glimpse

research *and* creative discovery

Clemson University

spring 2013

Cracking the case of creativity.

shattered

Shattered, from the series *Crushed, Burned, and Shattered, 2012,* by Christina Hung, is a panorama micrograph of a gardenia petal and broken microscope slide. For Hung and others you'll meet in these pages, the energy of science fused with art can break through the safe and ordinary to create something new. Page 13.

glimpse

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Spinning its delicate web, this golden orb-weaver will soon wind up in the hands of Michael Ellison's students, who will milk it for silk. A flexible material with herculean strength for its weight, spider silk has yet to yield the secrets of its remarkable structure. That may be changing, and the results could yield new materials with broad applications. For more, see page 30.

in this issue

Connecting the dots

The last word you might expect to find on the cover of a research magazine is *creativity*. Somewhere along the line, creativity came to seem fuzzy and soft—a topic for the humanities, perhaps, but not for the clear-eyed realm of science and technology. For several decades now, a chasm has yawned between these two cultures and their two ways of understanding the world. At Clemson, we are bridging the chasm. *Glimpse* is a magazine of research *and* creative discovery because creativity matters, in every corner of our society.

These days, we hear a lot of talk about lagging test scores in science and math, and how they might presage a decline in American competitiveness. Yes, we must find ways to equip our students with the technical skills they need for success in the new economy, and at Clemson we are doing just that. But when you ask business leaders what they value most, they are likely to say, "creative thinkers and problem solvers."

Here is one quote from David Attis, writing for the Council on Competiveness: "Companies say that the skills they find most valuable—collaboration, communication, creative problem solving—are not typically found in science and engineering graduates." Here is another from the late Steve Jobs, cofounder of Apple, as quoted in *Wired* magazine: "Creativity is just connecting things," he said. "…A lot of people in our industry haven't had very diverse experiences. So they don't have enough dots to connect, and they end up with very linear solutions without a broad perspective on the problem. The broader one's understanding of the human experience, the better design we will have."

How do we instill that broad perspective? In part, we do so by asking our students and our faculty members to connect some new dots. We ask them to reach beyond their academic disciplines, beyond their comfort zones, and experience the world from other points of view. In these pages, you will read how Catherine Paul in English collaborates with anthropologists and mathematicians, how Christina Hung in art is working with bioengineers, and how Lesly Temesvari in biological sciences reaches out to people in math and behavioral science. In engineering, Joshua Summers pushes his students to read broadly, study languages, and learn to draw—to give them more dots to connect.

None of this is easy. Any time we venture off the beaten path, we put ourselves at risk. As David Brooks has written, in the *New York Times,* "Creative people don't follow the crowds; they seek out the blank spots on the map… Instead of being fastest around the tracks everybody knows, creative people move adaptively through wildernesses nobody knows."

Creativity, as we see it, is not soft and squishy. It is as edgy, unpredictable, and prismatic as shattered glass. Sometimes, there is no breakthrough without actually breaking something. But destruction is never the goal. It is only a first step toward making something new.

R. Larry Dooley
Interim Vice President for Research

zoom in


Allisyn Miller

Cloaked in green, Molana Abbey was crumbling, and Ireland was losing a witness to history.

Detectives at the abbey

On what centuries ago was an island in the Blackwater River stand the ruins of thousand-year-old Molana Abbey. Roofless for centuries, its upper stone courses have tumbled to the ground, some of its arched windows have collapsed, and other sections of wall seem ready to fall. If it is to survive for another thousand years, Molana Abbey, one of Ireland's most important historic ruins, needs help.

Last summer, eight graduate students in the Clemson's Master of Science in historic preservation program spent two weeks at the abbey, taking measurements, collecting data, and drawing sketches. With the help of their professor and program director, Carter Hudgins, they studied how the abbey has changed since its construction and how best to secure its stabilization and conservation.

Their goal was to decipher the site's structural evolution from religious abbey to a private residence to a ruin. Founded in the sixth century, the abbey played an important role in the spread of Christianity in Ireland. Remnants of the abbey's original buildings, all of them timber, were replaced by stone buildings. The oldest surviving portion of the abbey, the nave of its church, was built in the eleventh century. Most of what remains is a result of significant expansion during the fourteenth century.

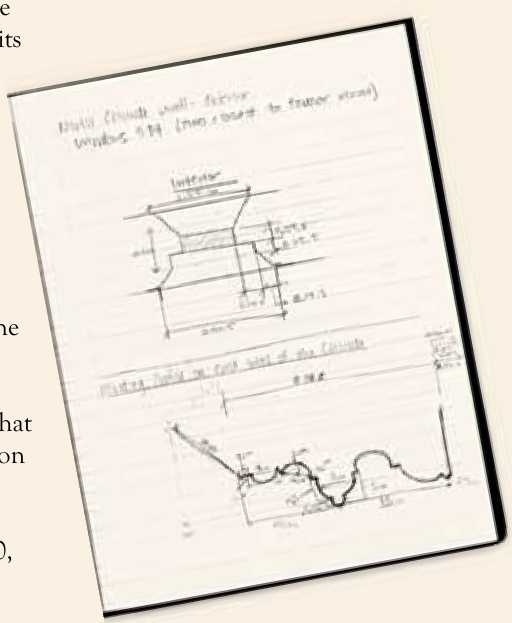
After Henry VIII dissolved the monastic orders between 1536 and 1540, he distributed former canon lands to his allies and supporters. When Queen Elizabeth I granted extensive holdings in the Blackwater River Valley to Sir Walter Raleigh, one of her favorites, Molana and its associated lands were among them. Much of Raleigh's fame today stems from his unsuccessful efforts to plant an English colony on Roanoke Island in what is now North Carolina. One of the leaders of Raleigh's second Roanoke expedition in 1585, Thomas Hariot, rented "the abbey house of Molana" from him.

From his observations as a cartographer, surveyor, scientist, and linguist for the second Roanoke expedition, Hariot wrote *A Brief and True Report of the New Found Land of Virginia*, which shaped perceptions of the New World for centuries after its publication in 1588.

So for the Clemson team, Hariot's brief residence at the abbey gave the project special significance, and they were careful to document the ruins, recording the current condition and deciphering the abbey's architectural evolution. The students' research revealed how changes in ownership affected the landscape and the abbey's form and use from the eleventh century to the nineteenth, when new owners transformed the ruins into an ornamental garden folly.

Spanning the centuries

For Hudgins and his students, summer research in Ireland offered a rare chance to trace structural alterations made at a site over a millennium. "It was pretty crazy to work on a building with four building phases that spanned centuries," says Mary Margaret Schley, a student in the program.



A page of field notes from Pam Kendrick.

Using a total station, an electronic surveying instrument, and hand measurements, the students prepared documentation drawings of the site and its buildings, techniques they learn during their first year in the program. With that information, the students will formulate a plan they will present to the owner of Balllynatray Estate, the property that contains the abbey, and to authorities responsible for ancient monuments in Ireland.

"Putting on detective lenses and picking out which stones look different or out of place is not always easy, but when you find a clue, like elements of a former door or window arch, it's a thrill," says student Neale Nickels.

"It was difficult at first to wrap your mind around drawing and measuring crumbling facades and interiors," Schley says. "We quickly realized that our traditional technique of segmenting the structure and dividing into teams would be the best way to handle the documentation." The group worked with an American archaeologist who has studied medieval sites in County Cork for three decades as well as Irish archeologists.

While the students concentrated on their drawings and observations, Hudgins, along with program coordinator Allisyn Miller, completed a photographic survey of the abbey. Later, using AutoCAD software, they created perspective-corrected photo mosaics of the ruin.

"It was a challenge working with materials—stone architecture—we don't see in Charleston at all," Hudgins says.

The Clemson team will recommend that sections of the abbey be reconstructed, Hudgins says. They will also recommend removal of the ivy that covers much of the structure as well as shrubby plants and small trees growing out of the ruins.

"The amount of ivy growing on practically every surface became problematic when measuring and photographing, but we had to be careful to not remove anything for fear that we would harm the building underneath," says student Liz Shaw.

When not working on the abbey, the group visited Irish towns and archaeological sites—among them Tintern Abbey, Mahon Waterfalls, Blarney Castle, and Kinsale—that helped place Molana in the broad sweep of Irish history.

"The landscape was even more breathtaking than I had anticipated and local residents were so welcoming and sincerely interested in what our project involved," Shaw says.

The students say they left Ireland not only with a greater appreciation for historic preservation but of Irish culture and history, and even its weather.

Carter L. Hudgins is director of the graduate program in historic preservation. Caroline Stec is a senior majoring in English and publication studies with a minor in political science.

—Caroline Stec

A careful accounting

Above: Carter Hudgins analyzes the abbey's interior with student Liz Shaw.

Right: Pam Kendrick takes the measure of a tower.

Below: The entire group on their last day at the abbey. From left: Carter Hudgins, Neale Nickels, Rebecca Quandt, Julia Tew, Mary Margaret Schley, Liz Shaw, Laurel Bartlett, Pam Kendrick, Allisyn Miller, and Eric Klingelhofer.

Laurel Bartlett

Dan Noonan

This time, the foe is corrosion

On April 12, 1861, Confederates opened fire on Fort Sumter in South Carolina's Charleston Harbor, unleashing what historians have said was the longest bombardment in the history of the western hemisphere. Artillery battered the fort for thirty-four consecutive hours before Major Robert Anderson and his Union forces surrendered.

A century and a half later, traces of the battle remain. Under a Cooperative Extension Studies Unit agreement, Clemson University Restoration Institute's Warren Lasch Conservation Center and the National Park Service have teamed up to safeguard Fort Sumter and nearby Fort Moultrie, along with their architecture and historic metal artifacts.

Last December, Clemson conservators worked meticulously to preserve three Union shells implanted in the masonry wall at Fort Sumter, silent reminders of the estimated forty-five thousand artillery rounds fired at the fort during the five years of conflict.

Liisa Näsänen, a conservator who has managed the collaborative project at the forts since 2009, ultimately decided to preserve the artillery shells within the fort's wall since removing them may have further crippled the nineteenth-century structure. These shells had to be preserved in place, a challenge quite different from the conservation of objects transportable to the best location and conditions.

Näsänen and her team removed as many salts from the metal as possible, hindering active iron corrosion, and then dried the shells before applying a material to help consolidate the iron on the shell to prevent further damage to the metal.

Lasch Center

A contractor applies a polyurethane topcoat to a 13-inch seacoast mortar tube.

Conservation, shell by shell

Clemson and National Park Service research aims to develop assessment, treatment, and maintenance protocols applicable to the entire collection of weaponry at Fort Moultrie and Fort Sumter. The idea is to preserve the forts' cultural heritage—including the cannons, artillery platforms, doors, railings, steps, and many small artifacts now in the park's museum collection.

The conservators admit that protecting objects from outdoor conditions is a challenge.

"It's always something we have to battle with outdoor projects," Näsänen says. "We have to look at the humidity and the temperature and factors like that. We have to not only look at the artifact itself, but also the conservation materials we use to make sure they are compatible with the object and the environment."

Today, the shells are visible to the 325,000 people who visit the fort each year.

The major part of the first phase of the Lasch Center collaboration with the National Park Service was dedicated to assessing the two forts, setting priorities for treatments and conservation protocols based on a complex set of factors such as condition assessment, results from analytical testing, and the historic significance of the item and its need for treatment. Six cannons inside Fort Moultrie and at its cannon row were in urgent need of care, as were several architectural items. Stéphanie Crették, the Lasch Center's chief research scientist, collaborated with Näsänen, providing analytical and coating expertise.

High-tech preservation

Although major artifacts at Fort Moultrie were preserved using traditional conservation methods, several smaller iron artifacts from the park's museum collection were conserved using subcritical fluid technology to stabilize the corroding iron. (See "Ridding metal of salt," Fall 2012 *Glimpse*). So far, five rare Civil War artillery shells and nine other artifacts have successfully undergone this conservation method. The National Park Service sponsors and participates in this state-of-the-art preservation technique, developed by Néstor González-Pereyra, a chemical engineer at the Lasch Center.

Now under way, the project's next phase homes in on the conservation needs at Fort Sumter. Artifacts there will mostly require conservation in place. The fort is in the middle of Charleston Harbor, and moving artifacts such as cannons from the fort to a conservation lab would involve risky, expensive, and complex logistics.

These projects with National Park Service have not only supplied valuable information to the park staff but have also provided a number of Clemson students with real-world training and experience in caring for the nation's cultural heritage.

–Brian Mullen

Work described in this article has appeared in "Coating Challenges in Cultural Heritage Conservation," written by Stéphanie Cretté and Liisa Näsänen and published in the journal Coatings Tech, *2012. Brian Mullen is the director of research communications in Clemson's Office of Public Affairs.*

zoom in

Lasch Center

Ray Stanyard

Help for embattled forts

Using technologies developed at Clemson for conserving metal, conservators at the Warren Lasch Conservation Center are working to protect artifacts from Fort Sumter and Fort Moultrie.

Above: A thirteen-inch seacoast mortar tube before treatment at Fort Moultrie's Cannon Row.

Left: Liisa Näsänen, a conservator who manages the project, works on an artillery shell in a laboratory at the Lasch Center.

Dysentery's life raft

In regions with poor sanitation, amoebic dysentery delivers gut-wrenching misery to about 50 million people worldwide. The perpetrator is a protozoan, *Entamoeba histolytica***,** one of the world's top three parasitic killers.

"Approximately two point six billion people worldwide do not use modern sanitation practices, and eight hundred and eighty-six million do not have access to clean water," says Lesly Temesvari, professor of biological sciences. "The risk for getting this disease is substantial."

With thirteen years of sustained funding from the National Institutes of Health and the National Science Foundation, Temesvari has been studying the biology of *Entamoeba*, probing for a weakness in its complex cycle of life. She has found, in a membrane that surrounds the parasite, one likely suspect: cholesterol-rich areas known as lipid rafts. Apparently, *Entamoeba* uses proteins in the rafts to thrive, reproduce, and attack its host.

Temesvari's lab is connecting the dots in a chain of events that lead to amoebic dysentery. The parasite, she explains, secretes proteins that degrade the mucous lining of a human intestine, which allows them to adhere to the host's intestinal cells. This adhesion triggers biochemical reactions in the parasite that rely on the parasite's rafts, an attack that eventually perforates the intestine, giving the parasite entrance to the circulatory system. Once in the bloodstream, *Entamoeba* can infect the liver, brain, and lungs.

In a related project, Temesvari's lab has found that bubble-like vesicles within cells traffic proteins between parasite and host. "We are trying to understand the molecules that assist in this trafficking," she says.

Sorting out such molecular mechanics may help Temesvari and her colleagues find ways to prevent infection or interfere with the parasite's progress. Because some of the *Entamoeba's* lipid-raft proteins differ from those in humans, it may be possible to target the parasite's proteins without harm to the host.

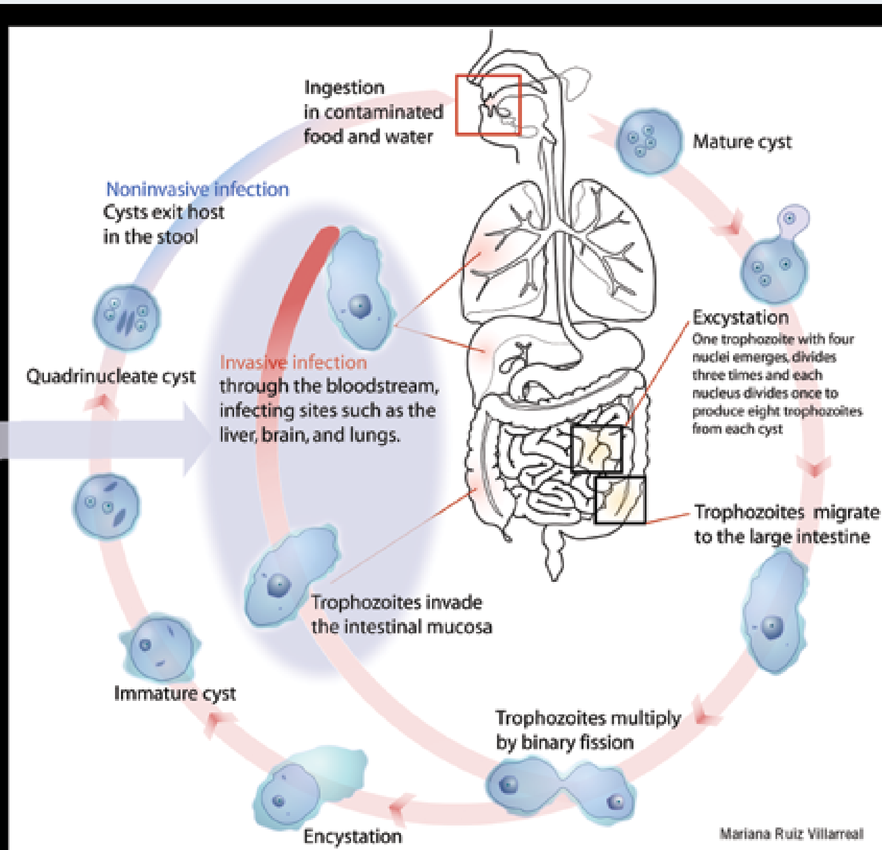
"I am hoping that we may be able to identify some target for a vaccine or a new drug or therapy," she says.

The effort will get a boost this year, as Temesvari moves her lab into Clemson's new life sciences building, whose top floor will be devoted to studies of *Entamoeba* and other parasites enclosed within membranes. The move will help Temesvari interact with colleagues Kerry Smith and Cheryl Ingram-Smith, both of whom also study *Entamoeba.*

"Being in close proximity with these scientists will be very beneficial for all of us," she says.

Lesly A. Temesvari is a professor of biological sciences, College of Agriculture, Forestry, and Life Sciences. Kerry Smith is a professor and Cheryl Ingram-Smith is an assistant professor, both in genetics and biochemistry, College of Agriculture, Forestry, and Life Sciences.

