"I was basically trying to forecast the role that new communication technologies will have in the forthcoming presidential election in Colombia," says Rojas, an assistant professor of life sciences communications.

Rojas is uniquely qualified to provide that kind of analysis. For the past five years, he has been monitoring levels of media consumption and community involvement in Colombia through a series of biennial surveys. The newest data he's collected, which show significant hikes in Internet usage and civic engagement since 2006, will be published this fall. But his expertise also has him in demand with both political operatives and the media in his home country.

Leading up to the Colombian elections next spring, Rojas will work with El Tiempo, one of Colombia's largest media conglomerates, crunching the company's monthly poll numbers and sharing his analysis through television, radio and newspaper outlets. "We're going to try to explain why the population thinks the way it does," he says. "Typically, this kind of analysis would end up in an academic journal somewhere. We're going to try to bring it to mainstream media in language that people can understand."

Rojas's media role will give him access to mounds of data to support his academic research, which seeks to understand how Internet use leads to real-world civic engagement. He first considered a direct model, whereby people who express themselves online—through e-mails and posting comments on blogs and news web sites—go on to join political or civic organizations. Rojas discovered, however, that there is an intermediary step, where these individuals try to convince their friends, family and colleagues to get involved in various causes online. Only then do they join more-traditional organizations.

The spring elections may offer the first test of just how powerful that mobilization can be. "As happened in the Obama campaign in the United States, this is probably going to be the first election (in Colombia) where the Internet will be decisive," Rojas says. "Grassroots web sites and online social networking are going to affect the course and outcome of this campaign."

From his office in Hiram Smith Hall, Hernando Rojas monitors candidate web sites to check the pulse of the upcoming Colombian elections.

BANGLADESH

Breeding Bulls Can't Take the Heat

For three months each year during Bangladesh's hot season, the nation's artificial insemination industry ships out a bunch of blanks. That's because the sperm collected from bulls is often so heat-damaged that it doesn't support life well.

"The temperature in the testes only rises about two degrees Celsius. It doesn't take much at all," explains John Parrish, a professor of animal science who studies male fertility problems in dairy and beef cattle.

With funding from CALS' Babcock Institute, Parrish established a collaboration with National Bull Stud, Bangladesh's federal artificial insemination institution, to test a hypothesis he'd been examining for a number of years: that heat damage, which affects the shape of sperm cells, can be measured.

In Bangladesh, National Bull Stud employees collected semen from a set of dairy bulls during hot and cool seasons. They then stained the sperm cells, took pictures of them under a microscope and e-mailed them to Parrish in Wisconsin for analysis. "We found significant changes in the shape of the sperm in those animals (between the hot and cool seasons)," says Parrish, who added hundreds of lines of code to an off-the-shelf software program to get the sperm-cell coordinates he needed. "It's only very slightly different; there's no way you could see it with your eye."

Although Parrish originally set out to answer a basic scientific question, his work could end up benefiting Bangladesh's dairy industry. That's because a small percentage of bulls are able to maintain their fertility during the hot season. "We can use this test to look for bulls that are not affected by the heat," says Parrish. "Those should be the parents of the next generation."

Similarly, the test could be used to monitor when heat-affected bulls recover their virility after the hot season ends. "The idea is to test semen and say, 'Now it's okay to ship out.'"

—Nicole Miller MS'06

John Parrish

When temperatures rise, bulls in Bangladesh start firing blanks.

Root Lessons

In the classroom, **Bruce Allison** delivers the tools of the trade—and a message about our connection with trees.

IF YOU ARE A TREE, it's a good thing to know Bruce Allison, proprietor of Allison Tree Care and all-around champion for Wisconsin trees. As a professional arborist, Allison has nurtured thousands of prized trees to ripe, old grandeur, including the majestic oaks that shade Memorial Union's Terrace. As an author, he's written three books that chronicle some of Wisconsin's rarest, most beloved trees. Now he's a teacher, leading a new course on urban tree care for the Department of Forest and Wildlife Ecology, where he serves as an adjunct professor.

g Tell me about the class you're teaching. How did it come about?
Well, a year or so ago, the department approached me about teaching because they wanted to have the knowledge that people like me gain by working in the field available to students. And of course I'm in favor of that. I think it's a great function of an adjunct professor. And I thought that with some of the new tools that I've been working with, it might be a good opportunity for students to see some of this new technology and what we're trying to do with it.

g What kind of new tools?
Acoustic tomography, for example. Sound waves pass more quickly through solid wood than they do through wood that is decayed or cracked, and so we can use sound to alert us to decay or defects inside the trunk. We use multi-path acoustic tomography, which has 12 sensors that you can put around the trunk of the tree to create a matrix of measurements. The software turns those measurements into a graphic diagram, which gives you a very good visual idea of what's happening inside the trunk—if there are internal wounds or decay that could affect its stability.

The key is that we're able to non-destructively see inside the tree. When I'm looking at a tree that may have internal defects, I don't really want to be drilling big holes into it. We're using the same kinds of tools now that are used in human medicine—it's the same concept as in MRIs or cat scans. It's all very new. Only three companies make this equipment, and they're all in Europe. My company was the second one in the United States to bring it over here.

g When was that?
In 2005. I purchased it when I had a contract with the Wisconsin Department of Administration to examine 153 trees around the State Capitol.

g I remember that project. There was a lot of concern about what might happen to those trees.
There was, but I think in the end the public dialogue ended up being very positive. We were able to

Bruce Allison strings acoustic tomography sensors around a tree to allow him to see the interior structure of the trunk.

explain the science behind what we were doing and show people the data we had collected on the trees, and people were very supportive of our management plan. I felt that once the facts were presented, people understood that everything was being done to protect the trees and preserve public safety.

Are those things always consistent—protecting trees and protecting safety?

Well, whenever you have trees in an urban setting, you have a responsibility to manage trees for safety. That's one of the unique aspects of managing an urban forest. The biology of a tree is going to be the same whether it's growing in a city or in a forest. But in a city setting, you're not looking at them solely in terms of a production cycle, where you know you're going to cut them down after a certain time and use them in forest products. Your goal is to carry them as long as you can, to have as much aesthetic contribution as possible. So structure and stability become very important. It's not just about protecting every tree—it's about managing trees intelligently for the best benefit of future generations.

cover in urban settings virtually eliminates the heat island effect of cities. You can reduce energy use and improve stormwater runoff by planting trees in cities, and that's what many urban areas are starting to do. In Wisconsin, there is a plan to plant 20 million new trees by the year 2020. So the career possibilities are excellent right now.

How does your class give students a taste of those possibilities?

I want students to have a good classroom understanding of the science, and I want them to be able to see the new technology in practice. We select a hands-on project each semester, where we do a complete evaluation of trees for a real client. Last fall, we did a report on the six large trees at the Memorial Union Terrace, and it was fantastic. We were able to diagnose some problems and propose some solutions to help protect those trees, which are so important to the character of the place. And I think that makes things more tangible for the students. They've been walking and sitting under those trees for a long time, and now they can see them in a way that they hadn't before.

> "We're using the same kinds of tools now that are used in human medicine—it's the same concept as MRIs or CAT scans."

Do you talk with students about the role of urban forestry in your classes?

Absolutely. In a forest, you might plant a tree and walk away for 50 years, but in a city setting, you have ongoing issues of maintenance. Community foresters have responsibilities to prune trees to keep roadways and utility corridors clear, and they also have to think about the interaction between trees and people.

Trees have a special role in our communities. There are some great studies that show hospital stays are shorter where patients can look out the window at trees, for instance. We also know that in neighborhoods with healthy tree cover, the incidence of crime and other social problems is less. So we know that trees are making far more than biological contributions to our neighborhoods. There are sociological and cultural benefits, as well.

I imagine the career opportunities must be pretty good, then.

There is a tremendous need out there. The U.S. Forest Service has concluded that a 40 percent canopy

Are you targeting students from areas other than forestry?

That is definitely the goal. I see this class as a chance to talk to students from a number of different areas—plant pathology, horticulture and even some of the other sciences. I was asked to give a lecture on tree stability to an honors physics class this fall, and that was just fantastic. It was at 8 a.m., and I was expecting that they were going to be half asleep. But they were totally engaged in the topic. If you subtract the fact that a tree is a biological organism, it's also just a giant structure that is subject to the same physical forces you study in physics.

One outcome of that talk was that I mentioned to their professor that I was trying to develop a portable cat-scan device for trees. And he said to me, "I've got some old equipment around. Let's see if we can pull it out and conduct an experiment." And he took me over to meet another professor who had X-ray tubes that we might use. And I just thought, well, this is what's great about this university. There's this cross-fertilization going on all the time.

A beetle's newfound abilities remind us that life is always adapting to overcome our best strategies. How the eternal struggle for survival changes the way we farm.

The Evolution is

By Michael Penn

On

On a strip of yellow adhesive tacked to a wooden stake in the middle of a Wisconsin soybean field, a beetle crouches in an eternal pose, frozen by a last, fatal landing. She'll never know how close she came to immortality.

Here is how life might have played out for this beetle, a brown, winged speck known as a western corn rootworm. Had the trap not snared her, she might have buzzed around the soybean field for a few days, searching for soft soil to house her eggs. Finding a suitable spot, she would have burrowed in, laying her eggs deep enough to shelter them from the winter freeze. The eggs would hatch the following spring, yielding dozens of tiny, hungry larvae. Being corn rootworms, they would have looked around for some corn roots to munch on, giving them energy for their pupal transition to adult beetles, but potentially crippling the plant in the process. And that's where this beetle was particularly clever. She was about to lay her eggs in a soybean field, somehow knowing that the following year corn would be planted there, a crop rotation designed in part to ward off pests like her. Staying in the cornfield where she was born—a field that next spring would rotate into another crop—would have meant certain death for her brood. It was a brilliant strategy, spoiled only by a moment of misfortune that landed her in Sarah Schramm's trap.

Dealing with corn rootworms is nothing new for farmers, explains Schramm, an entomology researcher who has monitored the insects on Wisconsin farms for the past three summers. According to the U.S. Department of Agriculture, rootworms infest 30 million acres of U.S. corn each summer, causing nearly $1 billion in crop losses and control measures.

But dealing with them in soybeans is something no one expected. "It's definitely surprising, because crop rotation usually controls these beetles," she says, hip-deep in soybeans as she wades through the field to retrieve another of her traps. "But this variant seems to have figured it out." First discovered about 10 years ago in east central Illinois, the new, rotation-savvy beetles have expanded into Iowa and Wisconsin, where they have now been identified in six counties. At the same time, the closely related northern corn rootworm beetle appears to be working out its own strategy to defeat rotation: Some northern beetles are now laying eggs that rest dormant in the soil for two years before hatching, essentially waiting out a rotation cycle until corn plants return.

One might admire the beetles' spunk, but of course spunk has nothing to do with it. As the project's lead investigator, entomologist Eileen Cullen, points out, the beetles aren't really learning anything. What they've done is evolved, the oldest trick in the book.

D**arwin had pigeons. Mendel bred pea plants**. For farmers and agricultural researchers, the most immediate illustration of evolution is the constant tussle between crops and the pests that prey on them. Every season, plants wage a game of can-you-top-this with their enemies—a legion of weeds, insects and disease-causing pathogens that can weaken or outright kill cultivated crops—to settle who holds dominance in the field.

Because we depend on them for food and energy, we side with the plants. We breed them to have genetic superiority over their foes, and, when that isn't enough, we assist them with chemical and cultural aids, among them crop rotation, fertilizers, insecticides and herbicides that cut down competitors and nurture vigorous development. But our efforts are fleeting. No matter how clever the technique to kill them, a few pests manage to survive, sometimes by quirk of circumstance, but sometimes with the benefit of superior genes. Deploying a single insecticide or herbicide repeatedly over wide areas only serves to eliminate competition for those gifted few, allowing them to pass their genes on to huge numbers of descendants.

"There's really no way around the fact that if you expose an insect population to one suppressive method over time it will develop resistance," says Cullen, an associate professor of entomology for CALS and UW-Extension. "Most insects reproduce quickly, and that means that they have more opportunity for exchanging their genes and adapting to management practices."

That ability to adapt has turned our chemical assault on bugs and weeds into a long and frustrating arms race. Despite the millions of pounds of pesticides now applied to food crops around the world, research by German plant pathologist Erich-Christian Oerke has shown that crop losses due to pests really haven't changed all that much during the past 40 years. That's not to say we shouldn't be using some form of intervention. Oerke's studies estimate that if we let pests have their way, the world could lose more than a quarter of its soybeans, nearly 40 percent of its potatoes and corn, and half of its wheat. We may not be winning the war on weeds and bugs, but without an uninterrupted stream of innovative ways to keep them under control, we might not even be holding our own.

A striking example is the creeping vulnerability of glyphosate, the most widely used herbicide in the United States. More commonly known by its original trade name, Roundup, glyphosate has been a potent assassin of weeds since it was first introduced by Monsanto in the 1970s. Homeowners spray nearly 8 million pounds of the herbicide around lawns and gardens annually, but its real dominance is in agriculture. In the mid-1990s, Monsanto pioneered corn and soybean crops that were genetically engineered to withstand glyphosate, allowing farmers to spray Roundup broadly across fields to combat weeds. Farmers planted millions of acres of Roundup Ready crops, dramatically increasing the application of glyphosate. Recent estimates say 90 million pounds of the herbicide are applied to crops in the United States each year.

But the widespread use also increased the selection pressure for weeds that aren't felled by glyphosate, says CALS weed specialist Chris Boerboom. As early as 1998, ryegrass in California had adapted to survive the herbicide, and now 20 states and 13 countries have identified glyphosate-resistant weeds. Wisconsin isn't on the list yet, but officials are investigating a suspicious case that arose this summer.

Boerhoom says it's no accident that resistance has been slow to arise in Wisconsin. "We've spent a lot of time with Wisconsin corn and soybean growers discussing resistance and practices to reduce the risk of glyphosate-resistant weeds," he says. A survey conducted by CALS colleague and agricultural economist Paul Mitchell found that Wisconsin growers were more aware of the dangers of overusing Roundup and more likely to rotate herbicides than farmers in any other state.

Does that mean that Wisconsin farmers are more friendly to Darwin and his theory of evolution? Not necessarily, says Cullen. "I don't think we often talk about it in terms of evolution. I, for instance, certainly don't think of myself as an evolutionary biologist," she says. "But really, it is evolution. The concept is there in many of our conversations on the farm."

In the case of the western corn rootworm beetle, for instance, the insects were pressured to adapt by the common practice of upper Midwestern corn farmers to rotate fields between corn and soybeans in alternate years. With an unbroken cycle of corn, beetles would never have developed an urge to leave the cornfield behind because staying put would have worked for generations of ancestors. But a rootworm employing the same strategy in a field that rotates between crops would find its lineage cut short. The advantage would go to the beetle that, for whatever reason, liked the look of a nearby soybean field and thought it would make a nice place to raise a family. Researchers don't yet know what genes may have been passed along to drive that instinct, but the

Pea aphids climb the stem of a bean plant.

> We may not be winning the war on weeds and bugs, but without new ways to keep them under control, we might not even be holding our own.

growing size of the soybean-nesting beetles tells them that it's more than chance. Why did the beetle cross the road? To survive.

Not all western corn rootworm beetles know the trick, and that's one reason the variant population hasn't spread uniformly across the corn belt. In southern Wisconsin, where the emerging beetle was first discovered in 2003, the variants intermingle and mate with beetles that are still prone to crop rotations, helping to dilute the transfer of their genes to future generations. But rotations are already failing to keep the insects under control in several counties in Illinois, and farmers near the border are beginning to ask whether they should change tactics.

Cullen tries to help them answer that question using integrated pest management, an approach that employs a spectrum of management options, from cultural to biological to chemical. One of the central dogmas of IPM is to do nothing that you don't have to do, especially when it comes to spraying pesticides. Schramm's traps are essentially testing whether farmers should worry about these new beetles at all. During weekly visits to farms in August, she was looking for an average of five beetles per trap per day. Anything less and the tenets of IPM suggest that it would be more expensive for a farmer to fight the beetle than to just live with it. And while that appeals to farmers' economic interests, it is also a strategy rooted in an understanding of evolution.

"We don't want to constantly expose (pests) to one particular pressure to adapt," says Cullen. And that desire is putting farmers in charge of another process on their fields that they may not often think about. They're now running the show when it comes to the evolution of the plants and animals that live under their domain.

Perhaps its no revelation that humans are now turning the gears of evolution. We've dabbled in the field for some 10,000 years. Since the birth of agriculture, we have commandeered the natural evolution of plants and animals and directed them toward human uses. Without human-directed selection, we would have few of the crops and animals we depend on: no dairy cows, no donkeys, no woolly sheep and no ears of corn. The family pet would be a wild menace.

But things have gotten considerably more complicated than crossing plants or gathering desirable seed. Scientific advancement and an exploding human population have combined to give us unparalleled influence on our environment. Our use of the planet's resources has profoundly reshaped the species who share space with us. Some, like the dodo, couldn't compete and went away. Others, like cod, which mature faster and smaller than before we fished them, look considerably different because of us. As the evolutionary biologist Julian Huxley wrote more than 50 years ago, "It is as if man had been appointed managing director of the biggest business of all, the business of evolution … and the sooner he realizes it and starts believing it, the better for all concerned."

David Baum, a professor of botany who leads UW-Madison's Evolution Initiative, says Huxley's sentiment is even more apt today, when disease-causing microbes are developing resistance to antibiotics and invasive species are altering the landscape. "We're really coming to appreciate how many human problems are evolutionary problems," he says. "There are situations in which we

'Oddballs in Every Way'

The organisms that live in the lab are evolving, too. Could we be wrong in thinking we know them so well?

What Audrey Gasch saw in her Petri dish made no sense. The assistant professor of genetics was just getting a research program launched on the genetic mechanisms of yeast, the fungi that naturally convert sugars into alcohols like wine and beer. But she was having trouble with a lab-bred strain of *Saccharomyces ceravisiae*, a type of yeast studied by scientists for nearly a century. It just couldn't hold its liquor. After producing relatively small amounts of alcohol, the cells shut down, too stressed by the alcohol around them to go on.

"We thought, 'Hold on, yeast naturally produce alcohol, so they should be able to handle this kind of environment,' " says Gasch BS'94. "Either what we thought about nature was wrong, or something about this lab strain was wrong."

To figure out which, Gasch began studying strains of yeast collected from all over the planet, including yeasts found growing in an Italian winery, a Trinidadian rum distillery and even a patch of Wisconsin soil. In the lab, she subjected the wild strains to tests to see how much alcohol they could tolerate. Her conclusion: Strains of yeast raised in labs are wimps.

"They're really oddballs in just about every way that we look," she says. "So what's happened is that lab scientists have inadvertently been selecting a strain that is very friendly for genetic

want to stop, slow down or direct evolutionary processes, and in those situations, we can use what we understand about evolution in nature to provide us with insights about how to do that."

One of the pressing questions in the current influenza pandemic, for instance, is how and where the H1N1 virus evolved. Its heritage matters to people such as Christopher Olsen, a professor in the School of Veterinary Medicine who studies flu viruses, because they can learn a lot about a virus by understanding to whom it's related. An evolutionary link can help public-health officials more quickly design vaccines and identify what populations are most vulnerable to the virus. By tracking and probing the evolution of emergent viruses, Olsen says, "we can get ahead of the curve when we see a virus begin to spread or change in a way that concerns us."

But evolution matters to Olsen for other reasons. He's particularly interested in how viruses make the leap from infecting birds to other species, namely pigs and humans. It's a complicated transition that involves far more than a simple genetic tweak, he says. But many viruses do it. And that's partly because there are just so many viruses. In his lab, where Olsen's research team grows flu viruses in chicken eggs for experiments, a single egg can produce several million viruses in a day.

"For something like a flu virus, the evolutionary time scale is so much shorter than it is for us," says Olsen. "It's a matter of hours, not decades or centuries."

It is true about most of the things that make us sick: They change faster than we can. The same dynamic plays out in agricultural fields, where pests turn over one or more generations each season while engineering resistant crops and new crop treatments can take decades of research. Our best defense is to use something that can adapt more quickly than our genes: our understanding of how evolution works.