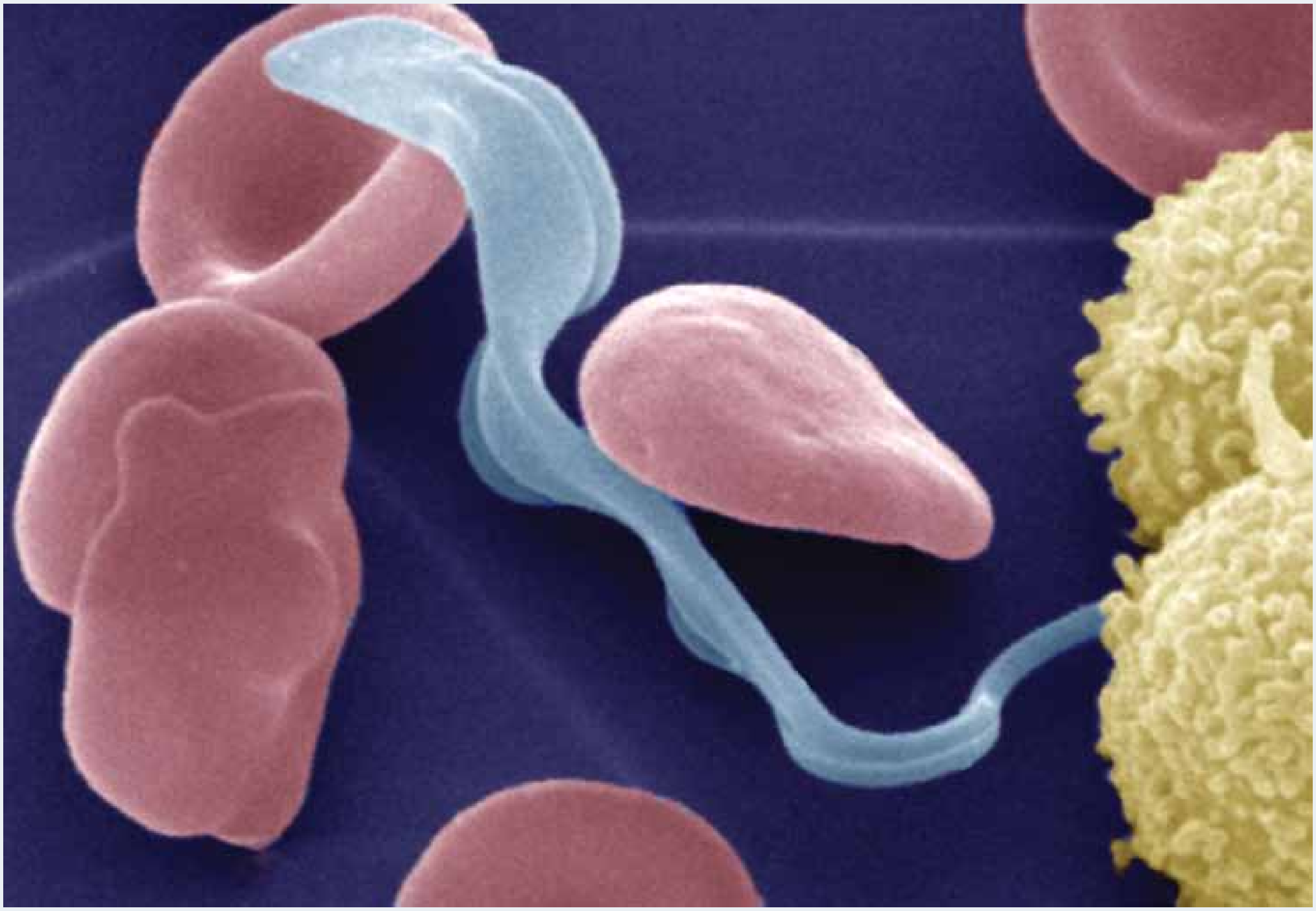
–Katie Ward and Neil Caudle



a cycle of invasion

To home in on the cause of dysentery, Lesly Temesvari's lab concentrates on the invasive stages of the parasite's life cycle (shaded oval).

Michael Duszenko, University of Tubingen



Colored electron micrograph of the bloodstream form of the *Trypanosoma brucei* parasite (light blue) that causes African trypanosomiasis (also called sleeping sickness) in humans in the presence of erythrocytes (red) and lymphocytes (yellow). After infection of the mammalian host by bite of the tsetse fly, the parasite lives the bloodstream before it invades the central nervous system and the brain.

Waking from the nightmare of sleeping sickness

Jim Morris has found a way to kill the deadly parasite, at least in the lab. The next steps are crucial, for Africa and for science.

You've heard, "Starve a fever," but what Jim Morris is trying to starve out is African sleeping sickness. The parasite that causes African sleeping sickness is the microscopic *Trypanosoma brucei.* And it may have a weakness.

"There's a very well-tuned relationship between parasite, fly, and mammal," Morris says. When the tsetse fly bites a mammal for a delicious blood meal, it sucks up parasites especially adapted for life in the fly. The parasite then colonizes the fly's gut. Later, some parasites will migrate through the fly's tissue to its salivary glands. The next time the fly takes a bite out of someone, it'll also inject parasites adapted for life in a mammal. The cycle starts over again.

"So the idea is," Morris says, "when the parasite is migrating through the tissue of the fly, it encounters some molecule that signals the parasite is about to enter a mammal. It's quite clear that this happens. But what the trigger is, that we don't know."

When Morris was a postdoc at Johns Hopkins, he used a

Craig Mahaffey

Jim Morris (right) with undergraduate researcher Katie Gray.

genetic trick to identify genes involved in an important and well-understood step of the parasite's development. And this led to them identifying genes involved in the environmental sensing. One of those genes was a metabolic enzyme, hexokinase, a protein involved in digesting food. So, the theory went, by measuring the amount of food in its environment, the parasite was able to figure out where it was.

If scientists can figure out how to disrupt this protein, they'd be able to starve the parasite, prevent it from breeding its army of clones, and trick it into believing it was safely in a fly so that our own immune systems could ambush it with impunity. That would be one effective weapon in this war.

"So the million-dollar question is how does this all work," Morris says, "and can we find a molecule that will inhibit this enzyme?"

Cells like ours

Like many other challenges, that sounds easier than it is. The parasites are eukaryotes, higher organisms like us, and that means they operate using much of the same equipment as your standard human. Morris encounters problems similar to those seen in cancer research: how to kill cells that are similar to their human host without killing the host.

"Historically, the drugs for this have been really terrible," Morris says. "The drug that you take right now for late-stage sleeping sickness kills about ten percent of the people who take it. It's that poisonous. It's a tricky game, a real challenge for everyone in our field."

Another drug, eflornithine, isn't always even effective. Morris says, "The average patient needs several hundred grams of the stuff administered four times a day by IV. Imagine transporting that into sub-Saharan Africa. Finding a clean needle is challenge enough, but administering it four times a day sterilely…"

He fades out. It's clear what he means. It sounds like any doctor's nightmare.

If a person infected with the disease goes untreated, the parasites will infect the person's brain. "It's clear that parasites in the brain are bad for you," Morris says. "That's why you get late-stage disease where people are incoherent, drool, have very disrupted sleep patterns—hence the name—and your immune system mounts a very strong response. So is it your body killing your body or the parasite itself doing damage? That's a very hard thing to distinguish."

The good news about all of this is that the enzyme these parasites use to digest glucose is different from our own; that means it's possible for Morris to find a compound that kills the parasite but not the person. He started his search with two hundred and twenty thousand molecules. His collaborators at the University of Virginia used robots to test the molecules' effectiveness against the parasite's enzyme. The best of these molecules were then passed on to other collaborators, organic chemists at the University of Kansas. The chemists "decorated" the molecules, adding or subtracting additional molecules, to see if that made the compounds more or less effective. The compounds that were effective against the parasite's enzyme, hexokinase, they returned to Morris.

"Unfortunately, none of them killed the parasites," Morris says. "That was a shocking finding."

But Morris spoke with his collaborators, the organic chemists, who told him that they could tell, by just looking at the compounds, that they wouldn't get into cells. The chemists set to work at decorating the molecules again, to make them more appealing to the parasites. Morris says, "Recently, we've received third-generation molecules, which now have modifications to improve cell penetration. We are now killing the parasites."

A tough customer

But his work isn't done yet. He has to prove that the compound works by inhibiting the parasite's hexokinase enzyme. Morris says, a little wryly, "That's a very difficult experiment. And we're doing it right now, of course."

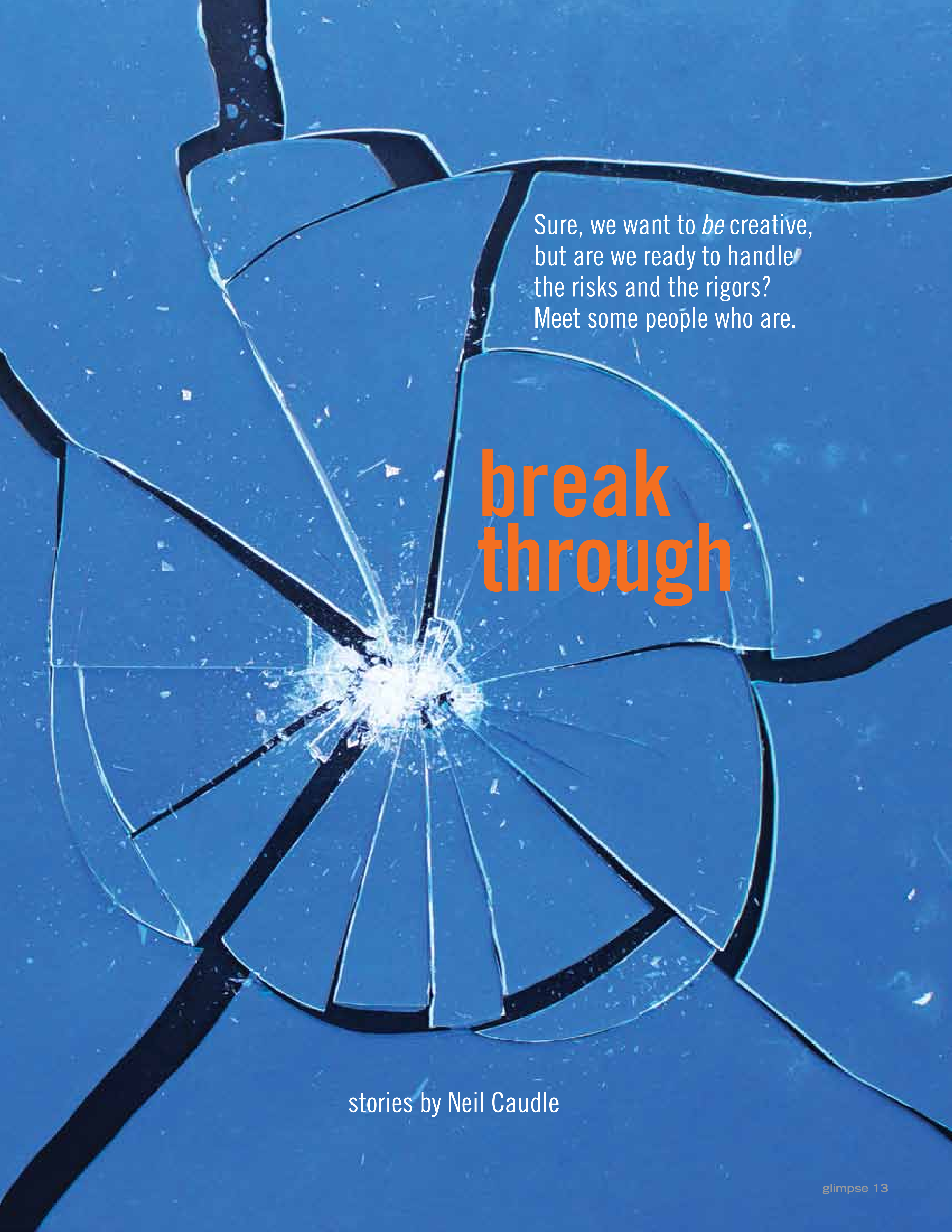
In order to test the drug, Morris essentially has to create a parasite control group—i.e., he has to make, in his lab, parasites that are resistant to the compound. There are two ways he can do this: One way is to mutate the parasite so that it creates a resistant version of the hexokinase enzyme, and if he can do that, this would spell bad news because it would mean that it would be possible for the parasites to develop a resistance in the wild; the second way is for him to genetically modify the parasite so that it produces extra hexokinase and it could therefore survive a normal dose of the drug. In parallel to all of this, there's also a long-term experiment running in his lab that exposes the parasites to low dosages of the drug over time; if they then develop a resistance, he'll be able to sequence the survivors' DNA to see how they did it.

"What I hope is that we never generate a resistance," Morris says, "but I think that's unlikely given how tough these guys are."

After this, he'll be going on to larger studies, measuring how the drug works in animals, and if they're successful, he'll be collaborating with a medical school. But, he says, "If we can cure animals that are affected, you have something that works in vivo. That's a home run."

James Morris is a professor of genetics and biochemistry in the College of Agriculture, Forestry, and Life Sciences. His research is funded by the NIH, the Clemson University Honors College, and Creative Inquiry. Jemma Everyhope-Roser is the assistant editor of Glimpse.

– Jemma Everyhope-Roser



Sure, we want to *be* creative, but are we ready to handle the risks and the rigors? Meet some people who are.

break through

stories by Neil Caudle

Jumping the ditch

Catherine Paul ventures into science and returns with some clues about the nature of creativity.

If there were a shelter for abused terms, *creative* would find refuge there. The word gets knocked around. Accounting is creative if it bends the rules. Aunt June is creative if she over-decorates her cakes.

And yet we yearn to *be* creative. We sign up for painting classes, buy expensive cameras, fire up the kiln. We dream of the time when we can dump our day jobs and hammer out novels, weld sculpture, reinvent rock 'n' roll. While our workaday lives entangle us with, ugh, other people, the urge to create is personal, individual, and *ours*. Creativity, as we imagine it, is a kind of sanctum, a comfort zone where we can safely be ourselves.

Catherine Paul has a different idea. No safety. No comfort zone. And lots of other people.

Before we set about undermining the very foundations of the creativity culture, on which rest so many hopes and dreams (not to mention large sectors of the economy), we should issue the following disclaimer: There is absolutely nothing wrong with decorating cakes.

But the kind of creativity Paul has in mind doesn't sugarcoat culture. It rips it apart and bakes a new layer from scratch. At first, people generally fear and reject that kind of change. Think of the near riot that broke out in 1913 when Igor Stravinsky debuted *The Rite of Spring*. And the music of composer John Cage, not exactly easy listening, aroused as much anger as admiration, when it was new.

So creativity, Paul says, does not necessarily yield a work that everyone instantly recognizes as good. In many cases, it reconfigures our idea of what good *is.* And that can be painful.

"It completely unsettles you," Paul says. "Even with music that we think of as conventionally good, we've forgotten how to hear it. We forget to notice how radical Beethoven was, in his time."

Paul doesn't just study this kind of creativity; she lives it. She is a professor of English, but of late she has abandoned the well-trodden path she had followed since graduate school and has gone crashing off into the underbrush to consort with anthropologists, biologists, and statisticians. In fact, you might say that Catherine Paul is destroying her career.

To create it.

Learning from the dead

I inquire about her decade of labor to understand Ezra Pound's sordid affair with fascism. She winces. "That's a project that I'm *so* ready to lay to rest," she says. "It isn't where my head is anymore."

Okay, how about her study of William Butler Yeats's loopy infatuation with automatic writing, involving his wife and spirits of the dead?

That one makes her smile. Paul is interested in how people learn from the dead. The poems of American Indians, she says, are full of old bones, as are the laboratories of anthropologists and medical schools.

At the marrow is the question of meaning and how we make sense of the world. In this enterprise, the usual toolkit of literary analysis has lost some allure for Catherine Paul. She so admires great poetry that she dreads to submit it to invasive surgery, to treat it like a patient etherized upon a table.

"I love W. H. Auden," she says, "because I just think his poetry is so moving and so powerful, but I don't know that I have anything to contribute to it."

And so, at the stage of her career when she might have settled comfortably and respectably into literary scholarship for the long haul, Paul has opted for open revolt.

"I finished the book about Pound and found myself exasperated with literary scholarship," she says. "I just wasn't finding a way to ask and answer new questions that were interesting to me. I was so frustrated that I was even thinking about leaving the profession and going back to graduate school in anthropology."

This kind of talk from an English professor will seem heretical to some, a crisis of faith to others. But Paul hasn't given up on the study of English. She thrives on helping her students experience the life-altering force of great literature. Nothing has shaken her faith in that force.

In her scholarship, though, she wants to break new ground. To do so, she has ventured away from her comfort zone.

Pack rat pee

It began, more or less, with pack rats and their pee. Paul had been reading about how scientists in the Southwest were finding a well-preserved record of the environment and ancient human life in pack-rat middens. A pack rat, she learned, pilfers whatever it can from its surroundings, including from human habitations, and brings the loot back to its nest, where it pees all over it. Eventually, the viscous urine crystallizes, sealing the stash in an amber-like preservative.

For Paul, the notion of using a pack-rat midden to piece together stories about the past was irresistible. Here was a new kind of narrative, mostly uncharted by literary types.

"I got very interested in biological anthropology," she says, "and the idea, for instance, that in human bones you can read a story of what that person's life was."

But she didn't know enough science to master the narrative. She would have to go back to school.

And so, after having attained the lofty status of tenured professor, Paul took a seat among the undergrads again. It was humbling and a little scary; it was also a rush. "A colleague of mine teases me about being an adrenaline junky for school," Paul says.

She had done this kind of thing before. To understand Ezra Pound's life in Italy, she studied Italian at Clemson, working her

At first, creativity may resemble destruction.

Catherine Paul hasn't abandoned literature. She reaches into science for insights that help her read poetry anew. But that can mean breaking with carefully tended traditions and piecing together new patterns from the

shards.

Neil Caudle

Forensic Anthropology Center and University of Tennessee

Learning from the bones: Catherine Paul at the University of Tennessee's "Body Farm."

way through Italian 101 and 102, 201 and 202, and 302. She hung around long enough that the Italian department put her to work: She and one of her professors, Barbara Zaczek, collaborated on a couple of articles.

Altruism and the monster

But that was in another life, when Paul was still in the throes of Ezra Pound. For her new life, the subject would be science—biology, ecology, and more. In a class on the evolution of human behavior, taught by Lisa Rapaport, Paul wrote a paper about *Beowulf*, the epic poem and masterpiece of Old English. In the paper, she tallied the evidence for altruism, counting the times people in *Beowulf* played nice with one another when they had no expectation of reward. Rapaport liked the paper but thought it lacked statistical rigor. So she took Paul to see Patrick Gerard, a professor of mathematical sciences, who had been helping Rapaport with statistics in her study of New World monkeys.

Paul remembers the first meeting in Gerard's office: "So he was helping Lisa with her monkeys, and I was there too, and he said, 'What are you working on?' And I said, 'A study of *Beowulf*.' He took his glasses off and said, '*Excuse me?*'"

Before long, Gerard and Paul were having long conversations about, for example, whether to count acts by Grendel, the monster, in their tabulation of human behaviors.

"Patrick speaks a different language than I do," Paul says. "We set up a database, and we'll say 'this is the question we want to answer,' and he types a bunch of stuff into this program, and it shoots out results, which he can just *think* in, but I can't. So we're constantly translating back and forth, and it's been astonishing."

This collision of academic mindsets propels Paul, for better or worse, into territory strange and new. Will the work yield a paper worth publishing? Will it inspire other humanities scholars to jump the ditch into science and math? Too early to say. But the excitement and sense of adventure are just what she had been lacking, before she went AWOL from Big Lit.

Will her quest be truly creative? And what exactly *is* creativity, anyway? How can we know it when we see it?

These days, Paul is obliged to ponder such questions. She serves as one of seven creativity professors, so appointed by the College of Architecture, Art, and Humanities. Job requirements for this gig, which supplements her regular work, are a little fuzzy, but they seem to entail hanging out with scholars and artists from various disciplines to kick-start creative ideas.