One difficulty is that evolutionary processes don't always behave in ways that we might expect. Take the case of the pea aphid, a ubiquitous and occasionally troublesome guest in pea and alfalfa fields across the United States and Canada. Pea aphids prefer cool temperatures, and so one might guess that global warming would portend bad things for their kind. But when UW-Madison postdoctoral researcher Jason Harmon and ecologist Anthony Ives set up an experiment to test that hypothesis, they found a more complex web of interactions at work.

"The reason I started working with pea aphids is that they are a really great example of biological control. They don't die natural deaths," says Ives, a professor of zoology and entomology. Instead, a suite of predators, including ladybugs and parasitoid wasps, keep the aphids in check. When Harmon and Ives covered alfalfa plots with shrink-wrapped plastic boxes to simulate the temperature spikes that might come experiments, but not very representative of what's in nature. They've evolved to live in the lab."

Scientists have long known that animals that they raise in labs are a more domesticated bunch. A white-haired lab mouse will often sit patiently in a lab technician's palm, a model of pink-eyed civility. "If you ever catch a mouse in your house, you know that's not how they behave," says Bret Payseur, an assistant professor of genetics who studies both wild and lab mice in his lab. To some extent, all model organisms—from mice to fruit flies to tomatoes and corn—have been changed by our studying them. Over generations, they've grown accustomed to the perks and hardships of life in the lab.

Some researchers are beginning to explore just how different lab species are from their wild relatives—and what that may mean for the research we perform on them. Beth Dumont, a graduate student in Payseur's lab, has found that DNA recombination rates can vary widely among mice that live in the wild, which she thinks reflects divergent patterns in their evolution.

"Something really interesting is going on with regard to recombination in house mice," says Dumont. "In subspecies that are about as diverged from each other as humans are from chimpanzees, recombination rates vary by about 30 percent." That suggests that far greater genetic diversity may have evolved within species than one might guess from studying their lab counterparts.

That doesn't mean that studies on lab mice aren't useful. "A big reason why we can study wild mice is that we know so much about them from lab studies," says Payseur. "If you want to understand natural selection, that's best done in a natural environment. But there are things you can do in a lab that you can't do in the wild. What we try to do is use them in combination."

Ultimately, Gasch had the same idea. Her team is now using wild yeast as a platform for engineering lab strains that can better stand up to the pressures of a hard life. Toughening up yeast could aid the industrial production of ethanol, which requires fungi to perform in hot, caustic surroundings.

"We're finding that it makes sense to look to nature first," says Gasch. "There's a lot of genetic diversity out there that isn't reflected by these happy little lab strains."

—Michael Penn

from global warming, they found that some aphids did suffer. But aphids that harbored particular bacteria suffered less, suggesting that they might evolve symbiotically as temperatures climb. The researchers also found that one of the aphids' main predators gave up when there weren't as many of the bugs around, which means that in a real warming scenario, aphids might actually get a reprieve from predator pressure.

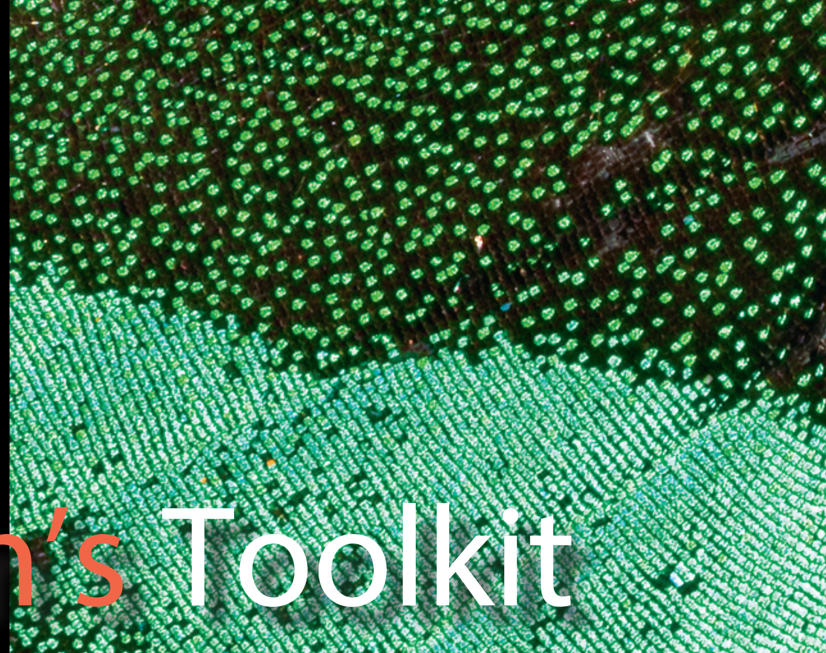
The bottom line, says Ives, is that "you can't simply add the effects together and come up with a conclusion. There are layers of interactions involved, and when you throw evolution on top of that, it produces something that's quite complicated. But it's not entirely unknowable."

That kind of thinking increasingly is finding its way into agricultural policy decisions. "Really, the U.S. government regulation on insecticidal crops is all about resistance management," says Ives, who has modeled the effects of various regulation schemes in his research. When the U.S. Environmental Protection Agency approved commercial use of Bt corn—a transgenic crop modified to produce the bacterial toxin Bt to deter plant-eating insects—the agency imposed rules that require farmers using Bt corn to plant at least 20 percent of their fields with non-Bt crops to stall the evolution of Bt-resistant bugs. And while farmers and environmentalists have far from settled their differences on the use of Bt-producing crops, Bt resistance has not yet become an issue.

As for corn rootworm beetles, evolutionary biologists are on the case. Scientists are actively searching for the genes that allow western and northern corn rootworm beetles to independently outwit crop rotation. If those genes are identified, they could help biologists devise new strategies to keep the beetle from spreading or forestall its evolutionary development.

But in Eileen Cullen's lab, the mysteries of evolutionary biology can't compete with the present demands of economic reality. "Farmers can't really wait to find that out," she says. "We know that the insect is changing, and that means we need to change, too."

That immediacy was apparent on the day that I joined Sarah Schramm to check insect traps in a soybean field south of Darlington. We arrived in late morning, under a blanket of heavy gray clouds that were just beginning to burn off to reveal the high August sun. As we worked our way through the fields, a cacophony of life buzzed around us: grasshoppers, ladybugs and beetles of various colors and sizes. Schramm pointed out a western corn beetle on a nearby leaf, easily distinguishable with its yellow-and-brown striped wings. I wondered if the beetle was getting ready to lay eggs, a small, solitary act of rebellion against farm management practices that might trigger a series of reactions. To alter crop rotations. To treat or not to. The game is on, and it's our move.



Darwin's Toolkit

Sean Carroll says exploring the creative power of genes is the next frontier in evolutionary biology.

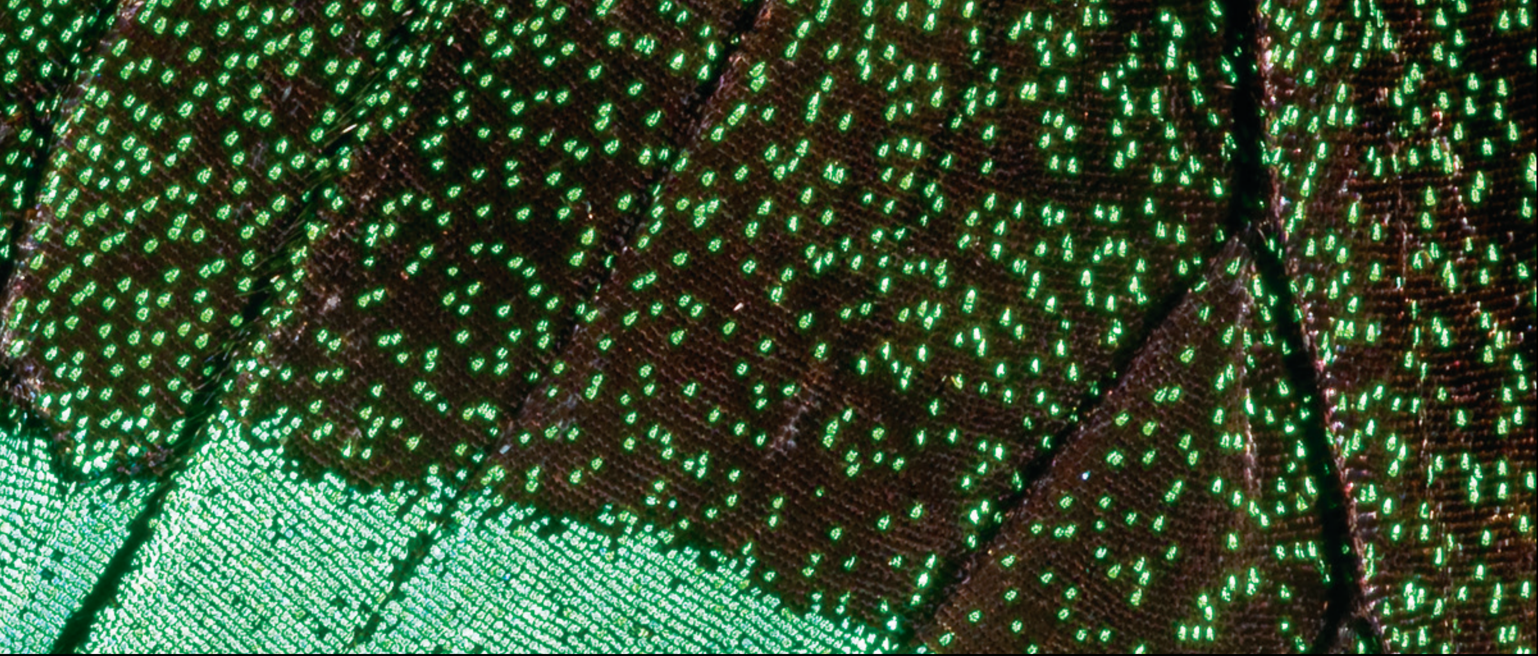
A butterfly's wing is like a pointillist masterpiece. Fragile, brilliant and diaphanous, it resembles a solid canvas, painted with swirls and spots of elaborate design. But each wing is in fact a mosaic, comprising hundreds of individually colored scales. From a distance, the effect is the same as viewing a Seurat mural. We take no notice of the dots and see only the whole.

In the middle of the 19th century, naturalist Henry Walter Bates looked at the wings of butterflies and saw a different kind of picture, a vision of how species evolve on the fly. On an expedition in the Amazon rainforest, where he catalogued hundreds of butterfly species never seen by Europeans, Bates began to conclude that the insects' wing patterns were anything but fanciful decoration. In the competition to mate, eat and avoid being eaten, the odd splash of color or eye spot that deterred a predator became a life-or-death utility. Returning to England after seven years in the jungle, Bates wrote excitedly to his friend Charles Darwin: "I think I have got a glimpse into the laboratory where Nature manufactures her new species."

Bates had the picture right, but he couldn't see the dots. The genes and proteins that build butterfly wings and other body parts were a frontier even more remote than the Amazonian wilderness. That territory would remain unknown for another 100 years, until the discovery of DNA and the birth of molecular genetics. Now scientists such as CALS molecular biologist Sean Carroll are using those tools to answer the question that bewildered Bates: How did butterfly wings get that way?

"When you look at something as beautiful as a butterfly wing, it's hard to imagine that there's an explanation for why it looks the way it does," explains Carroll. "But it's decipherable. We know now how to peel back those layers and figure out how it's put together piece-by-piece."

The key lies in understanding development, the furious transi-



tion when cells divide and specialize to form everything from fish scales to tiger fur. Carroll is among a group of scientists who have figured out how to spy on the genes that do the heavy lifting during this phase, building limbs, wings and other major body parts, and then make cross-species comparisons to describe how they evolved. In studies of fruit flies, Carroll's lab has pinpointed small changes in DNA that explain why some flies have spots on their wings while others don't. His work has shown that in some cases flies can gain or lose the ability to create those wing patterns with the flip of a single genetic switch.

This branch of evolutionary biology, known as "evo devo" for its marriage of evolution and development, has gained scientific footing on par with big fossil discoveries. At the American Museum of Natural History, the genetic evidence for evolution shares equal billing with bones in a permanent exhibit on human origins. Carroll has begun writing a regular column for the *New York Times*, and he appears prominently in an episode of *Nova* on the genetic evidence of evolution, which airs in December.

"What Sean is doing is unlocking Darwin's toolkit," says Neil Shubin, a paleontologist at the University of Chicago and a frequent Carroll collaborator. "He is giving us a mechanistic understanding of how body forms are created and change over time."

But like Darwin and Bates before him, Carroll is still compelled by what he doesn't know. He cites the explosion of information unleashed by the sequencing of plant and animal genomes as one example of a vastly unexplored frontier. "We used to get words about a few species, and now we get encyclopedias," he says. "And that gives us the means to investigate all kinds of new questions."

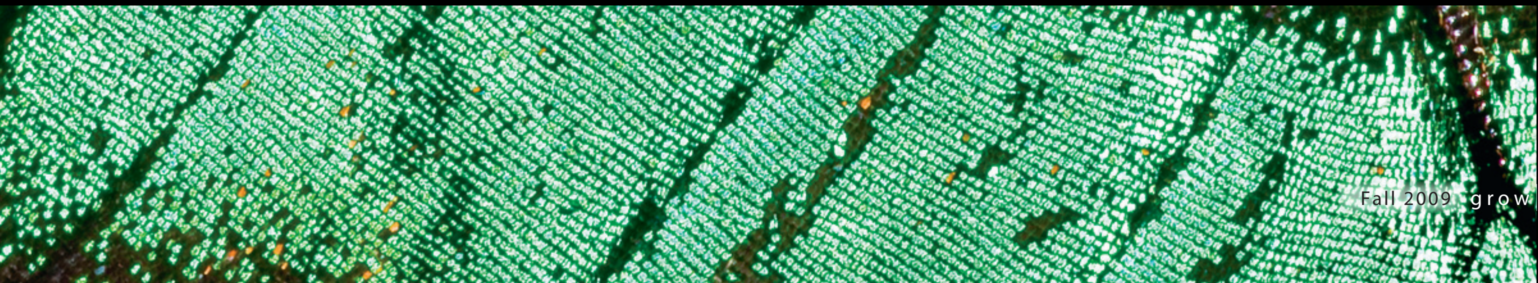
But can molecular fossil hunting match the flesh-and-bone dramatics of the early explorers, who battled disease, famine and the occasional cannibal on the way to their discoveries? Carroll spent two years researching the exploits of evolution's pioneers for his most recent book, *Remarkable Creatures*, which he says he wrote partly to capture the derring-do of the scientists from that golden age.

Today's lab-based adventures afford more creature comforts, but Carroll says they are no less exhilarating. "Scientists are all explorers. We're all trying to explore the unknown, whether it's the cosmos or a protein structure. And that thrill of discovering an insight is just amazing," he says. "Maybe it's not viscerally exactly like stumbling upon a field full of dinosaurs, but it's close. That feeling of coming upon a hard-earned insight … it can just blow your mind."

Carroll relates a story from early in his career, when he was working as a postdoctoral fellow in a lab at the University of Colorado. He was struggling to come up with a method to see which genes were active during a critical stage of a fruit fly's development. He had been at it for 18 months without success, and his frustrations were getting the better of him. One more try, he figured, and then he'd give up.

It was nearing midnight by the time the experiment ran its course. In the deserted lab, Carroll put the embryos under a blue light, anticipating and fearing what he might see. The light illuminated tiny green stripes across the embryos, marking the invisible function of genes as they went about the business of building a fly. He had seen the dots, and they were coming together to form a breathtaking picture.

—Michael Penn



NO LEAF UNTURNED

THEY ARE FARMERS, DOCTORS AND AMAZINGLY ADEPT TRAFFIC ENGINEERS. LEAF-CUTTER ANTS HAVE BEEN PRACTICING THE GOOD LIFE FOR MILLIONS OF YEARS.

WHAT DO THEY KNOW THAT

BY ADAM HINTERTHUER

IT'S AN AGE-OLD STORY. A young woman sets out on her own. She leaves behind the only place she's ever known, a city crawling with millions of citizens engaged in the activity of making a metropolis run. Workers build new homes and roads. Farmers plant, weed and harvest their gardens. Others are busy cleaning the streets or guarding important landmarks or deploying to fight disease.

Our heroine seeks a life less crowded. A place to call her own. So she heads somewhere new. Takes a flight. Her only carry-on a little memento from home.

When she settles down, though, her story veers from the familiar script.

Reaching her final destination, she digs a tunnel into the earth, removes the piece of home from a pouch in her cheek and tears the wings from her body. The memento is actually a fungus. Those wings are its first meal. And that piece of home grows and grows under her care—the key to sustaining the new colony that will soon spring from the eggs she lays.

Every rainy season in Central and South America, this story unfolds a million times over. It is the saga of the leaf-cutter ant, and it may one day influence everything from how we produce fuel to how we fight disease to how we think about evolution.

But first, it just might make us reconsider what it means to be human.

As they slice perfect circles from leaves to carry back to their nests, leaf-cutter ants practice one of the oldest forms of agriculture on the planet.

ANTS HAVE BEEN GROWING THEIR OWN FOOD FOR ABOUT 50 MILLION YEARS, WHICH IS ABOUT 50 MILLION YEARS LONGER THAN WE HAVE.

Thirty years ago, noted physician and essayist Lewis Thomas observed that it is a generally accepted metaphor that humans, when viewed from a great height, resemble ants at work. However, Thomas continued, it's frowned upon to peer through the magnifying glass and make the opposite analogy. Which is odd, he wrote in his book The Lives of a Cell: Notes from a Biology Watcher, considering that "ants are so much like human beings as to be an embarrassment."

We regard our ancestors' transition from hunting and gathering to agriculture as the accomplishment of human industry, one that allowed us to thrive upon this earth. But ants have been growing their own food for 50 million years, which is about 50 million years longer than we have.

Think the discovery of antibiotics was only made possible because of our big brains? For millennia, ants have used some of the same bacteria we "discovered" to create disease-fighting antibiotics. What's more, they've managed to avoid the problem of antibiotic resistance that plagues our medical field.

Of course, the human-ant comparison falls apart at the individual level. A lone ant has little in the way of self-awareness or cognitive thought. The ant harbors no brain, just a few thousand neurons strung together. But once that ant joins the swarm teeming about a nest, it becomes a model for societal organization and technological accomplishment. Then, Thomas writes, "you begin to see the whole beast. And you now observe it thinking, planning, calculating. It is an intelligence, a kind of live computer, with crawling bits for its wits."

From the fourth floor of UW-Madison's Microbial Sciences Building, associate professor of bacteriology Cameron Currie is trying to crack the code of this "live computer." An entomologist by training, he has since ventured into realms as diverse as microbial ecology, evolutionary biology and genomics to help him sort out the myriad interactions that help fungus-growing ants thrive. His work has led to grants from places like the U.S. Department of Energy and the pharmaceutical giant Roche. He's also garnered several awards, the most recent (and prestigious) being the Presidential Early Career Award for Scientists and Engineers, which he'll have handed to him by President Barack Obama this November.

It's an enviable career arc, but it didn't begin with the desire to study ants. Currie was first a student of ecology, finding inspiration in Darwin's description of the "tangled bank"—an attempt, Currie says, to explain how "birds and worms and insects all interact and (how) these complex communities shape each others' evolution and are shaped by evolution."

Like most young students, Currie was first interested in applying that theory to more charismatic fare. "I started (out) being more interested in bigger animal interactions," he says, "like in the Serengeti—lions, wildebeest, stuff like that. But it's hard to work on lions and wildebeest, right? You can't collect them, you can't contain them in the lab, you can't sample them." So Currie looked to smaller organisms that could be raised and studied in the lab. Soon he realized that many insects lived in close association with microbes around them, and that these relationships drove the evolution and ecology of the whole system. He'd found his bank—still tangled, just smaller.

Currie's particular interest in tropical ants was lit during graduate studies at the University of Toronto. His advisor, mycologist David Malloch, was in Costa Rica for a workshop on fungal

diversity when Currie called to get ideas for a dissertation topic. Malloch, intrigued by what he was learning at the conference about leaf-cutting ants and their fungal gardens, suggested that he study ants.