So this route to creativity leads us back to the moiling, roiling realm of other people once again. Can't we just go it alone? Don't most great creative works spring intact from the depths of a solitary soul? No, probably not, Paul says. If you follow to its source the trail of creation, you very often find another set of tracks. A patron, perhaps, or an editor. A spouse or partner who toiled in obscurity. An antagonist. A foil. A mentor. An apprentice. A muse.

And even without the direct contribution of another, the creative act does not occur in a void, Paul says. It needs the context of culture, even when the act *defies* its culture.

The story in the bones

The necessity of context is just as true in science as it is in the arts, Paul says, and breakthroughs in science are very often creative acts that buck the status quo. Paul has been studying one such event: the discovery by Donald Johanson and his team (including Maurice Taieb, Yves Coppen, and students) of perhaps our most famous human ancestor, an australopithecine named Lucy.

Lucy's discovery ripped up and rewrote a goodly chunk of prehistory, sometimes to fierce opposition. But it also relied heavily on decades of work by many scientists in multiple disciplines. Johanson and a student, Tom Gray, may have been the first to glimpse Lucy's fossilized arm bone gleaming white in an Ethiopian gully, but the fragment would have meant very little if the scientists had not been so well schooled in the knowledge of their field and so gifted at telling Lucy's story.

Even in science, discovery is inseparable from narrative, Paul says. What scientists say about their discoveries, and the stories they weave from and about their findings, represent a mighty continent of influential literature, mostly unexplored.

Paul has begun her own exploration of that continent, reading what Johanson and others have to say about Lucy.

"One of the things I found in those papers that I thought was surprising is that Lucy seems to have had a significant spinal malformation that would have been disabling to some degree," she says. "Not being a scientist, I was surprised that the papers were just sort of glossing over this, and it wasn't until much later that I actually found a paper that tried to get into it and figure out what was going on. So I said, 'Why are they glossing over this?' And my husband, who has a science background, says, 'Because they don't know what it means yet, and they can't talk about it until they know what it means.'"

But for an English professor trained to read between the lines, probing old bones for new meaning is exactly the point. "Why," she asked, "has the fact that our most famous human ancestor was a disabled woman not been part of our conversation?"

Sharing the load

Paul took the question to Lisa Rapaport, her biology professor, who pointed out that collaborative care—helping those who can't care for themselves—relates to cooperative breeding, which is how some but not all primates help one another raise their young.

"Lisa was saying that once we were working together to take care of our young, then we were more likely to work together on other things, and then we were more likely to make the kind of advances that led to *Homo sapiens*," Paul says. "So if *Australopithecus afarensis* were taking care of each other to the point where Lucy could survive to be the age when she died, then that means cooperative breeding may have been happening earlier than people had thought, and that hasn't been documented."

Paul's take on Lucy isn't ready to publish yet, but it's a topic she'll pursue. She thinks that humanities scholars like her can help demystify the stories of science for citizens and consumers. This is crucial, she says, in a society driven by science and technology.

"In our culture, if you're not a critical reader, you're being snowed," she says. "We should teach scientists to be better writers and humanists to be better readers of science."

The pursuit of creativity may include cracking a masterpiece with statistics.

Statistician Patrick Gerard helps Paul reveal patterns of altruism in *Beowulf*.

Was Grendel the monster ever altruistic?

Neil Caudle

Craig Mahaffey

Catherine Paul with a model of Lucy's skull. "Why," she asks, "has the fact that our most famous human ancestor was a disabled woman not been part of our conversation?"

There will be people from both sides—from the humanities and from science—who will shudder at the notion of contaminating one with the other. For some, interbreeding of that sort is strictly taboo. But taboo is a fine place to look for creativity, Paul says. Taboo is a place where the culture pushes back and pushes hard. And creativity, it seems, is a very pushy business.

Fighting for every line

Sometimes the pushiest force in a creative struggle may the form of the work itself. Take poetry, for example. Done well, rhyme and other formal conventions can be fiendishly difficult to manage, forcing the poet to fight for every line.

"I'm a fan of form," Paul says. "The fact that you've got something pushing back forces you into territory that you didn't necessarily know about. And I think that's true of any kind of work. We've been talking about poetic kinds of form, but I suspect that it's also true in the kind of forms that scientists deal with."

In some circles, creativity has come to mean the outright rejection of established form. Today, it may actually be socially riskier for artists to conform to rules and conventions of form than to scrap them. But form and craft, Paul says, are not the enemies of creative work.

"I buy the idea that we haven't exhausted extant forms, and if you play with them, they play back," Paul says. "Yeats's use of *ottava rima* [a type of rhyming stanza] is amazing. Auden's play with various literary forms is amazing. Edna Saint Vincent Millay challenged conventional views of gender, but she did so using a very conventional form, the sonnet, which makes the challenge to convention even stronger."

The culture is a moving target, and an artist who attacks it with shock alone isn't necessarily creating anything of lasting value, Paul says. "What the avant-garde does is shock and break rules and emphasize the new, and if that's all you're doing, you're going to very quickly run out of new, and the thing doesn't work anymore. I think you've got to have the back and forth, the push and pull."

Embracing the paradox

Sometimes, the opposing forces exist within a single personality, where the tension of holding competing or contradictory ideas can generate not just energy and angst but, on occasion, extraordinary insight.

William Butler Yeats—Nobel laureate, pillar of the Irish and British literary establishment, and a grounded realist in much of his best-known verse—could embrace, with his wife, the practice of talking with ghosts. His mind could encompass both realms.

"He was fascinating," Paul says. "Not only was he open to that kind of endeavor, but he believed that he was getting wisdom from it. I think that says wonderful things about the agility and expansiveness of his mind."

Even in Ezra Pound, contradiction may have served the poet's creativity. At the same time Pound was writing his sublime *Pisan Cantos,* he was broadcasting anti-Semitic speeches in support of Mussolini's fascist ambitions. There is nothing about creativity that necessarily leads one down the path of virtue, Paul says.

"I think the propaganda in the radio speeches and the breathtaking poetry in the *Pisan Cantos* are absolutely intertwined creative acts," Paul says. "And there's a tendency in Pound scholarship to want to separate them as though they were irrelevant to one another. I don't agree with that."

Is it a contradiction to admire a man's poetry but condemn his politics? Maybe, maybe not. But ignoring, excusing, or explaining away repellant facts does not bring us closer to the poet or the poem. Sometimes, Paul suggests, an academic compulsion to resolve contradictions or inconsistencies leads us away from the truth of a creative force like Ezra Pound.

Flawless consistency doesn't seem to rank very high on Paul's list of life goals. She would rather think about her next risky adventure into parts unknown.

"I've always liked that sense of exploring," she says, "and I guess I have enough intellectual arrogance to believe I can *try* something. And then I run into somebody who says, 'this is wrong, and this is wrong, and this is wrong,' and I say, 'Okay,' and I try again."

No tidy takeaways

It's tempting to wrap this up with a checklist of tidy talking points, a recipe for baking the perfect creativity cake: Leave your comfort zone. Learn a new body of knowledge. Expose yourself to viewpoints radically different from your own. Dare something risky. Embrace contradiction. Grapple with form. *Venture* something, and don't quit if it fails.

But a recipe won't cut it, if you're baking something new, and rules of thumb may work best when they are opposable and well opposed. So there are no inviolate rules, and the creative urge keeps us restless and moving, like Lucy, with no final product and no destination in sight.

"What's *interesting* about it," Paul says, "is that you do one thing, and that turns up another thing, and then all of a sudden you're…"

She stops; her hands come to rest on her chair. There is nothing more to say.

In this story, we will not arrive on a solid promontory we can stake out and claim for our own. The sands will keep moving, exposing old bones we can learn from—or not. As the poet A. R. Ammons wrote in "Dunes:"

"Firm ground is not available ground."

Catherine Paul is a professor of modernism in the Department of English, College of Architecture, Art, and Humanities. Lisa G. Rapaport is an assistant professor of biological sciences in the College of Agriculture, Forestry, and Life Sciences. Patrick Gerard is a professor of mathematical sciences in the College of Engineering and Science.

What *is* a creativity professor?

The Creativity Professorship Program recognizes and supports faculty members in the College of Architecture, Arts, and Humanities who are engaged in creative teaching and research. At least three professors are selected from the college each year, one from each of the college's three schools—the arts, design and building, and the humanities. Each professor is appointed for a two-year term.

Faculty members nominated for the program undergo a selection process, with the final decision being made by the dean of the college, Richard Goodstein. Each creativity professor receives a cash award and a stipend for professional development.

"The point is to encourage creative engagement of our students in the classroom, in the colloquium, in the studio, in the rehearsal room, in the lab," Goodstein says. "When I launched this program two years ago, I imagined it as a series of seed grants that would help faculty focus on using creativity in the classroom and in their research. What I've discovered, however, is a groundswell of creative initiatives, innovative thinking, and collaborative spirit among these seven professors."

Creativity professors meet often with Goodstein to exchange ideas and seek ways to support and increase creativity in teaching and research in the college. Last October, members of the group presented examples of their creative work during the Forum on Creativity, sponsored by the college.

By fostering a culture of creativity, Goodstein says, the college can prepare its students for a world in need of creative solutions and new ideas. "Our futures depend in large part on our ability to rise to challenges and harness opportunities creatively, with imagination and courage," Goodstein says.

– Jeannie Davis

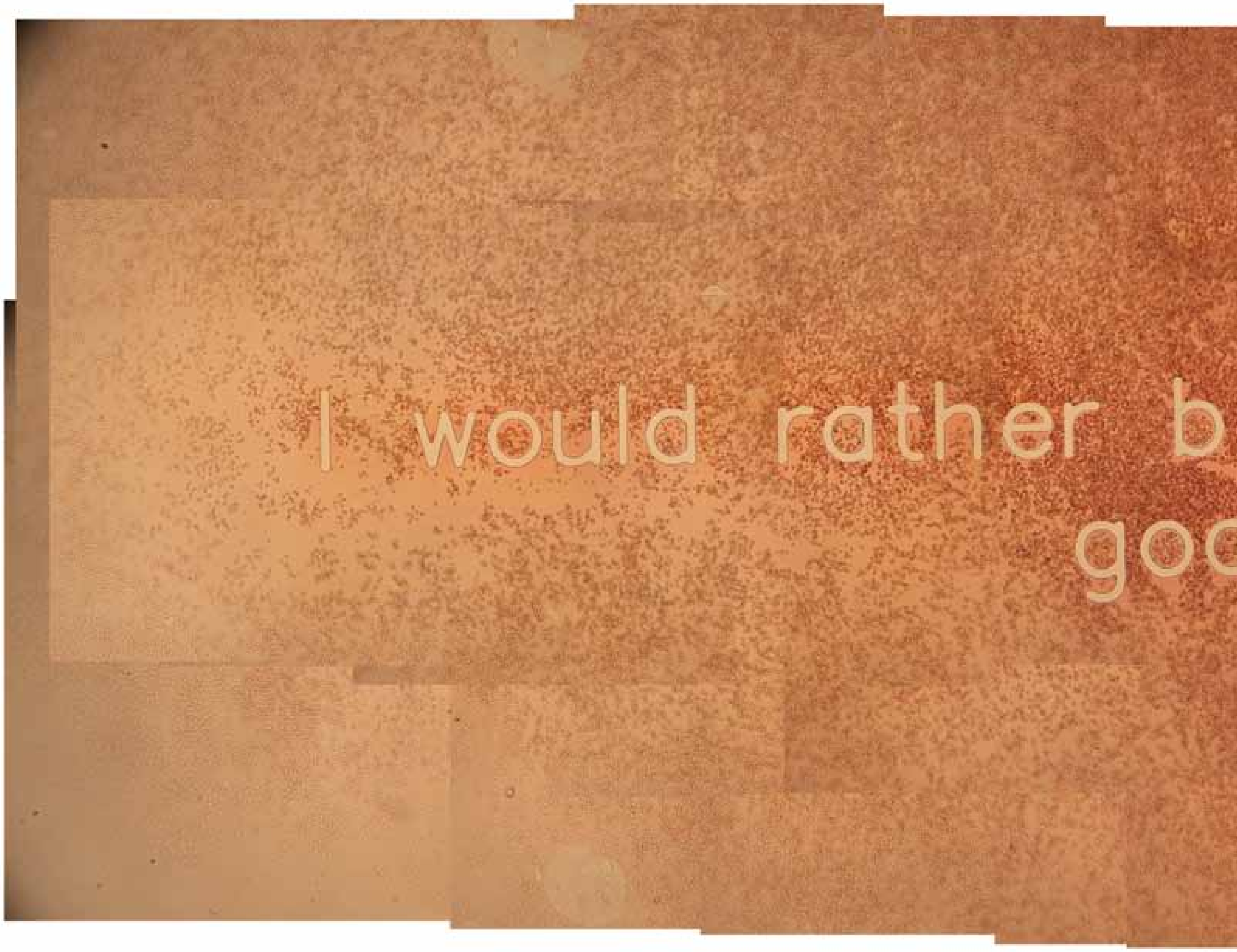
Creativity Professors

Terms end 2013

- James Burns, associate professor of history (see "Selling soap and saving souls," page 62)
- Keith Green, professor of architecture, professor of electrical and computer engineering, and director of the Institute for Intelligent Materials, Systems, and Environments
- Dan Harding, associate professor of architecture and director of the Community Research and Design Center
- Christina Hung, assistant professor of art

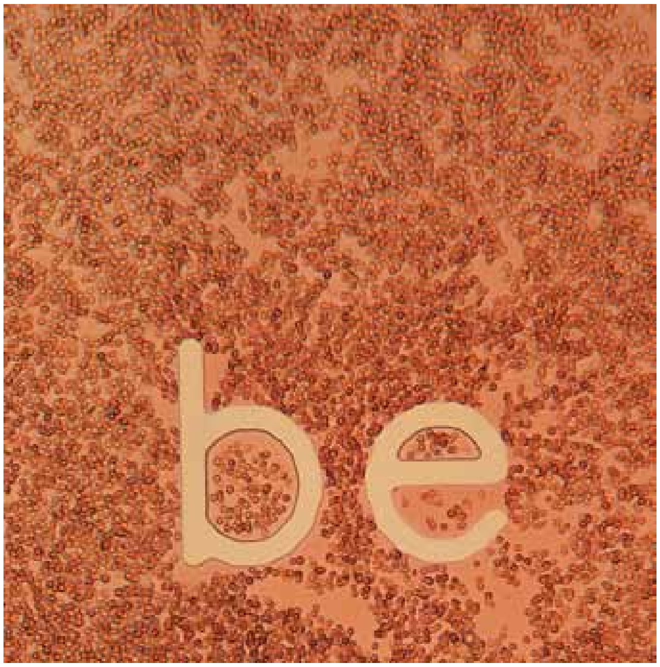
Terms end 2014

- Ulrike Heine, assistant professor of architecture
- Linda Li-Bleuel, professor of music
- Catherine Paul, professor of English



Above: *Goddess|Cyborg,* by Christina Hung, is a panorama micrograph of blood cells and a message imprinted using PDMS stamps, patterned pieces of polydimethylsiloxane. Kirk Pirlo, a former graduate student in biophotonics, helped Hung with the technology.

Below: detail from *Goddess|Cyborg.*

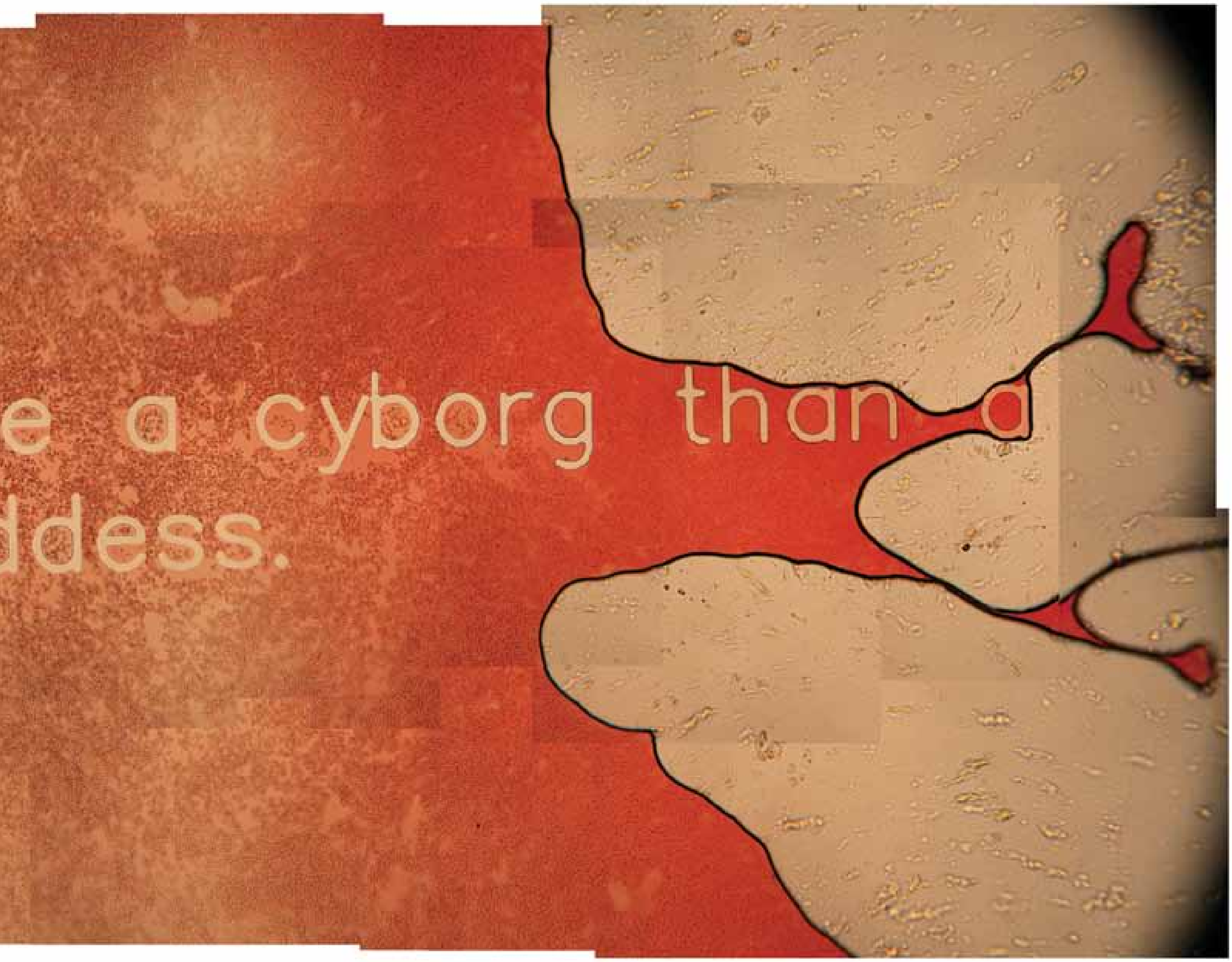


Christina Hung's microscopic interventions

Even in childhood, Christina Hung had an interest in science. A microscope, she learned, could help her see what was hidden in plain view. Today, she uses micrographs—photographic images on a microscopic scale—to compose her art.

"I enjoy very much photographing things at the microscopic level that I can perceive with the naked eye," Hung says. "Think of a leaf, for instance: It has a familiar surface and color. But with the tools of microscopy you can see an entirely different object, an entirely different world. It forces us to question what we think we know about a leaf, and this is something that contemporary art and scientific visualization have in common."

Working at the intersection of art and science, Hung "tweaks the methodologies of science," she says. Modern scientific tools can focus on a sample, convert its properties to data, and render the data automatically as images. Hung uses the tools but skips the automation. She intervenes.



"I'm looking at things and making the kind of interpretive decisions that can't be automated," she says. "I gather my own data using modified microscopic imaging techniques, and a blend of scientific and artistic methodologies. "

Sometimes, she works directly with scientists, because they offer some necessary tools and expertise. Kirk Pirlo, a former graduate student of Bruce Gao in biophotonics, helped Hung try to write words with neurons extracted from chick embryos. The writing proved elusive, but she was able to create micrographs for the first time. Lately, she's been stitching micrographs into panoramas that, with magnification, seem as enormous as walls.

In the microscopic world, she leaves her mark, her brief and poetic reminders that despite the aspirations of scientific objectivity we experience the world—even the world beyond ordinary sight—in a context of history and culture, with a particular point of view. As an artist and a feminist, she intends to claim some of the territories of science on behalf of other cultures and mindsets, starting new conversations about the nature of the world.

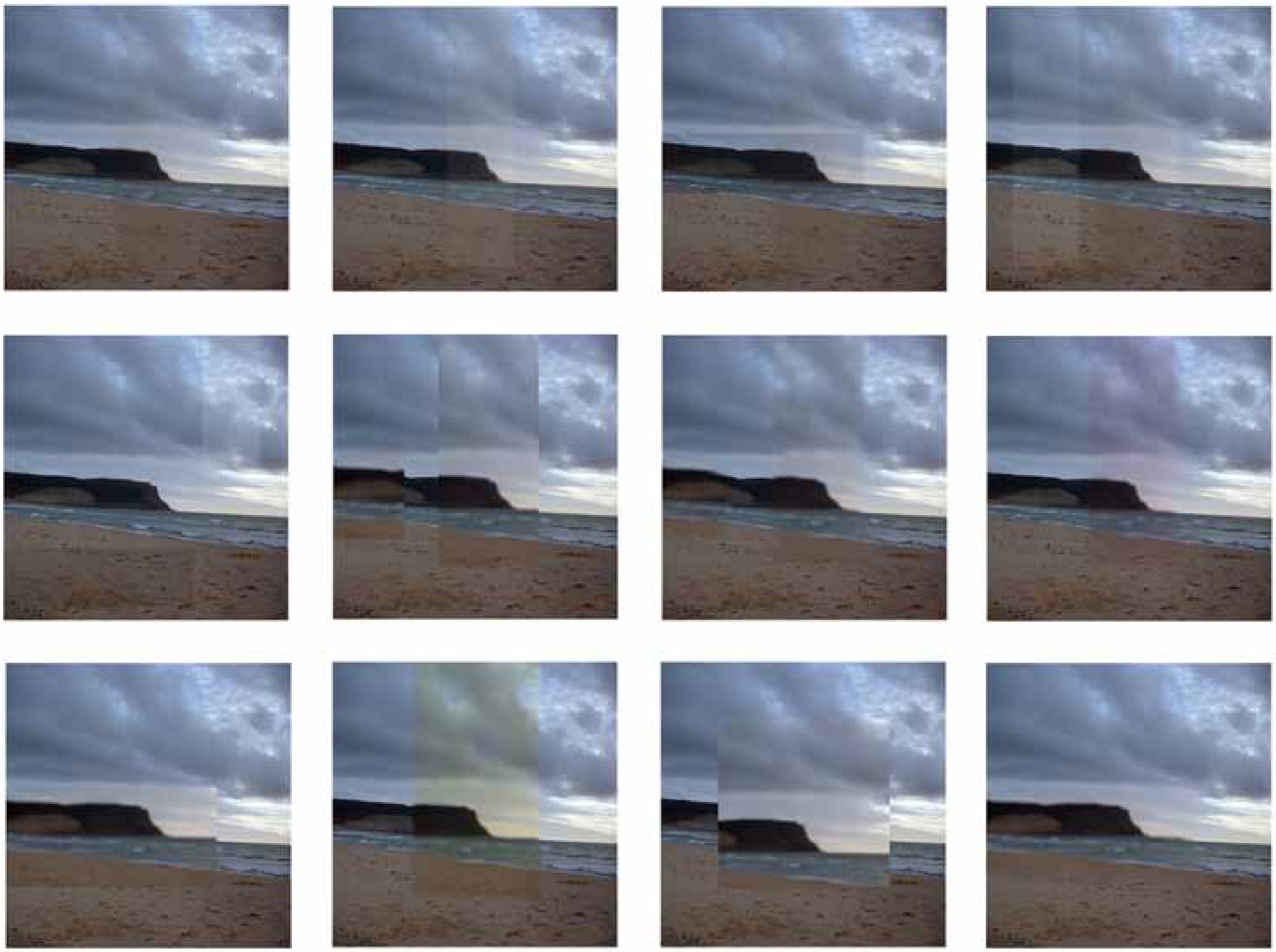
All of this makes her a rather unconventional academic, an artist and critical feminist with science on her mind. She laughs and says, "If there is a crack to fall into at Clemson, I fall into it."

Creativity can make art of science.

As one of her college's creativity professors, Hung often finds herself in conversations about what it means to be creative. "I generally take the stand that creativity is deeply tied to diversity," she says. "When we talk about creativity, we usually talk about how we shake ourselves up and break old habits, how we interrupt ourselves and introduce new ideas. What I add to the conversation is the idea that diversity, as it plays out in society, also helps drive creativity."

Christina Nguyen Hung is an assistant professor of digital art in the College of Architecture, Art, and Humanities (CAAH). Bruce Z. Gao is an associate professor of bioengineering in the College of Engineering and Science. Russell Kirk Pirlo completed his Ph.D. at Clemson and now works in tissue engineering as a scientist with the U.S. Naval Research Laboratory. *Hung received support for her work from the Clemson CyberInstitute, CAAH, and the Clemson University Research Grant Committee.*

Creativity can venture multiple versions.



Composite24, 2012, Ann Pegelow Kaplan

Ann Pegelow Kaplan's photographic fictions

Ann Pegelow Kaplan, candidate for the master of fine arts, specializes in contemporary photography and digital arts but was trained as an anthropologist. Rather than pursue traditional scholarship in a narrowly defined specialty, she explores the connections between subjects.

Before coming to Clemson, Kaplan earned a master's degree in ethnography and folklore, and she worked as a documentarian and museum curator. She admires the documentary and the exhibition, she says, because they both attempt to render a true presentation of reality, but she also wants to pursue creative forms often described as fictions, written or visual, and how they might present "an even truer representation of the world."

Kaplan arrived at this idea through a blend of arts and sciences. In neurobiology, she found science documenting the ways in which we construct and interpret every moment of our experience. "We can't really expect to truly know reality," Kaplan says. "It's not how we're built. What we do know is our own experience of it—our personal curation of reality."

In her photography, Kaplan presents multiple realities for a single location. A forest, a train, a seashore in Iceland—each appears in several versions.

"If different people can have varying realities, and multiple realities appear to be possible, then the difference between truth and fiction comes into question," Kaplan says. "We wonder which reality is true and whose vision is most correct. The line between documentary and art becomes blurred."

Sight I, 2012

Sight II, 2012

Sight III, 2012

Connecting two cultures

As a poet and as a scholar who studies science communication, Steve Katz finds one not-so-obvious relation between "the two cultures" of the sciences and the humanities: creativity. "Both scientific communication and poetry reveal the creative, metaphoric root of all language and knowledge," Katz says.

Steven B. Katz is the R. Roy and Marnie Pearce Professor of Professional Communication and professor of English in the College of Architecture, Arts, and Humanities. "From this Earth" first appeared in Groundswell 1 *(Winter 1985).*

From this Earth

I
A Science of Subjectivity

For the few moments on this earth,
we become too sensitive in these things:
green light, dusty plants
in blue windows, the sunny wood;

we seek a science of subjectivity
to escape—perceive cells of green leaves
synthesizing in the genesis of summer,
white tracery of a particle breeze

in the patterned chaos of trees,
atomic complexity of grass in the heat,
the sun radiating in fields,
chemical skies, cosmic weather:

and we dream, dream in the infinite
window we can't see through.
Oh yes, we will test for God,
attaching electrodes to the stars.

II
The Inhuman Stars

A human egg cracks; a white hatch
opens; and a satellite is born,
slipping out, alone, into a universe
that engulfs it like an infant star.

And is there something childlike
and prophetic, in those awkward sensors,
slowly extending, reaching out
to the expanding void of oblivion;

something comic and pathetic,
in that radar like an ear cupped
to a cosmic wall of darkness,
listening, listening to the static

of creation, searching for what
it cannot find here among the inhuman stars,
satellite falling, endlessly falling
into the night that is ours?

Steven B. Katz

In science, creativity is at first hypothetical.

For biologist Lesly Temesvari, a strong hypothesis requires more than mere method.

A mother, a child, and the question of nurture

Lesly Temesvari would like to bury the notion that creativity and science are somehow at odds, that creativity is all about making stuff up and science is all about mining data and building knowledge as ants assemble anthills, grain upon grain. It's just not that simple, she says.

A biologist who studies parasitic diseases (see "Dysentery's life raft," page 10), Temesvari has learned that the make-or-break moment for any new line of research may well be the leap of induction, invention, or pure inspiration that leads to *what if…* and then to a sometimes outrageous proposition called the hypothesis. Proceeding step-by-step through the scientific method does not automatically hand you this prize, a testable hypothesis. The scientist has to create one.

I ask her for an example of how this works, and she tells me a story. It's a story about her science, her little girl, and a magazine sort of like this one.

Rat pups need a licking

"I graduated from McGill University, so I get the alumni magazine," she begins, "and there was a story in it about two scientists at McGill from different fields—one was a behavioral scientist and one was a molecular biologist—who happened to meet at a conference. The behavioral scientist had been interested in maternal nurturing, and its effects on behavior, and he had a rat model he was using to study this. He used two groups of rats—nurturing and non-nurturing. Apparently you can tell the difference by whether or not they lick their pups. And he'd found that rats that were not nurtured had significant behavior changes; they were more anxious, and they didn't nurture their own pups. At the conference he started talking to the molecular biologist, who said maybe nurturing can actually change the genetics in some way. Now this interested me, because I have an adopted daughter who is from China. So because she is not my biological daughter I am especially interested in the question of how much influence I can have on her development. If nurturing actually changes behavior at the genetic level, I want to know about it."

The researchers at McGill had been studying the epigenome, a code of biochemical tags that turn genes on or off. Something that affects these switches is called epigenetic, and the biochemical tags are methyl groups. So the process that alters gene function is called methylation, a topic of special interest in Temesvari's lab because parasites could very well interfere with the on-off switches. From the rat studies at McGill, it appeared that mother rats licking their pups had an epigenetic effect by changing the patterns of methylation.

"At McGill, they found some real changes at the genetic level," Temesvari says. "They took non-nurtured pups and moved them into a colony of nurturing rats, and genetically, these pups began to look more like the nurturing rats."

Applying it to people

But finding these epigenetic changes in rats does not guarantee finding them in humans. So the researchers looked for a way to study methylation in people, too. They had access to postmortem tissue samples from the Montreal Neurological Institute. The samples were from people who had committed suicide and who also had not been raised in nurturing homes.

"When the researchers looked at the samples, the pattern of methylation matched those in non-nurtured rats," Temesvari says.

In other words, a lack of nurturing apparently affects the genetics and behavior of people and rats in similar ways.

That's when Temesvari made her leap of induction.

"It dawned on me," she says, "that if something as extraneous as maternal nurturing can affect methylation patterns, the parasites I study may have some influence as well. One example is *Toxoplasma*, which you have been exposed to if you've ever had a cat. *Toxoplasma* is a very common parasite that goes into cells, and people have always assumed that it's harmless. Recently, there's been some research that shows *Toxoplasma* is not as harmless as we'd thought. One study out of Sweden showed that people with past *Toxoplasma* infections were seven times more likely to commit suicide. Another study showed that people with *Toxoplasma* antibodies circulating in their blood were more likely to be risk takers, and therefore more likely to have car wrecks or other serious accidents."

Don't blame the cat yet

Before we begin blaming our cats for our foul moods and fender benders, Temesvari cautions that the findings are so far correlations, not proofs. No one has established cause and effect. But the correlations seem strong enough to take the next step: forming a hypothesis. And for her, the *what-if* questions went something like this: What if a parasite like *Toxoplasma* alters methylation patterns? And if it does, wouldn't it also influence behavior?

These were the kinds of questions that pointed Temesvari toward a hypothesis that did not bubble up from her research alone. She read a magazine. She thought about her daughter. She connected the two with her science. And there it was.

She is applying for a grant from a private foundation, hoping to test the hypothesis that if maternal nurturing can change the methylation patterns and the expression of genes, causing a change in behavior, then there might be a similar connection between a parasitic infection and changes in behavior. In her lab, she will infect living cells with *Toxoplasma* and see what happens with the methylation.

Craig Mahaffey

Methylation modification in action: Lesly Temesvari and her daughter, Lilli, test the hypothesis that good nurturing brings out the best in our genes.

This is not a safe little puzzle to solve in the lab. It's a big and outrageously daring proposition that will raise a few eyebrows in her field.

"The whole idea is totally harebrained," she says, laughing.

Out of her comfort zone

Harebrained or not, Temesvari's idea is too big for her lab to handle alone. She will need help.

"I'm really out of my comfort zone on this project," she says. "Elena Dimitrova in math is going to help because she's good at analyzing very large data sets. June Pilcher is a behavioral scientist, and she's agreed to help us think about the behaviors involved."

The project will be daunting, and its implications could be huge. For years, researchers have labored to explain, for example, the effects of poverty or trauma on health and behavior. If conditions at home expose a child to parasites, will the child be at greater risk not just for infection but for behavioral problems as well? Is this one factor in the link between poverty and mental illness or crime?

As a scientist and a mother, Temesvari would like to help settle the question of how much a parent can matter in the life of a child. And she is only half joking when she finishes our conversation with a quip:

"When people meet my daughter and they say, 'She's so beautiful, or she's so smart,' I say, 'Yes, and it's epigenetic. It's me affecting her methylation patterns.'"

Lesly A. Temesvari is an Alumni Distinguished Professor of biological sciences in the College of Agriculture, Forestry, and Life Sciences. Elena Dimitrova is an associate professor of mathematical sciences in the College of Engineering and Science. June J. Pilcher is an Alumni Distinguished Professor, Department of Psychology, College of Business and Behavioral Science.

The story Temesvari read, "Are Your Genes Your Destiny? (Not if your mom has anything to say about it)," by Hannah Hoag, appeared in the Spring/Summer 2011 edition of McGill University's alumni magazine.

In 2010, Temesvari won a Fulbright fellowship, which took her to Italy to teach science writing. Building on that experience, she and Steven B. Katz, a colleague from English (see page 23), led Creative Inquiry teams that helped Clemson undergraduate students produce a science journal and a radio program about research.

Are engineers **creative?** Of course. But don't expect them to **admit it.**

Reality and the big, fuzzy blah

One suggestion: Do not use the term *science fiction* when you talk with Joshua Summers. "It is not *science* fiction," he says. "It is *engineering* fiction."

He has a point. A writer who invents a realm of exotic new technologies play-acts the role of engineer, without the considerable bother of actual reality.

"Engineers deal *with* reality," Summers says, "and we still have to *overcome* reality. We have all kinds of physical laws that we have to play within and still achieve things that have never been done before. Engineering is about creating what *can be*. Science wants to understand what *is*."

Reality doesn't just hand over a hunk of What Can Be without a fight, and Summers and his students are constantly testing the limits of physical laws. This gritty push and shove gets them going, makes them more—dare we say it?—creative.

"We don't like to use that word," Summers says, politely.

Why not?

"Because it's loaded."

Okay.

"And because other disciplines have staked a claim to it, and we don't want to fight them for it."

Okay.

Neil Caudle

The Sand Traction team of undergraduate students is testing Kevlar as a material for the treads of lunar rovers. In the photo at left, Steven O'Shields (right) presents test data to the team during a Tuesday-night work session. The team began with concept sketches in pencil, moved to CAD drawings, and began building prototypes like the one far right. They test the durability of their designs in a merry-go-round-like arena where the wheels travel a circle over moon-like soil. **Above:** Composite image from Apollo 16, Station 16, Shadow Rock.

“We tend use the word *ideation* instead.”

Oh. Okay, then.

Whatever term we apply to the struggle, its goals are simple, as Summers puts them:

1. Come up with something.
2. Build something.

Creativity—ideation—plays a role in both one and two. At the heart of design, Summers says, is an act of synthesis. Sometimes, synthesis means plugging old stuff together in new ways, as when a kid plays with Legos. Other times, there’s something missing, a gap. A kid can make do with a well-chewed wad of bubble-gum; an engineer has to plug the gap with something new.

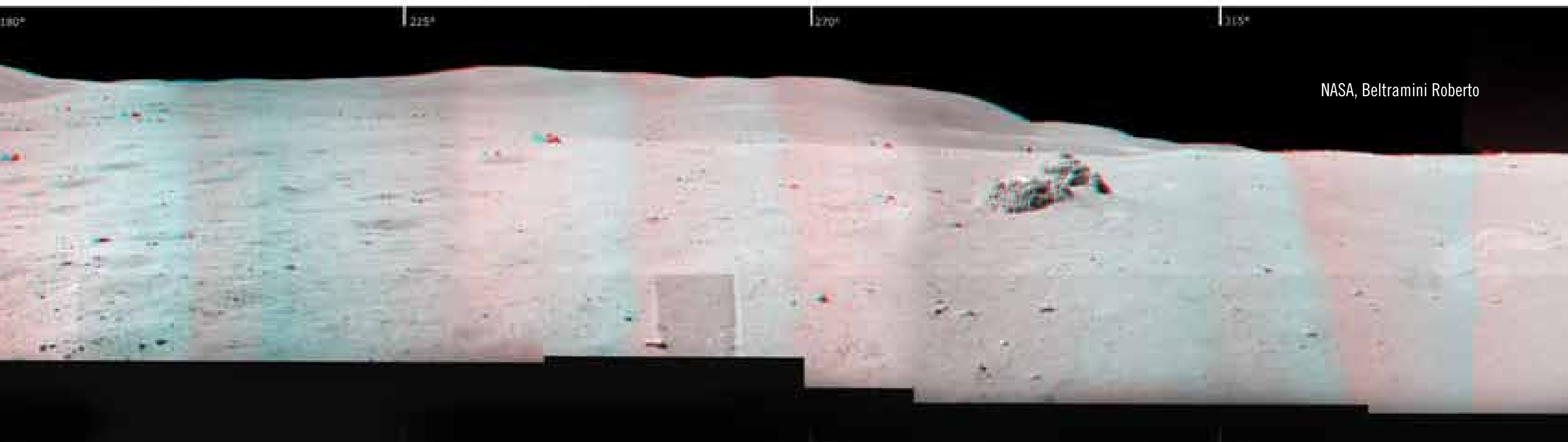
“That’s when we have to roll back on our understanding of the way the world works in terms of chemistry, physics, and biology,” Summers says. “And we have to work by analogy, by expanding our reach, by moving to a new frame of reference.”