MORE THAN 200 known species of ants grow fungus as their primary food source. The leafcutter ant is the most highly derived from an evolutionary perspective. In layman's terms, that means it is by far

Ants in Currie's lab navigate their plastic environment just as they would in the wild, carrying leaves back to a vast, spongy garden of fungus (above), which supplies the colony with its primary source of food.

the coolest. Leaf-cutters have the biggest nests, largest populations and the most complex societal organization.

After a queen makes her nuptial flight, digs a tunnel and lays eggs, she focuses solely on tending to that tiny piece of fungus she snipped from the old nest. Soon, new ants hatch into the colony all with pre-assigned roles. Some grow into minims. The smallest members of the colony, minims tend to the fungus and weed out any dead or diseased material. Other eggs produce foragers, which venture into the forest and bring back morsels of leaves, arranging them like scaffolding in football-sized chambers. The fungus then grows onto the fragments and consumes them for food. Guarding the whole enterprise are the soldiers. Aside from the queen, soldiers are the largest members of the colony, big enough to literally straddle the columns of foragers as they return to the nest with leaves. The soldiers stand alert, ready to turn back any threat with fierce mandibles that can easily cut through human skin.

All of them—minims, foragers and soldiers—are females. Males appear only once or twice a year, when the queen lays eggs that grow into reproductive males and females. When mature, these winged ants fly from the nest in a great swarm. The males, as is the common fate of many in the insect world, mate during the flight and die soon after. The females collect sperm from several different males, which fertilize the eggs that will start their new colonies.

The whole operation takes on a scale vastly outsized for the ants' tiny bodies. Their nests thrive for as long as the queen lives (up to 15 years) and can be home to more than 5 million ants. If you were to dig the entire thing out of the ground, the resulting hole would be bigger than your living room. In the tropics, leaf-cutter ants consume up to 20 percent of the fresh vegetation. A single nest is the equivalent of a cow settling in and eating non-stop.

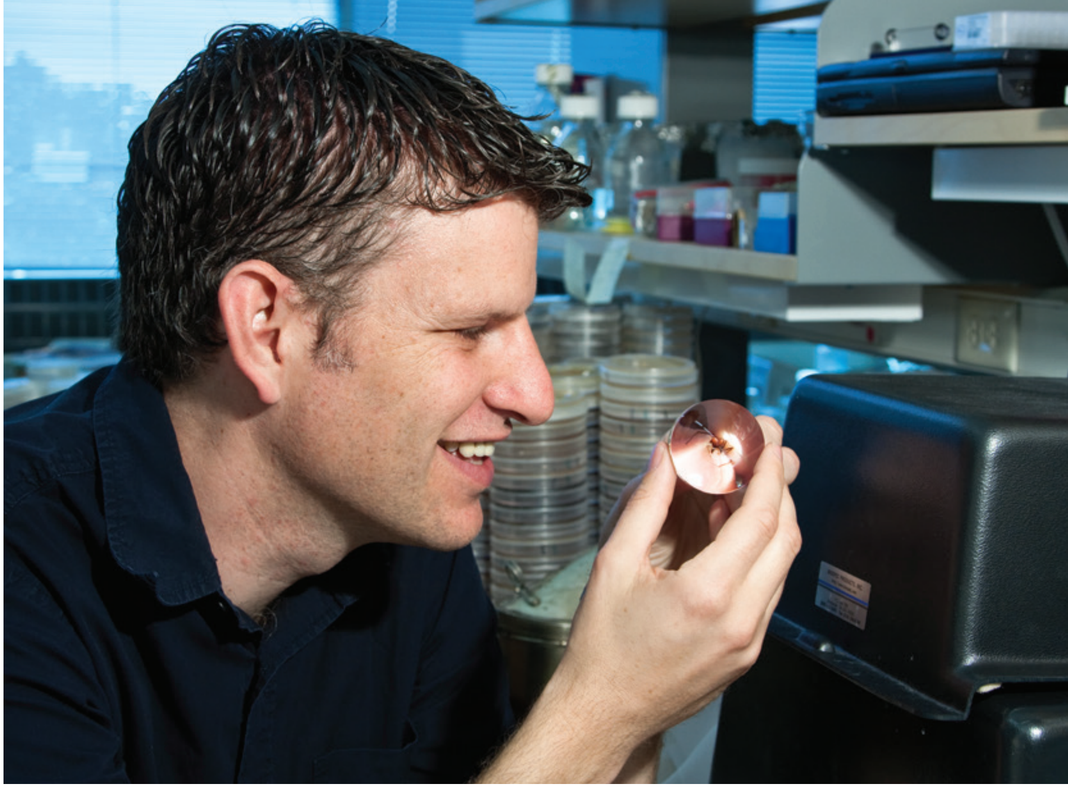
Scientists have spent decades studying fungus-growing ants, mostly in an attempt to understand their behavior and the structure of their societies. They have discovered that each species tends to its own distinct species of fungus, which cannot survive outside of the ants' nests. Scientists also know that the ants play an integral role in cycling nutrients through the rainforest. But there is almost nothing known about how any of this came to be.

"The mystery I'd like most to get to the bottom of is how … this complex suite of behaviors was assembled over evolutionary time," says Ted Schultz, an entomologist with the Smithsonian Museum of Natural History. "How did it begin?"

But scientists have only recently stumbled upon the complex inner workings that surround the ants' society. When Currie began studying leaf cutters in the late 1990s, the system was considered a fairly straightforward model of symbiosis, where the ants nourish the fungi that in turn nourishes them. But one facet of the system bothered Currie. No one had ever spotted disease in the fungus gardens. Currie knew that any human crop grown as a monoculture for generations would battle wave after wave of opportunistic parasites and diseases. Surely these fungus gardens weren't exempt.

Currie approached the system from a new perspective: He got out the microscope. Looking closer, he found that disease was indeed present, but it wasn't an assortment of attackers. The fungus was battling a single species of parasitic mold. It turns out that this mold is not some new invader, but an organism that has been part of the system for millions of years.

"What I showed is that, when the ants are there, they're suppressing the disease," says Currie, "but the disease



is having an impact and it's performing a persistent infection. So it's not like 'Ant there, clean. Ants gone, overgrown.' It's a continuous kind of interplay between the players."

But that's not all the microscope revealed. Currie noticed the ants had a waxy, white residue on their carapaces, which he discovered were bacteria that produced antibiotics that helped suppress the parasitic mold. The four organisms—ant, fungus, parasite and bacterium—were like players in a long-running drama, where each had something to gain by cooperating and everything to lose by taking advantage of the system.

Further studies have added more members to the cast. Currie and others have discovered yeast that live on the ants and feed the antibiotic-producing bacteria, as well as a bacterium in the fungus garden that fixes nitrogen and fertilizes the fungus. As Rebeccah Steffensen BS'08 one of Currie's lab managers puts it, "When most people think about symbiosis, they only think about two things. We think that if you keep looking you'll find more and more interactions. So it's more like this network of (different) symbioses."

In a long, windowless room in the back of the Currie lab, Steffensen pops the lid off one of dozens of Tupperware bins that house colonies of fungus-growing ants. There is a sweet, surprisingly earthy smell. Inside are several clear plastic cubes with holes cut in their corners, a leaf-cutter colony laid bare, doing everything their wild counterparts would. Foragers travel in and out, harvesting food—typically oak and maple leaves with a steady supply of ground corn—from an adjacent bin. Minims weed the fungi that grow on a latticework of decaying plants. A separate cube, set off from the others, serves as the ants' compost pile, where they take dead chunks of fungus and other refuse. Peering into the cubes, it becomes apparent that the fungus is more than a food source—it is the world the ants inhabit. The white, spongy mat is crisscrossed with well-traveled tunnels. Small chambers deep inside house the ants' brood, larvae tended and fed by minims until they mature and assume adult roles. The ants build and the fungus grows until it completely fills each chamber.

Despite being removed from their habitat, fed a foreign diet and confined in unnatural environs, the ants carry on without hiccup. Put a handful of leaf cutters in an empty bin with a small piece of fungus and a few leaves and you'll soon see their whole natural structure duplicated. It's just what they do. "Imagine if you took 17 carpenters, 14 masons and 13 electricians, and you put them all together without a foreman or a blueprint. Do you think they could build a house?" says Garrett Suen, a postdoctoral researcher in the lab. "Ants can do this."

The mechanism that enables ants to organize so productively is called swarm intelligence, and Suen got interested in it while working on his master's degree in computer science. He was dumbfounded, he says, by the fact that, even with millions of individuals moving through narrow tunnels and all heading to the same place, ants don't get into traffic jams.

A wince crosses Cameron Currie's face as a soldier ant bites into his thumbnail (above). The ants' strong mandibles aren't their only line of defense. Currie was among the first scientists to notice that the white spots that cover many leaf-cutter ants (right) were antibiotic-producing bacteria that the ants harbored to help keep their gardens disease-free.

"But look at us," Suen says. "Think about even in Madison, when construction cuts down one lane on University Avenue. What happens? It takes 10 times longer to get anywhere. Ants have clearly figured out a way (around) this. And that is clearly an intelligence we call 'lower' intelligence, but really from a computer science perspective, we have not unlocked that secret."

Swarm intelligence can be striking in its effectiveness. For example, when researchers lace maple leaves with a fungicidal agent, the ants soon discover those leaves are killing their fungus, and an announcement somehow goes out to the entire colony. After that, not a single ant brings a maple leaf back to the nest. No one knows how an individual ant identifies threats to the fungus. Or it could be the fungus alerting the ant. It's still unclear how the rest of the colony somehow receives the news. Even though it is operating in plain

THE ORGANISMS ARE LIKE PLAYERS IN A LONG-RUNNING DRAMA, WHERE EACH HAS SOMETHING TO GAIN BY COOPERATING AND EVERYTHING TO LOSE BY TAKING ADVANTAGE OF THE SYSTEM.

sight, caught in the Tupperware bin, it is a mystery how such a complex system keeps humming along.

The answer may be found, Suen says, via genomics. The Currie lab was recently awarded a grant from Roche

pharmaceuticals for 10 gigabases of genome sequencing. That's the equivalent to the complete genetic sequences of three humans. The award is not monetary—it's a service. Currie's lab isolates the DNA and sends it to Roche, where scientists sequence the genome. The result will be a genetic picture of the entire ecosystem.

Once they have the genome decoded for each organism in the system, Currie's lab will be able to use something called microarray technology to see what genes get turned off or on under certain conditions. They can then start tweaking the conditions to see how the ant, fungus, parasite and bacteria all respond to one another. For example, in the experiments where ants identify and avoid tainted leaves, scientists could look at what genes were activated or shut down in the fungus when it encounters the leaf. Then they could do the same for the ant and the parasite to look for similar responses, which will eventually lead to better understanding of what chemicals and stimuli are enabling them to all interact.

"What's really different about this project is that so far genome sequencing has been about understanding the biology of a particular organism," says Nicole Gerardo, an assistant professor of biology at Emory University and one of the co-investigators on the Roche grant. "And what we're asking is can you use genome sequencing to understand the associations between an entire group of organisms." She says taking a wider view will allow scientists to get at the inner workings of systems "we used to see as just cool natural history stories."

The hidden mechanism that most intrigues Gerardo is the ants' use of antibiotics to battle mold in their gardens. She already knows that microbes in the system can recognize each other, which means that there's some kind of chemical communication going on. Unlocking that communication on a genetic level could teach scientists more about how pathogens sense and respond to antibiotics, information that could help improve antibiotic drugs for human use.

But the fascinating aspect of Currie's lab is that no one of these potential applications holds center stage. His team is a melting pot of academic disciplines, where behavioral ecologists work alongside bacteriologists and bioinformaticists. This interdisciplinarity has led to collaborations with units such as the Great Lakes Bioenergy Research Center, which is funding part of Currie's work in hopes of learning how the ants' gardens break down and process the cellulose in plant leaves.

The emergence of these avenues of research are a function, Currie says, of the changes taking place in the way we study life. Science has moved from an era of field work, carried out by naturalists such as Darwin traipsing around in tangled banks, to lab work, where organisms are grown and observed in controlled conditions. Both methods have their drawbacks: Field work was hard to control, but lab work imposed a kind of false reality that didn't capture what was really happening in the environment. Genomics is opening the door to a new kind of science, where you can just bring the whole natural system indoors, preserving the diverse interactions of nature while providing the sophisticated observational tools of the lab.

And that brings an interesting twist in the saga of the leaf-cutter ant. Consider our heroic queen. It is a half year later. Her colony is up and running, boasting a few hundred workers and a fungus garden the size of a baseball. Suddenly, the wall of the chamber gives way. A pair of gloved hands reaches in and gingerly transfers the queen and her garden into a container. Then the queen takes another flight, this time tucked into the luggage of an overhead bin.

When she lands, she finds herself in a Wisconsin lab, unknowingly helping humans uncover the secrets of how to become one of the most successful animals in the world. g

VINTAGE WISCONSIN

By Theresa Lins BS'92

Wine is booming in the land of beer and cheese. Growers are hoping that CALS research on Wisconsin-friendly grapes can help uncork the industry's potential.

If things had played out just a little differently, America's love affair with wine might have started on a scenic hillside overlooking the Wisconsin River. In the middle of the 19th century, a Hungarian count named Agoston Haraszthy planted vineyards on those gentle slopes, hoping to introduce the European tradition of fine viticulture to America. But the harsh winters took their toll on both Haraszthy and his grapes, and after just seven years in Wisconsin he headed west. Eventually, he found his way to Sonoma, California, where he founded another vineyard and helped plant the seeds of California's powerful wine industry. ◆ Today, the fertile hills along the Wisconsin River are again planted with grapes, and Philippe Coquard sees signs that Haraszthy's vision may finally be coming true. Coquard is chief winemaker at Wollersheim Winery, which has operated a vineyard on the banks of the Wisconsin River for 35 years. Winning both national and international recognition for his wines, Coquard has put Wisconsin on the wine world's map. But these days, Coquard has lots of company. Fifty-two commercial vineyards have sprouted in Wisconsin, and interest in viticulture is soaring. And that makes Coquard wonder: Could Wisconsin be known not just as the cheese state, but as the wine-*and*-cheese state? ◆ "Wine and cheese are a natural pairing," he says. "Wisconsin has a history of growing grapes since 1850. Once

At CALS' West Madison research station, gardener Brian Emerson helps student intern Jenna Lind secure young grape vines to a trellis to support their growth, part of the station's new trials of wine grape varieties.

we know what varieties work here, we can grow grapes to make outstanding and recognized wines."

The idea is compelling. Last year, Americans drank up 25 percent of the wine produced worldwide, making the United States the world's leading consumer of wine for the first time. Combine that taste for wine with a growing interest in locally produced foods, and Wisconsin grape growers sense opportunity. "People actively go around the state looking for wineries," says Ryan Prellwitz, president of the newly formed Wisconsin Grape Growers Association. "As our industry expands, people won't have to go to California to find good quality wines."

True, Wisconsin winters haven't mellowed since Haraszthy fled for the coast. But the new crop of Wisconsin wine growers have a one thing the Hungarian entrepreneur didn't: the benefit of research. As part of a partnership with state grape growers, CALS' Agricultural Research Stations have launched a new program to evaluate varieties of grapes that may be best suited for Wisconsin's growing conditions. Supported by funds from the state's Agricultural Development and Diversification Grant program, the trial began in 2007 with the planting of 15 varieties of seedless table grapes. Last year, researchers at three research stations—West Madison, Spooner and the Peninsular station near Sturgeon Bay—added wine grapes into the mix. Four red-wine grape cultivars and three white-wine grape cultivars were planted at all three sites, which were chosen for their differing climates. Another five varieties are being tested at West Madison and the Peninsular to test warmer-climate grapes.

Coquard, who helped get the research project off the ground, is already encouraged. "Grape growers in Wisconsin need information on what can grow in cold winters and hot, humid summers, when to prune, what kind of trellis systems work best for which cultivars, what spray will control fungus, et cetera. We at Wollersheim, with (our) experience, have most of these answers, but what works for us might not work at a different site. We don't have the land or the time to sacrifice vines, either. There are also so many new cultivars available," he says. "We are looking forward to seeing some true experimentation coming out of these trials."

Wisconsin's geography is surprisingly advantageous for growing wine grapes. In addition to deep, rich soils that are conducive to grape vines, our rolling hillsides protect grapes from high winds while allowing gentler breezes to blow through the plants, keeping frost damage at bay. The lakes and rivers that surround the state create a variety of microclimates that can suit the crop quite well. Several vineyards are located near the Mississippi River in Vernon County, with others along the Wisconsin River in Richland and Sauk counties and near

Lake Michigan in Door County.

But geography also presents a challenge. "Grape growing is just so specific to the microclimate you are in," says Julie Coquard of Wollersheim Winery. "It's just a challenge to learn what to do all along the way, how to take care of (the vines)."

Until recently, most Wisconsin grape growers faced those challenges on their own. UW-Madison had done little research on grapes as a commercial crop, partly because the industry's profile was so small. Judy Reith-Rozelle BS'85 MS'88, assistant superintendent at the West Madison Agricultural Research Station, says most growers operated backyard operations and consumed their own grapes. There was little networking or information sharing among growers, she says.

In 2006, Reith-Rozelle met with Philippe Coquard to look into a more formal research program. "When Philippe and I had our first meeting, we wondered if we could get 20 people to show up at an informational session," she says. But a meeting in March 2007 at Wollersheim drew more than 100 growers, convincing the organizers that the interest was there. Growers simply lacked organization.

Last year, growers came together to form the Wisconsin Grape Growers Association to share information and promote the industry. Prellwitz, who grows grapes near Ripon, says the early discussions with the university were integral to forming the group. "We have a lot of people coming into this industry without a traditional agricultural background. There is significantly more support available from the university system than most people realize, and we'll take all of the help we can get," he says. But the relationship is reciprocal. Reith-Rozelle says grape growers have provided lots of advice about planting and pruning their trial vines.

According to a survey done this year by UW-Extension, the WGGA and the Wisconsin Winery Association, there are now more than 240 farmers growing grapes in Wisconsin. Wisconsin vineyards remain small, averaging less than three and a half acres. But in total more than 100,000 grape vines are now growing in the state. Some of the new growers are seasoned farmers who are turning to grapes because of their value. While the initial investment to establish a vineyard can run $12,000 an acre, each acre can yield two to three tons of grapes, depending on the variety. With a ton of wine grapes selling for about $1,200, CALS horticulture professor Brent McCown figures that an acre of wine grapes can return $1,500, about three times the average per-acre return for corn. Table grapes can offer good returns, as well. While Wisconsin has traditionally not grown many seedless table grapes, Reith-Rozelle says their high market value makes them a good choice for community-supported agriculture and farm-to-consumer sales.

But McCown adds that the growth in vineyards also reflects the popularity of viticulture as a hobby. "We have a lot of retirees from Minneapolis and Chicago buying land in Wisconsin and wanting to grow grapes, but they don't have any idea how," he says.

Julie Coquard understands the appeal. "It's part of getting back to nature and enjoying life. Grapes are a romantic crop to grow … At least it looks romantic until you understand how much work it is," she says with a knowing smile.

That's a lesson Lois Sterling can relate to. Sterling, who operates a vineyard in Viroqua, grew up on a dairy farm and never fancied herself a winemaker. Then in 2000, she attended a meeting organized by Tim Rehbein BS'81 MS'87, Vernon County's extension agent. Rehbein was looking to recruit farmers to grow grapes instead of tobacco, and Sterling thought it might make a fun retirement project for her parents. She came away thinking that she might want to give it a try herself. Now, with her husband and her parents, she cares for 2,500 grape vines on a five-acre vineyard.

"It's been so much fun. We've met so many interesting people," says Bonnie Sterling. Lois's mother. "Grape growers are totally eccentric. You have to be eccentric to do this."

As often happens with romance, the Sterlings' flirtations with grapes have led to maternity. "My grapes are my babies," says Lois proudly, and she cares for them with parental attention. To keep deer from eating sprouting vines, for example, the Sterlings hang pantyhose filled with soap shavings from trellises each spring. They have also nailed up old compact discs throughout their fields to create a shiny distraction to avert robins.

The lakes and rivers surrounding Wisconsin create a variety of microclimates that suit wine grapes quite well.