The synthesis that leads to creation is the good stuff, the nectar that draws problem solvers into engineering like bees into blossoms. So telling a student that engineering today is all about crunching numbers is a buzz kill. And it just isn’t so.

“Crunching numbers is a necessary evil for most of us,” Summers says. “You

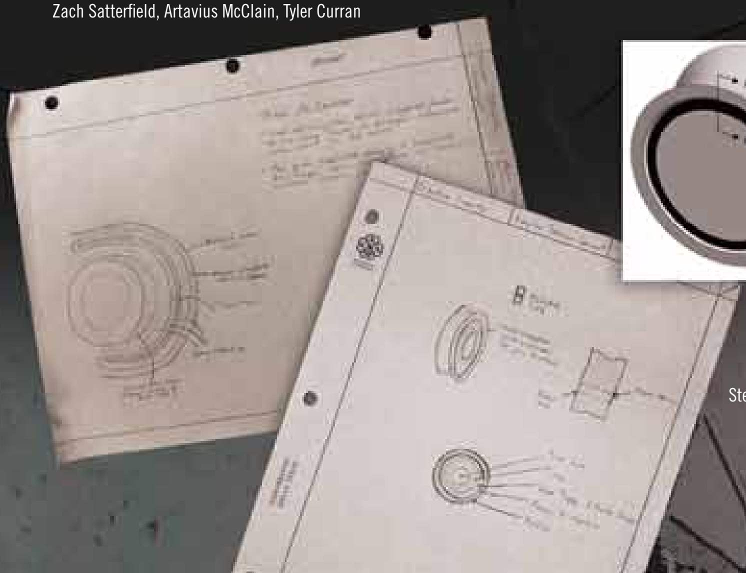
Traction to rove the moon.

Getting a grip on the rock-studded dust of the moon’s surface means reinventing the wheel. Joshua Summers’ Creative Inquiry team is taking it on.



NASA, Beltramini Roberto

Zach Satterfield, Artavius McClain, Tyler Curran



Zach Satterfield

Steven O'Shields, Shane Mims

Zach Satterfield

want to make sure that this new brake system works, so you crunch the numbers. But that's not why we want to be engineers."

The personal ambition to create, Summers says, is probably the same for an engineer as it is for a painter or a poet. "Even an artist has a goal," he says. "The goal may be an emotional evocation, but it's still a goal. It's an intentional act."

Summers' first and foremost goal is to teach people how to be creative engineers, and he's in a hurry about it. Our economy—check that, our *society*—needs thousands of good engineers immediately, if not sooner. And that's a tall order.

"Some people say it takes ten thousand hours of experience to become a good engineer," Summers says. "But we don't have time to wait for our students to get their ten thousand hours. We have to short-circuit that. We have to make our students competent engineers immediately."

Folding a burrito

This is risky business, because the stakes are higher than they are for other kinds of creative ventures. Writers, for instance, can struggle for decades to master their craft, and no one's life is in jeopardy if they don't get their novels right. With engineers, it's different.

"Something as small as a bracket on a car can cost people's lives," Summers says.

So it is his job, as he sees it, to make junior engineers work as smart as senior engineers. To do so, he and his colleagues have assembled a sizable toolkit of theory and practice to help them school aspiring engineers, not just in the facts they'll need to know but in the creative problem-solving essential to success.

Summers uses this toolkit to guide his students through what he calls the design space, which includes the problem space and the solution space. Spacey as this might sound, the notions are grounded in pragmatism. Any time engineers attempt to design something new, they have to weigh the merits of each conceivable option, analyzing its problems and potential solutions, its costs and practicality. In the throes of this struggle, designers pinball back and forth until the distinction between problem and solution begins to blur. Things get messy.

"Design space is this big, fuzzy blah," Summers says, "but I like the challenge of the fuzziness." He attacks it systematically, weeding out emotions and baseless assumptions.

Consider for example a class project that involved designing a burrito-folding machine. Let's pause for a moment while you wrap your head around the daunting prospect of inventing a machine that can make a burrito.

Here is how Summers and his students went about it: "First we had to ask, what will this machine have to do? Lots of things: load and position the tortilla, dispense the filling, fold the tortilla over and over and over, eject it, and so on. So what are some of the ways we can accomplish these functions? For every function, you come up with a bunch of different ideas. And we have tools for that, for generating the ideas. Within twenty minutes you can have several million ideas. So then we need other tools to refine and process the ideas."

To navigate the fuzzy realm of design space, students need the one thing they generally lack: experience. They need not just engineering experience but *life* experience. Creative people often generate ideas by analogy, and the best engineers cast a wide net in their search for analogues. Even Thomas Alva Edison designed by analogy, applying what he'd learned from the telegraph to his work on the light bulb, for instance.

Summers, whose own resume covers more ground than an engineering-fiction novel, pushes his students to branch out, take a drawing class, study languages, learn to write—absorb as much as they can.

"I'm a big believer in the idea that a variety of experience leads to a variety of understanding," he says. Reading, he says, is an especially useful shortcut. "When you read, you are indirectly developing experiences. And those will help you look at problems from a different perspective. It will help you reframe things."

Craig Mahaffey

Back to shop class: In high school, Joshua Summers defied his guidance counselor and signed up for shop. He is still there. Making stuff, he says, takes more than number crunching.

One of the lessons engineers learn from experience is not to go it alone. Engineering today, Summers says, is decidedly social. Our romantic old notion of a lone inventor tinkering away in his workshop is well nigh obsolete. Today's engineers, like the mastodon hunters of yore, attack each big, hairy problem as a tribe would, stalking the beast from all sides.

"An advantage of engineering as a social activity is that you have not two eyes but twenty eyes looking at a problem," Summers says.

Twenty eyes are good, but forty might be overkill. For his ideation sessions, Summers assembles a small group of people—five to fifteen in number—who are excited about solving the problem at hand. Depending on the nature of the problem, the team selects one of many "ideation tools," methods for guiding the group interaction. One such tool is called the Gallery Method. Each member of the team takes a pad of sticky notes, quickly sketches a bunch of ideas, and sticks them on a wall. The team reacts to each member's sketches with more sketching.

"The idea is to build on other people's ideas," Summers says. "We use a principle called provocative stimuli, which is a way for each person to see something and interpret it differently. So this is one tool. We have lots and lots of tools."

Whatever the tool of choice, the goal is to arrive at the best ideas as efficiently as possible. But ideas are not the only goal. Dealing with the ever-present risk of failure is another. In both the design space and the building space, engineers set up systems with what Summers calls gates, a series of checks, tests, and tough questions designed to ferret out the flaws. In Summers' view, failures in the fuzzy world of design space should be expected, not punished. They come with the territory.

Fail early and often

"Our philosophy runs counter to most," Summers says. "It is fail early and fail often. Engineers cannot be afraid of failure. We have to learn from failure. We have to explore as many ideas as possible. That might include throwing out a hundred bad ideas."

Very often, young engineers wander off track in the thrall of computer-aided design (CAD), a technology that can make even a bad idea look good. At the computer, a student smitten with his own half-baked idea can produce a seductively slick presentation that looks like a valid design.

"This is the biggest obstacle for some of our students," Summers says. "They fixate. Putting forth that little bit of effort to create an attractive presentation can wed you to the idea, and people will gravitate to it. Better-represented ideas will tend to be selected."

It's a tricky balance. On the one hand, engineers working in a social group must communicate ideas, often with models; computers help them crank out the models. On the other hand, chasing a bad idea off through the weeds is a waste of time.

To be fair, it's not only students who get snowed. Even the most prosaic technology, artfully rendered in CAD, can put stars in a client's eyes. "We've shown pretty representations of a trash truck, and the clients think it's great," Summers says. "But they're totally biased by the representation."

Summers has studied such problems in the course of his research. For an entire semester in 2007, Dave Veisz, one of Summers' graduate students, observed a team of student engineers working for Raytheon on a landing gear for an unmanned vehicle.

"When Dave watched the students, he was shocked to find that in the first meeting, kids came with CAD models," Summers says. There were no preliminary sketches; the students went straight to the computer. And sometimes, they floundered there.

"Dave identified times during the project when students would overcommit to a specific solution because they had spent so much time working on that model," Summers says.

Over the last decade or so, the addictive habit of instant gratification by CAD has found its way into the workplace. Veisz and Summers interviewed faculty members and people in industry, comparing responses from those who were relative newcomers with those who had more than five years of experience.

"The general pattern we discovered was that young industry people and young faculty members saw more value in computer modeling than in sketching," Summers says. "Older engineers argued that we still need sketching."

Summers is neither old nor anti-computer. (We had our talk via Skype, while he was in France.) But in his view, sketching by hand helps an engineer test many ideas before settling on the one worth modeling.

"Once you have an idea that you want to model, then the computer gives you a better way to make changes and try things out," Summers says. "You have to have both, the sketching and the computer."

Too many students are taught to regard computers as the go-to technology for each and every problem, Summers says. This is like assuming that because a hammer is useful for driving nails it will be great for window-washing, too.

To Summers, a toolkit should include more than a hammer, and an engineer should have more than a one-track mind. Maybe that's why some of his most successful students have begun as academic misfits, people who've had trouble playing the role of dutiful, grade-seeking drone.

"I've had some really great luck working with students who had very poor GPAs, and they've turned into some of my best graduate students," Summers says. "When we're recruiting students to graduate school, I'm looking first for people who are excited and willing to work. Number two, I am looking for people who are willing to ask questions. Those are the two traits."

Now and then, a student whose hard work hasn't paid off in high grades will have a breakthrough, a moment when engineering ceases to be an academic slog and suddenly becomes a passion, a drive. "Sometimes, a switch turns on," Summers says. He likes that switch. He has a passion for it.

The parts left over

Summers himself is a kind of misfit, an engineer astray from a family of educators (as in people with education degrees). With all due respect to his kin and their chosen pursuits, Summers doesn't put much stock in ordinary classroom teaching, if students can't build stuff with their hands. When I ask him what our society should do to produce more engineers, he has a ready answer.

Bring back shop class.

"When I was in high school," he says, "the guidance counselor told me not to take shop class. I said, 'But I want to be an engineer.' And he said, 'Engineers only need to know math and science.' I ignored his advice and took shop class."

He made the right choice, he says, but that doesn't mean he learned to be a good mechanic. His wife won't let him work on the family car because he winds up with leftover parts at the end of the job. But if shop class didn't make him a mechanic, it did help him appreciate how things are made.

"You can't just sit down at a computer and create something in a vacuum," he says. "You have to know how to make it. You have to know what it takes."

Joshua D. Summers is a professor of mechanical engineering and an IDEaS Professor in the College of Engineering and Science, where he codirects the Clemson Engineering Design Applications and Research (CEDAR) group. Dave Veisz is now the director of operations for MakerBot, a 3-D printing company.

In Michael Ellison's spider tent, a golden orb weaver, *Nephila clavipes*, stalks prey trapped in a silken web. For researchers, the silk itself is the quarry.

Craig Mahaffey

the web of science

by Nancy Marie Brown

In the depths of Sirrine Hall is a screen tent full of spiders. At least, it should be full of spiders. When materials scientist Mike Ellison peeks inside, on a day in November, he finds only one. "Looks like we'll have to catch some more," he says, demonstrating his swooping technique, jar in one hand, lid in the other.

He can't just pick them up; golden orb-weavers are too delicate. "I love to go out and collect them," he says. "It's fun."

An expert in polymer fibers, Ellison and his graduate students have perfected a technique of "milking" the spiders to collect their silk. He pops the lid off a pharmacy pill bottle to expose a homemade silk-collecting reel—it looks like a tiny fishing reel—and tilts it back and forth. A few strands of spider silk glisten like gold as they catch the light. Otherwise they are invisible.

And 800 times stronger than steel.

As a fiber, Ellison points out, spider silk is pretty remarkable. Strong when heated or frozen, and when wet, it contracts dramatically. It conducts both heat and light. It's also biodegradable, naturally. Since the 1970s, scientists have imagined making everything from bulletproof vests to parachute cord to computer chips to medical sutures and vascular grafts out of spider silk. But no one so far has identified the structural traits that give this extraordinary fiber its properties.

Ellison believes part of the secret lies on the surface of the silk. He dreams of making a synthetic mimic. So he milks his golden orb-weavers and sends his collecting reels over to Rhodes Annex, to Delphine Dean's Multiscale Bioelectromechanics Lab.

Banishing boredom

Dean is an expert in visualization at the nanoscale—in other words, she can see things so small as to be almost invisible, such as the individual amino acids on the skin of spider silk.

"Spider silk is really interesting stuff," says Dean, a bioengineer. A single golden orb-weaver can make seven kinds of silk, she notes, while spiders of other species make silk with different properties. "Which circumstances make those different characteristics?" she wonders.

To find out, she, colleagues Ellison and Molly Kennedy, and a team of Creative Inquiry students—two undergraduates from materials science, one from bioengineering, and materials science graduate student Benoit Faugas—take a tiny sample of dragline silk milked from a golden orb-weaver and examine it with an atomic force microscope (see the sidebar, page 34). "We are looking at the surface, not at the whole composition of the fiber," Dean explains. Spider silk, like wool or human hair, is a protein, a chain of amino acids. "We're not so much interested in what the fiber is made of," Dean says, "as much as in learning which amino acids are on the surface."

It's a technique Dean devised for an earlier collaboration with Ellison and Kennedy on wool. She also uses atomic force microscopy to study teeth, cardiovascular muscle cells, the effects of radiation on cartilage, how cells respond to growth factors, and the surface properties of dirt. Why so many projects? "I don't like being bored," she laughs.

She mentors still more projects: medical training simulators, a mind-controlled robot, the use of ultrasound for rotator cuff injuries, exhibits for the Roper Mountain Science Museum, and the design of medical devices for developing countries. One of these last projects brilliantly transforms an old inkjet printer into a device for making diabetes testing strips.

All told, Dean is responsible for one postdoctoral fellow, four Ph.D.'s, three master's, and forty-six undergraduates, in eight different teams. "Creative Inquiry is cool," she says of the Clemson-funded research program. "You get a team of undergraduate students, give them an idea, and let them run with it. Once you have a team, the senior members help train the new students, so it's also a great opportunity for graduate students to learn how to mentor."

Explaining these projects in the lab, Dean uses expressive arm gestures—the byproduct of years of figure skating and studying ballet. In the elevator, on the way down to demonstrate the atomic force microscope in the Rhodes Annex basement, she unselfconsciously takes up the ballerina's first position, her feet making a perfectly straight line, heels together, toes 180 degrees apart. Last Christmas, she danced, *en pointe*, in *The Nutcracker*, something she likes to tell school children when she's talking to them about science. "It's important for little girls to know that you can be a bioengineer and still wear a pink tutu," she says. "You can be a scientist and an engineer and still have a life outside of work." Her husband, computer science professor Brian Dean, she points out, is a pianist, a runner, and a cook.

Born in France, Dean came to the U.S. with her family when she was eight and was immediately thrown into the public school system, though she knew no English. Even then she was a fast learner. "I arrived in February. By June I was fluent in English." She traces her interest in bioengineering to two events. "My sister had a meniscus tear when she was in sixth grade and got arthroscopic surgery. I found that fascinating. I knew I didn't want to go into medicine, but I wanted to study cartilage." The other impetus was a toy robot. "I thought, 'Wouldn't it be cool if people who were missing limbs could have a prosthetic that basically was a robot controlled by their body?'

"But I like working with people too, so I love it when people come to me with ideas. The American public needs to know that scientists don't just sit at a bench in isolation. I think I prove that's not how it works. You can't solve problems all by yourself. You need a team.

"Why I went into academia was to mentor," she continues. "I like research, but you can do research in a lot of different venues, in government, in industry. What I really like is mentoring students. I like to see what ideas they come up with. It's fun. But the best part of training the new crop of scientists and engineers is that you can actually see them becoming independent researchers. They will come up with something that surprises you, something that you'd never think of yourself."

Is the secret to spider silk's amazing strength written on its surface?

Banishing boredom

Her collaboration with materials scientist Molly Kennedy and her students is a case in point. The third member of the spider-silk team, Kennedy usually studies nanocomposites—materials made of two or more substances combined at very small scales, such as wear-resistant or radiation-resistant coatings. Her expertise is in determining how the fine-scale structure of a material controls its properties.

She met Dean in 2008. "I had a gifted grad student, Bonnie Zimmerman, who wanted to work on biocomposites," Kennedy explains, "so we walked over to Delphine Dean's office. She said, 'What do you think about teeth? A lot of people have studied bone, but few have studied teeth.'"

They put together a Creative Inquiry team to examine what happened to the structure of a tooth when it was whitened, for

Craig Mahaffey

Delphine Dean: "I like research, but you can do research in a lot of different venues, in government, in industry. What I really like is mentoring students. I like to see what ideas they come up with."

example, by using a whitening toothpaste. They found, to their surprise, that whitening not only changes the surface of the tooth but also affects the structure of the dentin deep inside. Depending on the whitening process, it makes the enamel stiffer, and so slightly more likely to crack, while at the same time making the dentin inside the tooth stiffer in one case and more elastic in the others.

"Research is exciting," Kennedy says, "but it's not about going into the lab unprepared. Ninety percent of it is knowing what other people have done before you and using that information to create what we call a design map, a prediction of what will happen. It doesn't always work, though. We didn't think whitening would affect the dentin. That was a surprise."

They repeated the experiment and had the same results. Then students and professors talked it over and tried to develop a new hypothesis to test. They published their results in 2010.

"My job as an academic is not to produce papers," Kennedy says, "but to bring in and educate students to be better than me. That's what my dream job is. And here at Clemson, we can really focus on the students." In her collaborations with Dean, she says, "We're trying to create students who are well-rounded—students who have substantial knowledge in their home fields, but who can also work in related areas."

But what benefits the students also helps the professors, Kennedy says. "Students really aid our research, because they think in uninhibited ways. They aren't restricted by their expectations, by what we call investigator bias. It's also nice in a lot of ways to have a colleague from a different department. There's a synergy. Delphine can understand what the cells are doing, and I can understand the structure.

"But what I like about Delphine most," Kennedy adds, "is that she likes to educate and strengthen her collaborators. You not only get a chance to collaborate, you get a chance to grow as a researcher."

A tangle of scales

Dean, Kennedy, and Ellison and their students began working together several years ago. In 2011 they published the result of a very practical study of wool fibers, funded by Kentwool, a local company, with the goal of making wool clothing washable.

Wool shrinks because of its structure. Under a scanning electron microscope (SEM), a wool fiber looks scaly, like fish skin. On the wooly coat of a sheep, the scales don't tangle since they all face the same direction. Instead they serve the useful purpose of removing dirt from the animal's skin. Yet when the wool is spun into thread and woven or knitted into cloth, the scales are turned every which way. They catch on each other. In a washing machine, they ratchet closer together and the cloth shrinks. Taken to extremes, this process produces felt.

But wool treated to make it washable sometimes has a slimy feel. Worse, the standard chemical treatment isn't environmentally friendly. It produces high levels of pollutants—organic halides—in the wastewater.

Since wool is a protein, made up of chains of amino acids, theoretically enzymes could be used instead of chemicals to eat away the rough edges of the scales and inhibit the felting process. But unless they target just the scales, the enzymes also weaken the wool fibers. Few enzyme processes have yet met the industry's standards of less than 10 percent shrinkage in a washing machine along with less than 10 percent loss in fiber strength.

"But there are enzymes, or proteases, that are specific for particular amino acid sequences," Ellison notes. "They will remove amino acids only if they are in a particular arrangement. So our idea was, if we could map the sequence of amino acids on the surface, we could design a protease to remove only the amino acids that are on the ridges of the scales, and leave the rest of the wool alone.

"The idea was phenomenal," he says, "but our results weren't. There was not a real clear line of amino acids along the ridge. We had some luck with a protease, but it wasn't great. And we couldn't scale it up fast enough for our research sponsor. Given the intense competition in this business, they quit funding us—it was a business decision—and we went on to other things."

Namely, spider silk.

Craig Mahaffey

Michael Ellison at the spider tent. Ellison switched from wool to spider silk after a musician friend suggested it.

Ready to rock and roll

Ellison became interested in spider silk some ten years ago, looking for a way to make better vascular implants. "I was at a conference listening to a talk about polyester tubes used as vascular implants. I thought what we needed to do was to be able to make a tube using the person's own DNA, so I wanted to look at recombinant-DNA methods of making proteins that would form fibers. I was playing music together with a friend of mine who is a molecular biologist—we have a band and play rock-and-roll, country, swing, and just general old Americana together—and he suggested I model the fibers after spider silk. I graduated several students out of that program, but I didn't achieve the Holy Grail of making spider silk."

Working with Dean and Kennedy he hopes to learn more about the structure of spider silk, with the idea of mimicking it, not making it. The three researchers have submitted a proposal to the National Science Foundation.

"When you're a materials scientist," Ellison explains, "you study how process influences structure and gives you the resulting properties. That's the triangle: process, structure, properties. Now, people have analyzed spider silk for its amino acid content, and they have discovered most of the sequence, but when you do amino acid sequencing, it's a bulk study. You dissolve the protein." The results don't reveal which amino acids are on the surface of the fiber and which are inside.

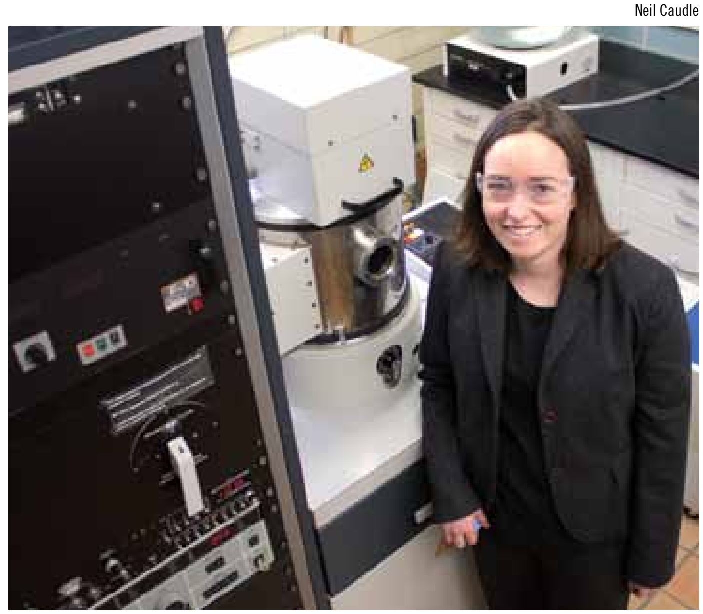
Ellison, Dean, and Kennedy believe knowing this is the key. "Nobody has distinguished the chemistry of the skin of the silk from the rest of it," Ellison says, "because the fiber is so small. But one of the tenets of materials science is that the surface contributes mightily to the properties of the material. It's the idea of there being an interface between the material and the outside world." Using the atomic force microscope, they hope to better understand the surface of spider silk, especially how its structure relates to the silk's properties. "Then we will better understand what leeway we have in trying to create a similar structure," Ellison says. "We'll know how close we have to fake it to still get a good fiber.

"Making spider silk is a ridiculously complicated process," he adds, "and the spider has about a million years' head start on us." In the spider's abdomen is a gland connected to a long tube. A protein is created in the gland, and by the time it has traversed the tube it is a silk fiber that the spider can extrude through its spinnerets.

"What goes on in between the gland and the spinneret is very, very complicated," Ellison says. "The spider is changing the pH, removing the water—and it's a self-assembly system. It doesn't take a lot of energy, though she does have to eat. If we could mimic that," says Ellison, "if we could learn to make a strong, light fiber with the remarkable properties of spider silk under ambient conditions, well, it would be really cool."

Delphine Dean is an assistant professor of bioengineering, Michael S. Ellison is a professor of materials science and engineering, and Marian (Molly) Kennedy is an assistant professor of materials science and engineering, in the College of Engineering and Science.

Neil Caudle



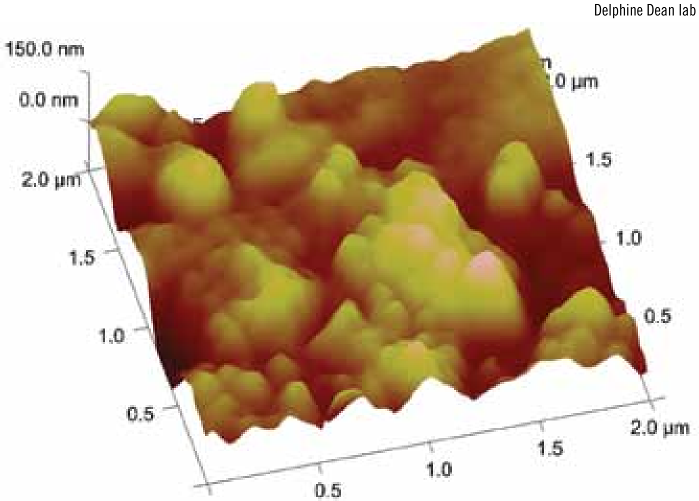
Molly Kennedy studies how tiny structures affect a material's properties.

How to see the *invisible*

Delphine Dean's skill with atomic force microscopy is key to the spider silk study. "You may have seen pictures from a scanning electron microscope," Dean says. "An SEM can image a whole bug, and then zoom in on its eye. With the AFM, we're more limited." The largest thing an AFM can look at is 100 microns in the X-Y, or back-and-forth, direction and 40 microns in the Z, or up-and-down, direction. "A strand of my hair is seventy microns thick," Dean says. Her adviser in graduate school, she says, "had gorgeous thick hair. It was one hundred microns in diameter. So that gives you an idea of the scale." A spider is too big for the AFM. But spider silk, at only 5 microns in diameter, is a perfect subject.

A relatively new scientific imaging technique, the AFM was invented in 1986 and commercialized in 1990. Dean was a junior at the Massachusetts Institute of Technology when MIT bought one of its first ones in 1999. Because AFM was so new, the faculty brought together an interdisciplinary team to, as Dean puts it, "see what it could do." The team included Dean, then a student in electrical engineering. "I was never bored," she says. She went on to do a Ph.D., studying cartilage with the AFM, looking at how the molecules that make up cartilage interact and especially how those interactions change with age to cause arthritis. "I had to learn how to set up the AFM and how to use it."

Delphine Dean lab



Atomic force microscope image of the surface of spider silk.

Explaining it to her students now, Dean compares the microscope to a record player: "A needle is dragged along a surface and moves up and down along the bumps and grooves." She shows them a picture of a turntable. "When I'm done, they tell me a record player works like an AFM!" Who has a record player these days? In this analogy, the record or LP is the sample to be tested. The needle is the probe tip that scans across the surface of the sample. The arm of the record player is the tweezer-like cantilever that holds the probe tip. But instead of turning the wiggles of the arm into music, the AFM turns the wiggles of the cantilever into an image by shining a laser onto it and measuring precisely how the cantilever dips and bobs. The result is a 3-D image of the surface topography.

"It's not an *improvement* over SEM, just a different imaging modality," Dean explains. To look at something under a scanning electron microscope, you must first coat your sample with carbon, gold, or some other metal, then place it inside a vacuum. "Because the AFM is all mechanical," Dean says, "you can do it in water or under physiological conditions, using living cells and tissues. You can characterize just the surface, or you can watch the tip interact with the surface. For example, we use the AFM as a very tiny mechanical tester to see how stiff or soft a cell is. Or, if you put a protein on the probe tip, you can look for the matching protein in your sample. You keep dipping the tip down until you feel it stick. You come down, you catch something, and you can pull on it. You can make a protein unwind and get an idea of the length of the protein or how elastic it is. If you know what's on your tip and you watch it interact with your sample, you can map the functional groups on the sample surface—though if the surface is really sticky, it's hard to do anything because the probe tip gets stuck."

Dean's lab at Clemson, the Multiscale Bioelectromechanics Lab, now has two AFM machines. The one upstairs in Rhodes Annex sits on a thick granite slab and is encased in a black protective housing the size of a large refrigerator. But most of the equipment inside the casing belongs to an optical microscope that lets you watch what the AFM is doing. "It looks impressive," Dean says. "But all the impressive parts are not the AFM. I remember back at MIT when the public information office sent people to the lab to take a picture of their new machine. They were so disappointed. It was so small. Nothing like an SEM, which is huge."

Small and also temperamental. "Sometimes you turn it on and it's not in a good mood and you get nothing," Dean says. "We have a love-hate relationship. It gets you cool data, and a lot of data, but it's a finicky machine."

Dean opens a small plastic case and points to a sliver of metal about the size of a fingernail paring. "This is the cantilever on top of which is the probe tip. It's a tiny, tiny probe, too small to see with the naked eye. How the heck do you put a protein on this probe tip so it will stick? I had to learn some chemistry really fast. So I talked to someone in chemistry who told me, 'We use this to stick molecules to gold.' I tried it and it worked." But it takes good eyesight to then properly mount the tiny probe tip and the delicate cantilever that guides it, like the arm of the record player, across the surface. "I can't have too much coffee before I do this," Dean says, "or I can't get the tip in there."

Then there is the problem of vibrations. Even with the AFM sitting on a sturdy granite slab supplied with shock absorbers—or, for the AFM in the Rhodes Annex basement, on a cushion of air continuously pumped from a canister—vibrations can ruin the data. "When we're doing surface characterizations, and we're looking at nanoscale differences," Dean says, "you can't even talk in the room while you're taking measurements. If I clap my hands, you'll see it in the data." If you turn on the ceiling fan, you'll get wavy lines. Forget about sneezing. The building construction on campus is also a problem. "There's only so much you can do while they're jackhammering. The tip goes all over the place."

—Nancy Marie Brown

A drop of water, a speck of coal

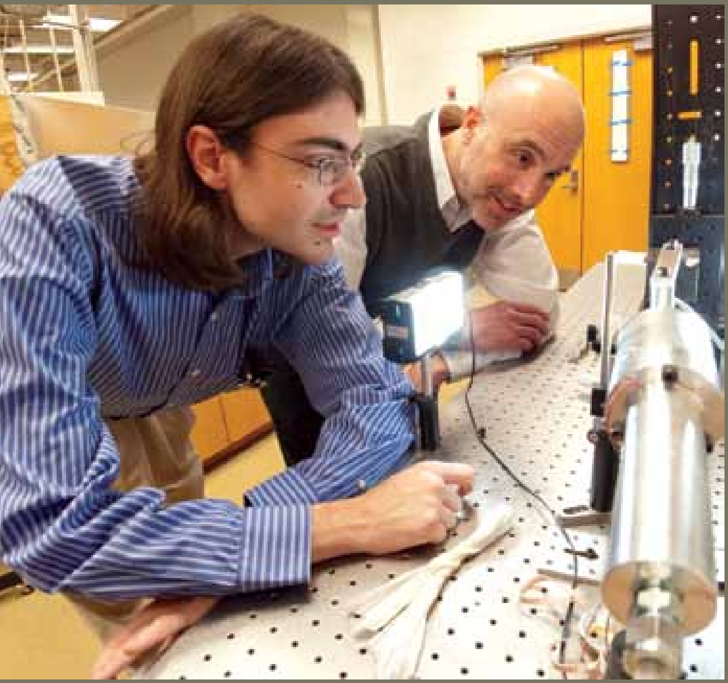
Ultrasonic waves and dancing droplets could help protect miners' lungs.

by Neil Caudle

Craig Mahaffey

Steven Fredericks thumbs the plunger of a syringe, expels a few squirts to clear air from the tip of the needle, and lowers the needle toward a polished metal disk. When a new drop appears at the tip of the needle, an invisible force seems to seize it and float it in air. Fredericks sets the syringe aside and twists a knob on an amplifier nearby. We hear nothing from the hardware, but the drop begins to vibrate, dancing. It leaps and darts, jolted from side to side. As Fredericks fine-tunes the voltage, the dancing calms, the drop aquiver, as though from its frantic exertion.

Craig Mahaffey



Steven Fredericks (left) works with John Saylor (right) to fine-tune a device they built to levitate droplets and help them study the effects of various frequencies of ultrasonic sound.

Fredericks, who helped assemble the equipment, is a master's student working in the lab of John R. Saylor, a professor in the Department of Mechanical Engineering. Fredericks has just demonstrated how to levitate a drop. He does it with unheard sound.

The force that lifts and holds the drop is inaudible to humans but would madden a dog. It is an ultrasonic standing wave field—one wave emitted and another reflected, matched in their coming and going so that in their symmetrical embrace the drop is trapped and held in place, pulsing like a heartbeat.

It's a clever trick that savvy magicians might try on the stage. But drop levitation, a technique developed in part by Saylor's collaborator at Boston University, R. Glynn Holt, has more to offer than sleight of hand.

Where it's dark as a dungeon

Hold in one part of your mind the gentle levitation of one silvery drop and in another its opposite: a vast, craggy underworld where enormous machines with burr-like cutters gnaw the bones of a mountain, shearing coal from the walls of a mine gallery, crushing the coal into chunks and great billowing clouds of black dust. People are working here, sometimes a mile below daylight. A ventilation system forces fresh air down a duct to them, exhausting a stale, dusty flow. And spray heads drench the workspace with water to settle the dust. But airflows and sprays do not capture all of the floating coal dust particles. Nor do they capture all of the particles from the exhaust of diesel engines that power the mining machines. These particulate contaminants flow into the coal miners' lungs.

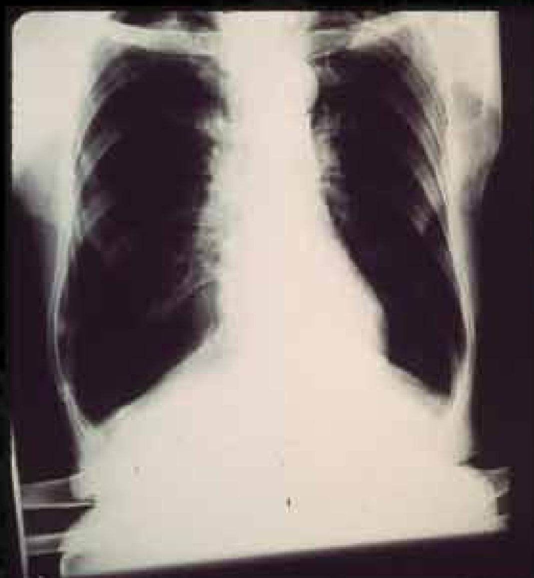
Saylor is not an epidemiologist, but he devotes careful attention to coal miners' lungs. He says our bodies can trap and expel most of the largest particles from coal dust and diesel exhaust. But particles having a size on the order of a micrometer in diameter elude our defenses. Cigarette smoke, coal dust, and diesel exhaust all carry a heavy load of particles in this size range.

"When you take a massive cutter and use it to grind coal into pieces that can be moved to the surface, you're going to create particles of all sizes," Saylor says. "Particles in this especially hazardous size range can navigate the twists and turns of our nasal passages, reach the most distal recesses of the lungs, and stay there. And that's what causes black lung disease."

Going deep

To avoid the deadly black lung disease, coal miners need better protection from the clouds of dust and diesel fumes their machines are making underground. Levitated drops of water (left) could help capture more particles before they invade the lung.

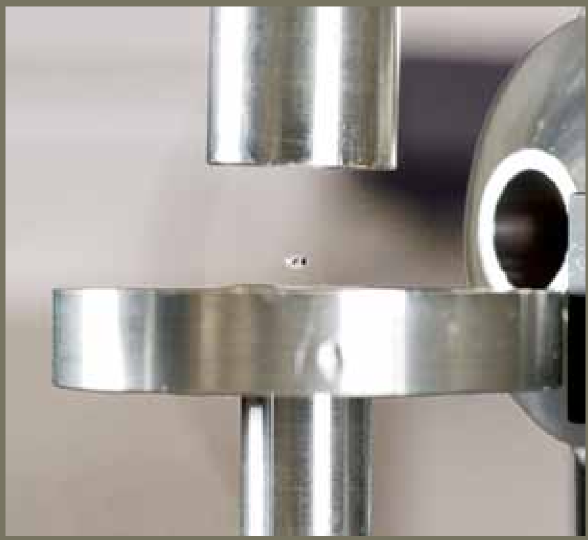
Leroy Woodson, U.S. National Archives and Records Administration



X-ray from a patient of A. H. Russakoff shows severe black lung disease.

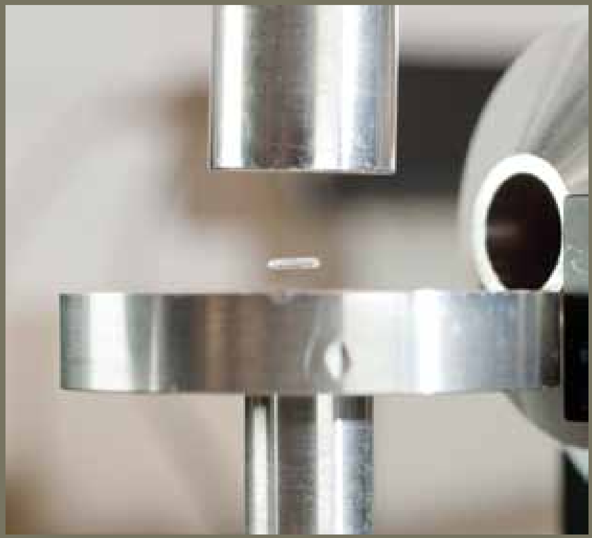
Spray heads on mining equipment control some but not all of the dust as giant cutters burr into walls of coal.