After just two seasons of growth, the grapes at the CALS research stations aren't ready for the winery. But studies of the vines' suitability for Wisconsin's climate are already bearing fruit.

"Each year, there is some new crisis," she says.

But nothing challenges the Midwestern grape grower more than weather. Some of the most popular wines among American consumers—such as Chardonnay and Merlot—are made from grapes that don't fare well in Wisconsin's short growing season. As a result, most Wisconsin's wineries have to import grapes to make their wines.

In the past eight years, however, researchers at the University of Minnesota have bred and released several new varieties of cold-hardy grapes. Grown by a Wisconsin plant breeder named Elmer Swenson, the new varieties include classically Midwestern-sounding grapes such as La Crosse, La Crescent and Marquette, as well as Old World-inspired lines like Foch (pronounced FOE-ish) and Frontenac.

"We now have a Midwest wine industry thanks to these Minnesota-developed cultivars," says McCown. "Funding from the Minnesota state legislature over the last three decades drove this grape research. Minnesota is now reaping the rewards because these varieties are patented, and they are getting a return on their investment in the form of royalties."

But while interest in growing the new varieties is high, little information exists on how the new cultivars perform in Wisconsin. That's why the trials at the CALS research stations are so eagerly anticipated. "We have an important educational role to play because no one has worked with these cultivars before. We can answer a lot of questions on how you manage these varieties, what kind of diseases and pests you're going to deal with, and which varieties you can grow in each region," McCown says.

The stations will publish preliminary results from the trials this fall, and McCown says the findings will be shared with extension agents and growers. Reith-Rozelle anticipates hosting one-day schools for current and potential growers at the research stations to help the industry develop.

But the industry's growth also depends on marketing. While some wineries are already growing the cold-hardy grapes, the names of the wines don't necessarily reflect the new varieties. For instance, Wollersheim doesn't offer a Foch wine, but it puts Foch grapes into its Prairie Sunburst Red and Prairie Blush wines. The WGGA's Prellwitz would like to see the grapes get higher billing. "We want to brand cold-hardy varieties and promote them as much as possible," he says. "When someone walks into a store we want them to recognize these varieties that grow well in Wisconsin."

McCown agrees that Wisconsin wines could come to occupy a special niche for regional consumers. "You could have blends that will make the wines unique to a particular region. For example, wine from the Driftless Area in southwestern Wisconsin would be interesting. I think that's a major part of the future—unique, high value, highly marketable wine," he says.

> "We have a lot of retirees from Minneapolis and Chicago buying land in Wisconsin and wanting to grow grapes, but they don't have any idea how."

But ultimately the choice to embrace Wisconsin wines will be up to consumers. Lois Sterling can recall the days when just the mention of Wisconsin wine drew a laugh or a gasp. "I hope with the WGGA in place everyone will take us seriously," she says. "Even wine people will say, 'That's not Merlot, or that's not Chardonnay.' I say, 'No, we can't grow that here, but wouldn't you like to try some Foch or Frontenac?'" Wisconsin winemakers are betting that soon the answer will be yes.

A bucket of biomass pellets represents opportunity for energy consultants such as Pam Porter.

Greening Business

Energy consultants making it easy bein' green.

No day is typical for Pam Porter BS'82 MS'85. As an energy consultant, she might be advising on public energy policies one moment and finding a good source of wood chips for heating a manufacturing plant the next. The common thread, she says, is "helping clients find answers to the questions they have. That means listening carefully—helping them develop creative solutions."

In the old days, meeting a client's energy needs required little more creativity than flipping a switch. But rising energy costs and growing concern about energy consumption have caused many homeowners and businesses to take a harder look at their energy bottom line.

That's created work for people like Porter, who as owner of P Squared Group helps companies and other organizations find practical ways to become more energy efficient. She might advise clients on everything from more sustainable business practices to how to harness renewable energy sources for electricity and heating fuel. One of her current projects is to work with Wisconsin's Focus on Energy program to implement the state's Fuels for Schools and Communities initiative, which aims to reduce energy costs by switching from natural gas to wood and biomass to heat school buildings.

"Global warming is a crisis/opportunity for our country to make significant and important changes," says Porter, who also serves as the Midwest director of the Biomass Energy Resource Center, a nonprofit that works with local and regional organizations to develop sustainable biomass energy systems. "There are exciting prospects for Wisconsin and the upper Midwest. We have significant biomass resources with wood and croplands that, if done right, can be part of a carbon-light future," she says.

Energy consultants can expect even more business in the years ahead, as Wisconsin and other Midwestern states launch into aggressive campaigns to reduce reliance on fossil fuels. Wisconsin has targeted the ambitious goal of generating 25 percent of its electricity and transportation fuel from renewable sources by 2025, and Governor Jim Doyle says he wants the state to corner 10 percent of the renewable energy market by then.

So what does it take to get a job in the energy consulting business? A good consultant "must have the skills to judge the energy savings or generation potential for a site, knowledge of the technologies available to tap that potential and the training to put those solutions into action," says Patrick Walsh, a professor of in CALS' biological systems engineering department, which has graduated dozens of students into energy-related careers. The jobs can be broad and challenging, but the rewards are powerful.

—Arla Dauscher

The Grow Dozen

12 Alumni who are making a difference in energy

About the Dozen

These 12 alumni represent the stunning depth and breadth of CALS graduates' accomplishments. Selections for the list are made by the Grow staff and are intended to reflect a sample of alumni stories. It is not a ranking nor a comprehensive list. To read more about CALS alumni, go to www.cals.wisc.edu/alumni/

Next issue: Nutrition

Know someone who should be in the Grow Dozen? Email us at: grow@cals.wisc.edu

Images courtesy of source unless noted


UW Athletics
Mike Allen

Mike Allen

BS'05, Agricultural Business Management

Now that he's finished setting records as a kicker for the Badger football team (2001-04), Allen oversees east coast operations for 1st Light Energy, one of the most experienced residential solar electric system companies in the nation. Even in this challenging economic climate, Allen says the solar energy industry and his company have seen tremendous growth. Allen credits his CALS professors with teaching him how to do business by their own example—to care across the board, to be passionate about what you do, and to provide individual attention to your relationships.

Ranjini Chatterjee

PhD'96, Biochemistry

Chatterjee worked as principal investigator at Farasis Energy, focusing on engineering microbes to produce more environmentally friendly fuel from biomass feedstocks. She remains fascinated by the energy of microbes, especially their capacity to generate potentially useful chemicals and the tools and technologies that can be applied to harness them for industry. Currently she works with Genetic Chemistry, a Palo Alto-based company that develops chemical compounds from microbes for pharmaceutical and other industries. Chatterjee is engineering and evolving microbial pathways in yeast to produce antimicrobial chemicals that could be used in drug development and other applications.


Ranjini Chatterjee

Carter Dedolph

BS'87, Construction Administration

If you want to be an Energy Star, Dedolph can help you get there. An energy-efficiency expert for the Wisconsin Energy Conservation Corporation and Focus on Energy, the state's renewable-energy initiative, Dedolph manages the campaign's Wisconsin Energy Star Homes project, which helps builders and homeowners make improvements to reduce energy use and take advantage of renewable resources. Even with the slowdown in home construction, Dedolph says the percentage of energy-efficient homes in the state has never been higher. Previously he worked with Focus on Energy's program for apartments and condos.

Seth Fischbein

BS'93, Bacteriology

Fischbein operates a series of fermenters for Coskata, a next-generation biofuel start-up that makes fuel-grade ethanol from synthesis gas. The process is amazingly feedstock-flexible, as the gas can be made from anything from switchgrass to corn stover to municipal waste. Fischbein runs experiments in small-scale bioreactors to optimize the Syngas-conversion process and screen modified organisms for potential improvements. If any adjustment seems promising, his team works to engineer the process and equipment to suit a large-scale plant setting. If he


Seth Fischbein

Mike Hass

didn't spend his days cooking up fermenters, Fischbein says he would probably have been a chef.

Elisa Graffy

MS'93, Agricultural Economics

Graffy has served as a policy advisor, analyst and departmental coordinator for the U.S. Geological Survey for more than a decade, where she has made a career working on agroenvironmental issues. She explores new ways to address energy issues and brokers interactions between research and policy development in partnership with agencies at the state and federal level along with nongovernmental organizations and universities. Much of her work is centered upon a federal interagency initiative to establish sustainability indicators for biofuels. Graffy helped lead a 2008 team that designed a national system of environmental indicators, which the White House directed federal agencies to pilot with state and nongovernmental partners.

Mike Hass

PhD'78, Biochemistry

Haas is nationally recognized as a leader in biodiesel research. As a biochemist with USDA's Agricultural Research Service, he and his team develop new biodiesel production methods, develop and apply new assays to determine purity, create process models to estimate the operating costs of various production methods, explore new uses for byproducts generated during production, and investigate problems that develop during use of this new fuel in the real world. Formerly president of the American Oil Chemists Society, Haas describes himself as a kid at heart, always waiting for the final bell with his nose pressed against the window so he can go outside to play. In his spare time, Haas organizes and leads teams to restore forests and fields, improving animal habitat.

Mi-Sun Kim

PhD'89, Food Science

Kim began researching bio-hydrogen production 15 years ago through the new and renewable energy research division of the Korea Institute of Energy Research. Now principal scientist for its bioenergy research center, she specializes in bio-hydrogen production from high-moisture content organic waste via anaerobic digestion. Last year, Kim directed the construction of a new 25-gallon reactor where soybean curd byproducts are converted to electricity using a hydrogen fuel cell. Kim's efforts have been rewarded with a number of prestigious honors, including the Korean government's Science and Technology Medal of Merit and the Woman Scientist of the Year award from the Korean Ministry of Science and Technology.

Brad Lystra

MS'07, Life Sciences Communication

Lystra is manager of economic development partnerships for the American Wind Energy Association, where his work is focused on forming alliances on policy advocacy initiatives. Specifically, he works with organizations interested in the economic development opportunities wind brings, offering analysis of the policies that support the creation of wind-related jobs. Lystra's interest in

Brad Lystra

The Grow Dozen

wind power was spurred by a course where he helped install a turbine on an alfalfa farm in Edgerton, Wis. When he's not going wherever the wind takes him, Lystra's favorite hobby is mountaineering, especially in glacial regions of the Cascades.