Office of Mine Safety and Health Research



Above and below: Rising to dance in thin air, droplets round or flatten in response to changes in the ultrasonic frequency. Learning how individual drops respond helps researchers project the behavior of a spray.

Left: John R. Saylor



According to the National Institute for Occupational Safety and Health (NIOSH), 1003 miners died from coal workers' pneumoconiosis—black lung disease—in 1999 alone. From 1995 to 1999, 26.2 percent of recorded exposures to coal dust exceeded recommended levels. And some 30,000 miners in the U.S. are exposed to unsafe levels of particulates from diesel exhaust, a carcinogen.

The main defense against these deadly threats? Tiny drops of water.

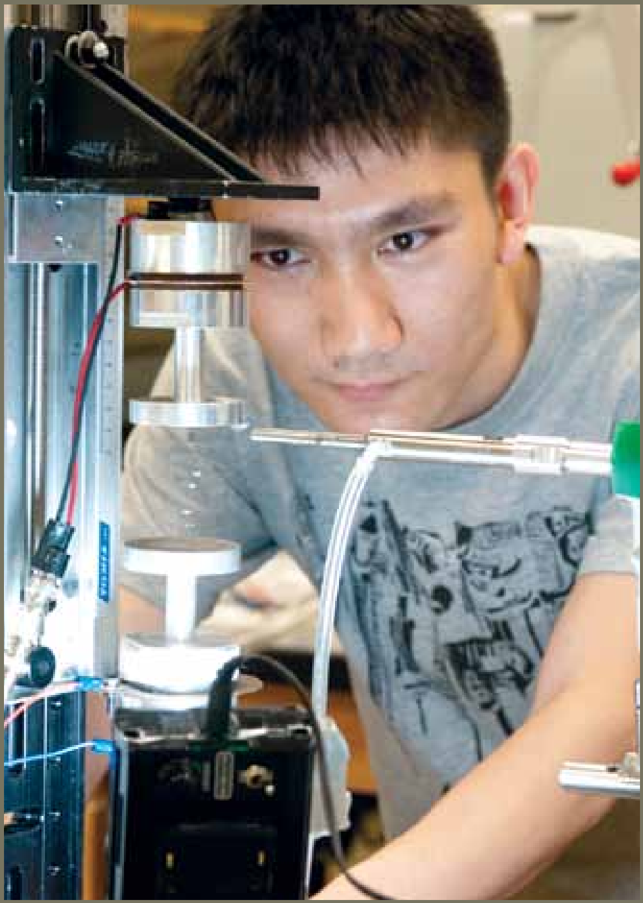
Bubbles and drops

Saylor has long had an interest in bubbles and drops, and a spray, he says, is nothing but a lot of drops. He also studies what he calls the nexus of water and energy, the inescapable fact that producing energy with conventional fuels requires vast amounts of fresh water. Coal mining is a case in point. If Saylor and his students can devise a way to make sprays more efficient in coal mines, they may help save water and lives.

Which brings us back to the levitated drop.

What if you could, with an ultrasonic standing wave, levitate not just one drop of water but millions, suspending them long enough to intercept most of the dangerous particles from coal dust and diesel exhaust? What if the drops and particles began crowding together so tight that their accumulating weight would sink them safely to a drain? This is exactly what Saylor and his students have done in his lab. Using their drop-levitation technique, they have created what Saylor calls an accretion disk, where drops and particles collect.

As Fredericks works drop by drop, Weiyu Ran, one of Saylor's Ph.D. students, works with many drops—with sprays. Saylor and Ran have designed and constructed a small-scale scrubber, a device that forces sprays and a flow of particle-laden air to photos both pages by Craig Mahaffey



Above: Weiyu Ran, a Ph.D. student, worked with Saylor to design and construct a scrubber, a device that forces sprays and particle-laden air together in a chamber.

Right: Large drops have been levitated at nodes of the ultrasonic standing wave field. These drops are formed from the accumulation of many fine water drops, introduced from the left in this image. The large drops continue to grow until they become too heavy to be supported by the ultrasonic standing wave field, at which point they fall and the process begins anew.

combine in an enclosed chamber. By creating accretion disks inside this chamber using ultrasonic energy, far more particles are removed from the air than would otherwise be the case.

Scaling it up

So at least in the lab, the method works. But what about in coal mines? Saylor is looking for ways to scale up the technology for testing in mine-like conditions. Mining operations would probably balk at the electricity required to power a very large wave field, because errant voltage in a dusty mine might spark an explosion. So an ultrasonic standing wave field may not be practical for treating whole underground rooms. There is also the problem of the volumetric flow rate of air, which is enormous in mines compared to values employed in the lab.

"The first step may be to use our device in a smaller compartment," Saylor says, "like the cab of a mining vehicle, or in a scrubber like those used to reduce air pollution from smokestacks."

Getting to that stage will require cooperation from industry and government, and Saylor is starting with NIOSH's Office of Mine Safety and Health Research in Pittsburgh. Meanwhile, he and Ran are preparing to publish their data from the small-scale ultrasonic scrubber. While the results so far are encouraging, Saylor knows that scaling up will mean taking the science to another level, analyzing in detail the complex interaction of particulates and drops in wave fields of various sizes. This will take some time, and the clock is ticking for people who work in the mines.

"Black lung disease has been increasing, not decreasing," Saylor says. "What would be very satisfying to me would be saving lives."

John R. Saylor is a professor of mechanical engineering in the College of Engineering and Science.


PEACE

the bullies of cyberspace

Kids get hurt when spite goes viral.

story by Jemma Everyhope-Roser
illustration by Stephen Durke

Suzannah Isgett—her nickname is Zan—was an honors student, a self-described bookworm who attended a public arts school. Her ordeal began in the eighth grade when two cute guys took an interest in her. She dated one of the boys and hung out with the other. She had no idea that two other girls had laid claim to them. The girls tried to turn the boys against Zan, but when that didn't work, they decided to befriend her. Zan had no interest in gossip and popularity contests. She avoided them. The girls started texting her, insulting her over AIM and MySpace, and excluding her at school. They'd ask Zan's friends to sleepovers and make sure than Zan knew she wasn't invited.

"It was a small school. I'm sure everyone knew it was happening," she says, and people even joined in. Boys threw rocks at her. Girls disparaged her appearance. The teachers felt they couldn't intervene, because most of the harassment occurred outside of school.

"It felt like my world was over," Zan says. "These girls wanted to see me suffer."

Craig Mahaffey

Suzannah Isgett says that working with Robin Kowalski helped her put bullying into perspective.

In the end, Isgett and White were lucky. No one died.

After eight months, it ended when the boys left Zan for the popular girls.

Zan says that the experience was one of the worst in her life so far, but she came out of it with a deepened understanding. Studying with psychologist Robin Kowalski helped her put it into perspective and eventually led her to apply for a Ph.D. in social psychology. She works in the Positive Emotions and Psychophysiology Lab at the University of North Carolina at Chapel Hill, where she studies how genes influence positive behaviors.

A "mean, mean girl"

Mackenzie White (not her real name) had a good life. She was popular, her parents came to her basketball games, she had dinner with them every night, and she had a computer in her room. She says she started cyberbullying in seventh grade to maintain her superiority.

Mackenzie mostly harassed people over AIM. She'd create fake screen names. Sometimes she'd make the names similar to other people's and impersonate them. Sometimes she'd pretend to have a crush on someone, leading them on and then disappointing them. She only harassed people she knew, though sometimes she did it anonymously. Her friends did it too.

"Really, I was just a mean, mean girl. I had no concept of others' feelings." Mackenzie remembers chatting with another friend of hers online. Her friend said that her comments were hurtful, that she was crying, and Mackenzie told her, "And I'm laughing at you."

Once, she found the results to an online love quiz and learned that a male friend was bisexual. She printed off the results and distributed them around the school, outing him without his permission. But, other than that, her online actions didn't really transfer over into traditional bullying. She says, "It didn't seem like it played into real life. I would have never been as mean to someone's face as I was online."

Today, Mackenzie White lives abroad and works at an international school as an academic advisor. She also teaches life skills to middle school kids and includes internet safety and cyberbullying prevention in the curriculum, all as a result of the research she's done with Robin Kowalski.

In the end, both Isgett and White are lucky. No one died. Sometimes, when cyberbullying bleeds over into real life, the consequences can be deadly. Tristan Christmas died at age eighteen after a "happy slapping" incident, when his assault was filmed and posted online. Ryan Patrick Halligan (www.ryanpatrickhalligan.org) died by suicide at age thirteen after years of physical bullying culminated in a cyberbullying episode where a girl pretended to like him online, copied and pasted his chat confessions to her friends, and then mocked him publically for it. The reasons leading up to a suicide are often very complex, but cyberbullying can be a tipping point.

The search for solutions

Cyberbullying can be hard to understand because the individuals involved can react so differently. Amanda Todd, a Canadian teenager, was targeted anonymously with an explicit photo taken when she was thirteen. She changed schools several times but the harassment followed her—and eventually she committed suicide. You can see her tell her story on YouTube. The video, posted a month before her death, now serves as a memorial.

Although cyberbullying is not as prevalent as traditional bullying, especially verbal bullying, approximately 18 percent of surveyed students reported being a target of cyberbullying at least once within the last two months. About 11 percent said they had cyberbullied someone at least once within the last two months. As adults, most of us wouldn't stand for being harassed, humiliated, or assaulted at work or online. Why are students expected to ignore what adults wouldn't?

"All children should be able to interact in school settings without fear of being harassed or humiliated," says Susan Limber. She is a developmental psychologist who started her career focused on violence against children. She now studies bullying and children's rights. Currently, she oversees the dissemination of the Olweus Program in North and South America, analyzes data from a nationwide database of bullying among children and youth to understand shifts in bullying, and provides consultation to the federal government's efforts to address bullying. She argues, in one of her most recent papers, that progress against bullying in schools represents some of the most important advances in children's rights since the child labor laws.

But, she says, "I am not in favor of criminalizing bullying."

Limber's collaborator, Robin Kowalski, began her career researching traditional bullying but grew interested in cyberbullying about ten years ago. She uses a variation of the Olweus Bullying Questionnaire to study the prevalence of cyberbullying among adolescents and adults—it's more critical than ever to understand cyberbullying as more states enact legislation about it.

In response to legislation, schools often search for appropriate responses to bullying. Unfortunately, all too often these schools develop zero-tolerance policies, which demand suspension or expulsion after bullying. Often, these solutions only make the lives of already at-risk kids worse and do nothing to improve the situation at school.

But bullying and cyberbullying can't be overlooked with a mild "kids will be kids" attitude. The negative effects from cyberbullying appear to be similar to those from traditional bullying, Limber says. Children who are bullied are likely to develop depression, low self-esteem, internalize their problems, and have lowered academic performance. Children who bully are at higher risk for externalizing problems, violent behaviors, drug use, and juvenile delinquency.

This is a problem for *everyone.* And it has to be solved.

Not a conventional conflict

Kowalski and Limber have worked with youth-advocate Patricia W. Agatson on the most recent edition of their book, *Cyberbullying: Bullying in the Digital Age*, which discusses not only current research but also its practical applications. Not all well-meaning efforts to prevent or stop bullying and cyberbullying work (if you want to know about programs that *do* work, visit the resources given on page 45). Some conflict resolution and peer mediation programs only force the bullied child to spend more time with the child who is victimizing them. Often, they resolve nothing; bullying is not a form of conflict.

Educators face a unique challenge when it comes to both bullying and cyberbullying (see sidebar, "The trouble with definitions," page 45). In addition to traditional bullying problems, evolving technology and new social media platforms make it hard for educators to keep up with adolescents, who were born into the Internet era and are often very tech savvy. By eighth grade, at least 80 percent of students have a Facebook account. In 2010, around 93 percent of twelve- to seventeen-year-olds spent time online; 63 percent of them spent time online every day, and 36 percent went online multiple times a day. The average teen sends fifty text messages a day, though for more intensive users it averages three thousand texts a month. Texting has surpassed IM as the leading form of communication among teens.

Cyberbullying is as real as traditional bullying—and as painful. Online, perceived anonymity is a dangerous weapon. If a victim isn't aware of the perpetrator's identity, then anyone and everyone could be a possible harasser. A single perpetrator can work under fake screen names so that the victim feels like the target of a larger conspiracy. A hijacked account can be misused to attack an entire contact list, permanently breaking friendships. Misinformation and poisonous rumors can be circulated with a single click. Easy access to private information, such as phone numbers and addresses, can make online death threats truly terrifying.

"Around fifty percent don't know the perpetrator's identity," Kowalski says. "At least, with traditional bullying, you can attempt to avoid a bully because they're identifiable."

Kowalski and Limber are both trying to understand the overlap between online and offline behavior.

When bullying is reported, educators can and should

Craig Mahaffey

Perceived anonymity is a dangerous **weapon.**

Susan Limber (left) and Robin Kowalski: Evolving technology and new social media make it hard for educators to keep up with what students are doing to each other in cyberspace.

If you thought the birds-and-the-bees talk was tough, try to chat about **sexting.**

approach the children's parents to discuss any allegations with them, Kowalski says. Parents can play a critical role in addressing bullying. But not all parents are responsive. Some approve of bullying as a way to "toughen up a kid for the real world" or want their kid to "learn how to defend themselves." Other parents may be overprotective. Parental overreaction, such as removing a bullied child from school or confiscating electronics, may only make a child more isolated and reluctant to report bullying when it does happen. Limiting children's technology use when they're being cyberbullied only makes the targets feel as though they're being punished for talking about it at all.

Bullying is often underreported because children don't want to be perceived as tattletales and they don't want to get their peers in trouble. The harsher the penalties, the more pronounced this is. If children do tell someone, they're most likely to tell a friend or a sibling before ever approaching an adult. Adult intervention to stop bullying can be helpful but it isn't a long-term solution. So what is?

Indulging the novelty of power

"Prevention," says Limber, succinctly. Stop it before it happens at all. Kowalski and Limber have developed curricula on cyberbullying for elementary, middle, and high school students, to be used as part of a comprehensive bullying-prevention effort in a school. Understanding a school's climate and culture is critical to preventing traditional bullying and cyberbullying, Limber says. Educators and parents should be aware of the patterns in each school regarding gender, race, and insider/outsider groupings. It's important for adults to have high expectations of good behavior and to reward children. A reward, depending on the school or the adult's philosophy, could be anything from a verbal acknowledgment to a gold star or an ice cream party at the end of the year.

In the younger years, Limber explains, bullying is more prevalent because children are still learning how to interact appropriately. Children, not yet powerful in the adult world, are playing with the novelty of having power over others. In elementary school, it's easier for older students to wield power over younger students who aren't as able to defend themselves.

Kowalski emphasizes how important it is for kids to talk about both traditional bullying and cyberbullying. She recommends a change in curriculum so that there can be class discussions. Peer leaders are also important. So is teaching kids how to deal with bullying when they encounter it in person.

"We know so little about the bystander's role," Kowalski says. "The vast majority of people aren't victims or perpetrators, they're bystanders, and they're the ones who can make a critical difference."

When it comes to cyberbullying, bystanders can also make a difference by stepping in. But kids need to know when it's appropriate to respond to bullying online, Kowalski says; parents and teachers should teach online courtesies, known as netiquette, as well as real-life *pleases* and *thank-yous*. Parents may feel technologically impaired sometimes, Kowalski says, "but the easiest way for us to keep up with changing technology is just to ask our kids about it."

Kowalski was involved in a focus group in which a kid said, "I want supervision, not snoopervision."

Beware the flirty pictures

Monitoring online behavior at regular weekly intervals by viewing browser and chat history can show parental attentiveness without invading a child's privacy. Asking what they've been doing and talking to them about password security and the dangers of posting identifying information online can help too. Making sure they know the difference between trolling and a genuine threat is also important.

And, if you thought the birds-and-the-bees talk was bad, try talking about sexting. But kids need to know that keeping flirty pictures of peers on their phones can count as possession of child pornography and could earn them a prison sentence and a place in the sex-offender registry. The legal consequences for online behavior are very real and could permanently affect a child's life. How can any kid be expected to know that without being told?

Robin Kowalski and Sue Limber are both parents. Kowalski has twin boys, aged twelve, and says that personally she's trying to focus on cyber safety. She relates to me an instance where she overheard her boys talking with another friend, who wanted to log on their computer. He asked for their password. After a long hesitation, her sons refused.

"But we're best friends!" the other kid argued, hurt.

Kowalski came in and explained that her sons weren't allowed to give out their passwords, getting them off the hook. She says she had a good talk with them about it. It can be hard to refuse someone you know—and otherwise trust—with details like that. This can be difficult for a kid to accept, when the kid desperately wants to believe that *friends* means *friends forever*.

As a parent of a seven-year-old girl, Limber has seen the issues she studies with new eyes. She wants to say that she's very impressed with how local schools handle the issue.

"I think there's really been a change in the time I've been working in the field," she says. "I'm very encouraged."

Susan P. Limber is the Dan Olweus Distinguished Professor in the Institute on Family and Neighborhood Life (IFNL). Robin Kowalski is a professor of psychology in the College of Business and Behavioral Science. Jemma Everyhope-Rose is the assistant editor of Glimpse.

The trouble with definitions

When you think about bullying, you may imagine a playground or a gymnasium's glossy floors. Although there's some debate about whether or not harassment among adults could constitute bullying, by and large it's considered to be something that happens among children. When asked what bullying is, you might think about kids pushing each other, shouting insults, or excluding unpopular peers from a game. But those are all "modes" of bullying.

To count as bullying, the behavior has to meet the following three qualifications: It must include an aggressive act to harm, a power imbalance between parties, and repetition of the behavior. But, as you can see from the table at the right, each part of the definition poses its own problem for a well-meaning adult.

What's more, the commonly used definition is further complicated by varying state-to-state legal definitions. Some bullying behaviors cross a legal line and may also meet the legal definition of harassment or assault. And although no federal law directly addresses bullying, sometimes bullying may count as discriminatory harassment when it is based on race, national origin, color, sex, age, disability, or religion.

Cyberbullying's complications

If you thought that wasn't enough, bullying's newest mode, cyberbullying, adds its own host of complications.

The problem with defining bullying—and proving that's happening—is yet another reason why reacting after the fact is not enough. Cyberbullying can be even harder to track, although it's certainly not as anonymous as many adolescents believe it is. Between the underreporting mentioned in these pages and the burden of proof resting on the victim, it can seem almost impossible to stop bullying.

As Kowalski and Limber's research in schools shows, prevention is what works.