Scott Pigg

BS'80, Agricultural Engineering, MS'89, Agricultural Engineering and Land Resources

Pigg does field research, program evaluation and technical consulting related to residential energy efficiency for the Energy Center of Wisconsin, an innovative and independent nonprofit that seeks to solve energy challenges through research and education. His recent projects include monitoring the electricity use of home electronics to identify energy-saving opportunities, studying energy use of gas water heaters and effects on air infiltration, and launching a multi-year evaluation of the national low-income Weather Assistance Program for the U.S. Department of Energy. Pigg is currently trying to learn how to ride a unicycle to keep up with his nine-year-old son, who has been riding one for several years.

Renee Rippchen

BS'97, Agricultural Journalism and Dairy Science

As vice president of sales and marketing for BioEnergy Solutions, Rippchen identifies new sources of revenue for dairy farmers while simultaneously helping their farms achieve


Renee Rippchen

reductions in greenhouse gas emissions through "cow power." Based in Bakersfield, California, the company builds methane digesters that allow farms to collect methane and convert it into renewable natural gas. Raised on her family's dairy farm in Richland Center, Wis., Rippchen has been working with dairy producers across the nation to enhance their profitability and add value to the future of their operations her entire life.

Carole Schmidt

MS'80, Water Resources Management, MS'86, Soil Science

At Great River Energy, Minnesota's second-largest electric wholesale supplier, Schmidt manages permit applications for transmission line and associated facilities construction and ensures regulatory compliance. The not-for-profit member-owned cooperative transmits electricity to 28 distribution cooperatives, serving more than 620,000 customers. Schmidt works with the public, natural resource agency staff and regulators to advance projects that avoid or minimize impacts to human and environmental resources. She "love[s] working for a progressive, well-rounded company that actually walks the talk," with a strong environmental policy that emphasizes conservation, compliance, a commitment to continual improvement and community focus.

Kim Zulke

BS'75, Agronomy

Formerly charged with new energy resources at Alliant Energy, where he championed the expansion of the utility's renewable portfolio, Zuhlke is now helping more green-energy projects happen as head of his own consulting firm, which focuses on wind- and biomass-powered energy. He loves that his work gives him the opportunity to team with some extremely talented and creative people passionate about making change happen. When he's not working on energy issues, Zuhlke enjoys taking on land stewardship projects on his 350-acre farm or simply spending time on his tractor, watching things grow around him.


Carole Schmidt

Catch up with …

Jack Newman PhD'01, Bacteriology

AT AMYRIS BIOTECHNOLOGIES, Jack Newman is focused on some of the world's biggest problems. He co-founded the company in 2003 with the goal of creating a more cost-effective treatment for malaria, and after some notable successes toward that end, he has turned his eye on developing new renewable sources of energy. As senior vice president of research, Newman talks about the unique blend of science, idealism and business savvy that underlies the company's lofty goals.

• You've had some enormous successes in your career. Where do ideas this big come from?

I have always enjoyed studying science, but I was inspired to seek a career that played an important role in world stewardship by where I grew up. Cape Cod is one of the most naturally beautiful places in the world. To me, it represents a microcosm of what's happening to all of our planet's beautiful places—an environment fighting a difficult battle with pollution.

• How did you go from there to starting Amyris?

I had been working in bioremediation—using microbes to clean up environmental waste—but there was a gulf between the technology and the marketplace that was fairly impossible to overcome. All the technology in the world really does no good without a viable business model, a way to take that cool new technology out of the lab and apply it into the impactful realm of the marketplace.

While doing a postdoc at the University of California-Berkley I met a few like-minded scientists, Kinkead Reiling and Neil Renninger, that wanted to solve real-world problems. We kind of stumbled into a real-world problem that our science could address. Strains of malaria were developing that were resistant to chloroquine, the reigning malarial treatment. To treat these new, increasingly life-threatening strains, medicine was turning to artemisinin, a pricey compound from wormwood plants that takes 14 months to produce. So we rallied around the idea of synthesizing an affordable alternative as a starting mission for our new company. With help from a grant from the Gates Foundation, Amyris met that goal, and we expect that this product will begin wide distribution within the next few years. Our process will be a stable second source to the plant-derived artemisinin for life-saving drugs.

• How did you synthesize it?

The technology is based on isoprenoids, which are chemical compounds produced by a plant that was cultivated to replace sandalwood as an essential oil when it became expensive and scarce. That's where the company name comes from—amyris is an oil derived from that plant.

• What can we expect next?

Well, we thought about ways to deploy the same technology we used to solve the artemisinin problem. Of the countless possible applications, our new goal was use synthetic biology to engineer a biofuel with more energy and less carbon emissions that could replace the fuel in the engines we use now. We figured out how to do it on paper, then at small scale in the lab. Now we are producing it by the barrel and scaling up in California and Brazil. Within two to three years, we expect this fuel to reduce greenhouse gas emissions by 60 to 80 percent for every gallon of petroleum it replaces.

Five things everyone should know about . . .

Beets

By Irwin Goldman

1 | Beets have a much underappreciated role in history. The vegetable that we call the table beet was a salad crop in Roman times. Farmers in northern climates selected for swollen roots that could be stored over long winters, creating the bulbous plant we know today. But beets are about much more than borscht. When the Napoleonic wars blocked France from obtaining sugar from the West Indies, European scientists turned to beets as a potential alternative source of sugar. These experiments revealed that beets produce sucrose exactly as sugarcane does, and beets were bred intensively for sugar content. Today, the world derives half of its sugar from sugarbeets. Beet sugar may well have played a small role in ending the Caribbean slave trade, as its emergence provided an alternative to sugarcane harvested by slaves.

2 | Today's beets are not your grandmother's root vegetable. Although table beets remain a niche crop in the United States, beet extracts are quite popular in a variety of foods. The red pigment that leaks from sliced beets, for instance, is commonly used as a natural substitute for artificial dyes in ice cream, drink mixes, yogurt and other dairy products, as well as natural-food snacks like Terra Chips. Recent studies have shown the pigment is a powerful antioxidant that can fight cancer and aid the function of your immune system.

3 | They don't really taste like dirt. When your kids turn their noses up at beets, tell them it's not the soil that gives beets their earthy flavor—it's the geosmin. An organic compound produced by microbes in the soil, geosmin gives off a smell like freshly plowed earth or a field after a rainstorm. Human noses are very sensitive to geosmin, and while some people don't like it, others love it. Other foods high in geosmin include spinach, lettuce and mushrooms.

4 | Actually, they're quite good. Unfortunately, many Americans are familiar with beets only as a canned product. But beets, like most root vegetables, are extremely versatile and can be prepared in a number of interesting ways. Among my favorites is to roast beets with a medley of root vegetables. Just chop and blanch roots and cover lightly with olive oil, rosemary and salt, and then roast in an oven at 450 degrees for about 25 minutes, until the outer surfaces are seared.

5 | And don't forget the greens. History demonstrates that both the leaves and roots of beets are useful as edible crops, and both contain substantial amounts of nutrients. Today, though, most Western consumers focus only on the roots, overlooking a wonderful salad vegetable. But many high-end restaurants, such as Madison's L'Etoile, are rediscovering the versatility of the beet and incorporating both roots and greens into their seasonal menus. Frankly, I consider this a monumental leap forward for society.

Irwin Goldman PhD'91 is vice dean of CALS, but he's probably more famous as "the beet guy." Since joining the horticulture department in 1992, Goldman has overseen one of the only table-beet breeding programs in the United States, which has done considerable research on the genetics of beets and their nutritional benefits.

Take the Final Exam!

QUESTIONS FROM ACTUAL CALS EXAMS

Fill out your answers online. Ace our quiz and we'll enter you in a drawing for a gift box of Babcock Hall cheese. Go to www.cals.wisc.edu/grow/ for more details.

Agricultural and Applied Economics:

Which of the following are true in regards to Wisconsin agriculture?

a. Dairy generates more than half of Wisconsin farm cash receipts.
b. Wisconsin Farmers produce more than half of U.S. cranberries.
c. Wisconsin's processing vegetable industry (snap beans, sweet corn, peas, potatoes) is very small by Midwest standards.
d. A and B
e. B and C
f. All of the above

From Agricultural & Applied Economics 320: Farming Systems Management, taught by Paul Mitchell

Forest and Wildlife Ecology:

As you walk inland from a beach in a natural area on the shoreline of one of the Great Lakes, which of the following changes would you most expect to observe?

a. The average depth of the soil would increase.
b. The trees would become shorter.
c. The plant community would become younger.
d. The amount of organic matter in the soil would decrease.

From Forest & Wildlife Ecology 318: Principles of Wildlife Ecology, taught by Jim Berkelman

Dairy Science:

Which breed of dairy cow is associated with the easiest calving?

a. Jersey
b. Holstein
c. Ayrshire
d. Brown Swiss

From Dairy Science 302: Dairy Cattle Husbandry, taught by Michel Wattiaux

Biological Systems Engineering:

Which of the following is not true of fuel ethanol?

a. High octane number
b. Low fuel mileage (compared to gasoline)
c. Clean combustion (low emissions)
d. Easy transportation through a pipeline

From Biological Systems Engineering 460: Biorefining: Energy and Products from Renewable Resources, taught by Xuejun Pan

Food Science:

What foodborne pathogen(s) is/are estimated to be responsible for the highest percentage of foodborne illnesses in the United States, according to the CDC?

a. Staphylococcus
b. Noroviruses
c. Salmonella
d. Escherichia coli (e. coli)

From Food Science 301: Introduction to the Science and Technology of Food, taught by Beth Briczinski

LAST ISSUE: Answers were 1: C; 2: D; 3: D, 4: A; 5: E. Congratulations to UW-Madison student Sam Kanson-Benanav, who was randomly selected from the twelve people who aced our Final Exam and wins a gift certificate to Babcock Hall.

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PIPETTE SHOW

A robotic arm hovers 96 pipettes over sample trays in the Mi*Syn*Bio lab, part of the UW-Madison's Great Lakes Bioenergy Research Center. By automating the work of 10 bench scientists, the machine enables researchers to more quickly screen microbes that may improve the efficiency of biofuel production. For more cool science, visit us online at **www.cals.wisc.edu/grow/.**