—Jemma Everyhope-Roser

Bullying in general

an aggressive act with intent to harm	How can you tell whether an act has an aggressive intent or if it's a joke that's been misinterpreted?
power imbalance between parties	How can an adult see a power imbalance between children that may be based on something as delicate as social status or a social group's politics?
a repeated behavior	Shouldn't the behavior be stopped, whether or not it's repeated?

Cyberbullying

an aggressive act with intent to harm	It's even harder to determine intent-to-harm if you can't see a person's face. In one study, participants believed that 97 percent of their email statements would be correctly viewed as sarcastic or ironic; in fact, only 84 percent of the statements were correctly identified.
power imbalance between parties	There is always a power imbalance, if the victim's identity is known and the perpetrator's is not.
a repeated behavior	Does it count as a repeated behavior if it's a single email sent to multiple recipients? Does it count if it's a single video posted online that gets millions of hits?

Resources about bullying

www.stopbullying.gov

www.clemson.edu/olweus

www.cyberbullyhelp.org

drive able

Johnell Brooks finds ways to keep wounded warriors, wreck-prone rookies, and slowing seniors safer on the road.

BY Lauren J. Bryant

From the sweaty-palmed

sixteen-year-old who just passed his driving test to the slow-moving eighty-six-year-old who still takes herself to the doctor, driving is the key to independence in America. Yet few, if any, of us prepare for the end of driving.

"As you age, you prepare for so many things," says Johnell Brooks, assistant professor in the Department of Automotive Engineering. "You prepare for where you want to live, you prepare for financial security. Few people, however, plan for how driving is going to change as they age, or for the end of their driving careers."

A Midwesterner by birth (she comes from Nebraska), Brooks moved to South Carolina while in high school and became

Neil Caudle

Johnell Brooks's simulator, with its realistic road scenes, lets drivers master new skills in a lab before they try them in traffic.

a three-time Clemson University graduate. With a Ph.D. in psychology (yes, her full-time appointment is in automotive engineering), Brooks is a human-factors psychologist who studies "individuals' capabilities and limitations in order to make systems that are safe, efficient, and satisfying for the user."

In Brooks's case, those systems are automotive. Her goal is to "do anything I can to keep people driving safely as long as possible." Why focus on driving? "I like it," she says simply, "because everyone can relate." By "everyone," she means not only adolescents and senior citizens, but also injured veterans, women, short people or tall, thin, obese—in other words, "people, who come in all different shapes and sizes with all different abilities."

From psych to engineering

When Brooks started out as a faculty member at Clemson, she was part of the psychology department, where she used the university's driving simulator to carry out her projects. An actual full-size vehicle parked on the third floor of Clemson's Brackett Hall, the simulator was connected to computers and surrounded by large, standing screens. Using this setup, Brooks and her colleagues and students conducted driving-related research including studies of visual limitations during night driving and of distracted driving due to multitasking.

Nearly every simulator project needed heavy instrumentation that required close collaboration with Clemson's engineering

Neil Caudle

Neil Caudle

testing team

Brook relies on volunteer “subject-matter experts” to test-drive her simulator.

Zeke Massie (above), a retired Marine Corps veteran, travels from Atlanta to work with Brooks and her team in the lab. He brings experience Brooks and her students don’t have. “The Clemson students are really smart kids, but they don’t live the way I do. I’ve been in my chair for almost as long as a lot of these kids have been alive,” he says.

Connie Truesdail (left), a retired English teacher from Easley, South Carolina, is a test subject and advisor with a keen eye for detail—not only in the simulator but in the team’s research manuscripts.

faculty and students. Eventually, after several years of working "hand-in-hand" with engineering, Brooks moved from the psychology department to the Department of Automotive Engineering in January 2012. She is also a member of the Clemson University International Center for Automotive Research (CU-ICAR), a 250-acre research campus that puts Clemson among the top ten automotive colleges and universities in the United States, according to the "car people" website www.edmunds.com.

Along the way, she developed a collaboration with physicians and occupational therapists at Roger C. Peace Rehabilitation Hospital (RCP) of the Greenville Health System. The driving-simulator scenarios Brooks had developed were ideal for helping seniors trying to re-learn how to drive after significant medical events, but the university's driving simulator proved too big, expensive, and complicated to work in a clinical setting. So Brooks worked with the Utah-based company DriveSafety to design and develop a smaller, sleeker unit, now called the DriveSafety CDS-250 Clinical Driving Simulator.

"We had wanted to create a simulation system optimized for use by clinicians with their patients," says Douglas Evans, CEO of DriveSafety. "Dr. Brooks and her team brought unique insight and expertise to help make it possible."

The colloaboration has resulted in intellectual property, which, through the support of the Clemson University Research Foundation (CURF), has been licensed to DriveSafety for commercialization.

Making data work for patients

Today, Brooks's major laboratory is based in the RCP Hospital, about thirty miles from the Clemson campus. Her research projects begin on the university side, where she and her team, including primary collaborator Paul Venhovens, collaborate with DriveSafety to develop scenarios to test various driving-related problems. After deciding what components a scenario will have and what metrics will be used to provide objective feedback, the scenario is tested with volunteers on the university side, then transitioned over to the hospital system. That transition, Brooks says, is a "very iterative process."

Brooks explains that computerized driving simulators have sensors that collect constant streams of data about an individual's driving performance as he or she navigates various digital driving scenarios. But in a clinical setting, that vast amount of research data may prove to be of little use.

"Academics think a ton of data is a wonderful thing," Brooks says. "But how do you present complex data to patients in a way that's meaningful? Or to clinicians who may not have a background in statistics?"

The solutions Brooks and her colleagues have come up with are usually visual. "In the clinic, it is important to make the driving performance information visual and easily understandable," she notes. "We transform the information and have it instantly appear on the screen at the end of a clinic driving session in a meaningful and valuable way." For example, for drivers being evaluated on how they drive within a traffic lane, the team came up with a simple color-coding scheme.

"We made color-coded sections of the lane: green for the center zone, yellow if someone is veering toward the edge, red if any part of the vehicle is touching the edge," Brooks explains. "Instead of talking about centimeters and 'deviations from the center position,' therapists can talk about how many times a person was in the red zone."

The simulator that Brooks helped design is now in use in twenty-six research facilities and clinical settings—three in Europe, two in Australia, two in Hawaii, and nineteen in the continental United States. A couple of the simulators are in university settings, and one is in a pharmacy school where it's used to study the effects of prescriptions on driving performance. But most of the simulators are in military and VA hospitals. That came as a surprise to Brooks.

"When we started developing the simulator," she explains, "we thought the aging population would be the major users. But it turns out that the majority of the simulators are in military hospitals where a huge portion of the patients are wounded warriors who have blast injuries, loss of lower limbs, traumatic brain injury, or post-traumatic stress disorder."

The realization that physical and occupational therapists in military and veterans' hospitals were using the simulator steered Brooks's research in a new direction. For the last couple of years, she says, she and Clemson engineering students have been using the simulator primarily to develop and test designs for hand controls. Hand controls are adaptive devices used to drive a car, instead of using one's legs and feet to control the gas and brakes.

Brooks says the DriveSafety simulator is a perfect tool for engineers, therapists, and most of all, patients, to test how different hand-control designs work. For one thing, she contends, the simulator is a lot safer. Typically, patients learned to use hand controls by driving in big parking lots, according to Brooks. "But just think about where military hospitals are located; most of them are in big cities," she says. "So the veterans were having to learn how to use the controls in congested, busy parking lots and frequently in high-density traffic."

With the simulator, military veterans try different designs of hand controls and get comfortable with operating the gas and brake on hills and around curves in the digital scenarios, before they ever go out on a real road.

"They can really get the nuances down of how hard to press for gas and brake and which direction you press," Brooks says. "It's just so different for someone who has already learned to drive with their feet to have to transfer that knowledge to their hands."

From racetrack to lab

To further develop the simulator for use by veterans with lower limb injuries, Brooks turns to Zeke Massie, whom she calls a "subject-matter expert." A retired Marine Corps veteran, Massie has been paralyzed from the armpits down for eighteen years, following a motorcycle accident. He lives in Atlanta, Georgia, where he's also been involved in motorsports since 1997.

Massie and Brooks met through a Clemson student of Brooks's who also is a friend of Massie's. When the student described Massie's involvement in motorsports, Brooks knew she wanted to meet him. They eventually connected at a racetrack in Atlanta, and a collaboration was born.

Recalling his own days of having to learn how to drive again, Massie says, "When Johnell told me she was working on a simulator, I thought it was such a good idea, a super idea."

Massie now visits Clemson several times a year. His initial visits were focused on helping Brooks and her students improve how people in wheelchairs would transfer onto the driving simulator's seat. More recently, he's been helping Brooks and her students with various projects including hand-control development, seat-belt design, and designs for cars that better accommodate wheelchair-to-car transfers. Massie says his biggest contribution is his life experience.

"The Clemson students are really smart kids, but they don't live the way I do. I've been in my chair for almost as long as a lot of these kids have been alive," he says. "They have great ideas, but sometimes they are far from what is really useable. I know what works. I don't want them to waste time going down the wrong track, so I get in there, and we brainstorm."

Massie is enthusiastic about the community he's found at Clemson. Working with Brooks's automotive engineering students gives him hope, he says. "These kids are engineers focused on cars, and I hope by giving them as much information as I can, they'll design cars that will really benefit the disabled community and make it better for everybody."

Neil Caudle

Zeke Massie can drive a racing car, but climbing aboard a standard passenger vehicle is sometimes a challenge. With Brooks's team taking notes, Massie tries out new models at a local dealership, describing obstacles to access. Brooks will use the results to advise automakers.

For veterans who do not have lower limb injuries but do have TBIs or PTSD, the driving simulator is used in a different way, Brooks explains. She and her team members have developed scenarios that present these returning vet drivers with stress-inducing situations, but in the safety of the simulator. Scenarios that seem benign to civilian drivers—featuring things such as potholes, dead animals in the road, or large trucks boxing in a car stuck in traffic on an expressway—can be triggers for returning vets.

"Dead animals, potholes, or trash bags on the road's shoulder don't cause stress for a typical U.S. driver," Brooks says, "but veterans expect IEDs. These soldiers who are reintegrating into civilian driving and the therapists who work with them have really motivated us to develop these scenarios in the simulator."

A woman's point of view

Expanding the ways engineering students—and future engineers—think about drivers is absolutely central to Brooks's work.

"My primary goal is to make sure that our automotive engineering students realize they are not designing only for young healthy twenty-year-olds but for all people," she says.

Venhovens, who leads Deep Orange, Clemson's innovative master's program in automotive engineering, calls Brooks's perspective an enrichment for the program. "Cars are operated by humans, and understanding the capabilities and limitations of the human operator or passengers and teaching graduate students how to evaluate and design vehicles from a human-factors perspective really needs to be part of every engineering education," he says. "Without this aspect vehicles are just robotized machines that don't get along well with their users."

Being the only female faculty member in the automotive engineering department comes in handy in the "getting along well" regard. Brooks laughs as she describes trying to get her predominantly male students to consider automotive engineering from a woman's point of view. For example, designing a car's seat or the seat of a motorcycle takes on a whole new dimension.

"They have to figure out how to talk to women about the size of their bottoms in a way that is not going to result in getting slugged," Brooks says. "How do you talk about a woman fitting comfortably on a seat, or getting on a motorcycle in India, for instance, where women sit sidesaddle wearing a sari?"

Brooks tells her male students to pretend they're having a discussion with their girlfriend, mother, or grandmother. "When I ask them how they think that's going to work," she says, "that usually puts it in perspective. They usually answer with, 'Ohhhhhhhhhhhh.'"

Blurred lines

A social scientist spanning the worlds of hospital clinics and research laboratories, Brooks believes it's at "the intersection of different disciplines where the most interesting work happens. When we bring different fields together, we're able to look at and solve problems with a broader perspective."

By blurring the lines (the fuzzier the better, she says) between psychology, engineering, and medicine, Brooks has brought something unique to Clemson, to military hospitals, and to South Carolina's automotive industry at large. Using the driving simulator and other tools, Brooks and her research partners can evaluate driving problems and automotive design features from the perspectives of an aging driver, a driver in a wheelchair, an obese driver, or a female driver, offering valuable data to hospital therapists and automotive manufacturers alike.

"Being a human-factors psychologist involved in a team like this, seeing the students think about how they need to design and apply concepts for different user groups, and seeing patients in the hospital use products and services we developed, has got to be the most rewarding job on the planet," Brooks says.

Johnell Brooks is an assistant professor of automotive engineering in the College of Engineering and Science. Paul Venhovens is the BMW Endowed Chair for Systems Integration at CU-ICAR and a SmartState Chair, South Carolina Center for Economic Excellence. Lauren J. Bryant is a science journalist based in Bloomington, Indiana.

Patrick Wright

Naren Vyavahare in the lab: Developing a new heart valve is never an open-and-shut case.

a valve for saving your HEART

BY Rachel Wasylyk

WHEN SNOW WHITE'S HUNTER used a swine heart to fool the malicious queen, his scheme wasn't very far-fetched. In its structure, a pig's heart is similar to a human heart. But the fairytale similarities end there. While doctors have been using aortic valves from pigs for decades, approximately half of these devices fail within five to fifteen years after they're implanted in patients. For twenty years, Naren Vyavahare has been dedicated to improving the treatments and procedures surrounding artificial heart valves.

A pressing need

Every year, more than 300,000 patients undergo replacement surgery after structural failure of their heart valves. The human heart consists of four valves that open and close with every drumming beat. The movement of the tissue flap regulates the direction of the blood, ensuring no backflow. When someone suffers from severe heart-valve disease, the structure must be replaced by an implant. With life expectancies on the rise, the number of surgeries is likely to increase, Vyavahare says.

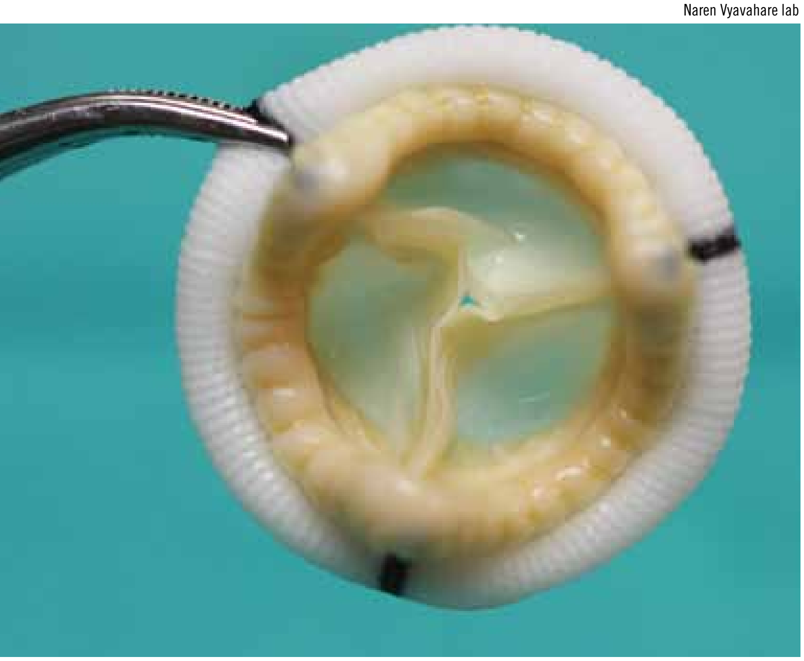
Through his research, Vyavahare finds ways to improve heart-valve implants. One treatment he helped develop several years ago is currently being used on implants that replace defective valves. Today, Vyavahare and his team are striving to create a new technology that would increase the functional lifetime of the device, thus allowing doctors to use tissue-based valves in younger patients.

Seeing the options

There are currently two forms of artificial heart valves on the market: mechanical and bioprosthetic. Mechanical valves are constructed around a metal ring and have been shown to withstand a lifetime of physical stress. Operating in the presence of a constantly beating organ, these structures can effectively resist degeneration. But patients with mechanical heart valves are required to take daily anticoagulants, drugs that thin blood, to prevent formation of blood clots on the heart-valve implant. While the consumption of this medication every day can be an inconvenience for some, it's not even an option for others. For women of childbearing age, the drugs interfere with contraceptive use and are also harmful to a developing fetus. In addition, patients have to undergo a monthly test to assess their blood's clotting ability.

In the 1970s, an alternative to mechanical valves was developed. Bioprosthetic heart valves (BHVs) are tissue-based implants that are fabricated from either a pig's aortic heart valve or cow pericardium, a thin membranous sac enclosing the heart. These devices are extremely compatible with the human body as they present little risk of blood clotting, and patients only remain on medication for a week following the implantation. But BHVs are far from perfect. Because they are composed of natural tissue, the lifetime of these devices in a human is limited. For young patients, a valve failure would require a second open-heart surgery—an experience no one wants to repeat.

Naren Vyavahare lab



A bioprosthetic heart valve has been fabricated from a pig's valve using the new cross-linking method developed in Vyavahare's lab.

What prevents a heart from beating?

Vyavahare's research primarily focuses on bioprosthetic heart valves and the two main issues related to their failure: degeneration and calcification. These structures, although once alive in animals, are chemically fixed to prevent immune rejection of the tissue, and the cells are no longer living. Degeneration occurs as bending forces in the heart cause expected wear and tear on the valve. With constant beating, the device begins to degrade and cannot repair itself.

In a living cell, approximately 10,000 times less calcium can be found in the interior of the cell than outside the cell membrane because the live cell actively removes this molecule. But in bioprosthetic valves, the dead cells aren't able to do the same. Calcification occurs as calcium phosphates build up within the bioprosthetic tissue and cause the structure to stiffen and tear, eventually leading to valve failure.

From pigs to humans

A bioprosthetic heart valve's extracellular matrix is comprised of three main components: collagen, elastin, and glycosaminoglycans (GAGs). Collagen fibers provide strength to the overall structure while elastin molecules lend the valve elasticity. Finally, GAGs act as a cushion between the collagen and elastin layers.

Pig-derived tissue undergoes numerous chemical treatments before it can be safely implanted in a human. Glutaraldehyde (GLUT) is the primary tissue fixative used on the valves. It has been shown to sterilize the tissue, reduce inflammation, and allow collagen cross-linking, a binding that ensures the retention and stabilization of the fibers.

The problem is, GLUT fixation makes the valve prone to calcification and degeneration. In fact, GLUT may actually increase calcium deposits in the tissue. Additionally, and most importantly, GLUT does not stabilize elastin or GAGs. Since GAGs retain impressive amounts of water, they typically provide the lubrication and cushion for a living valve. This lessens the stress induced by cardiac mechanical forces and increases the durability of the structure. Without these GAGs in place, the BHVs begin to degrade at an alarmingly faster rate, significantly shortening the overall lifetime of the device.

On the edge of discovery

Vyavahare's team was focused on finding a chemical that would bind to GAGs, creating a cushion to protect the valve. In 2005, after several years of research, Vyavahare's group found out that the chemical fixation of GAGs is not possible because enzymes can still degrade the GAGs in the tissue. That summer, while looking for enzyme inhibitors, Vyavahare had an idea. Neomycin, a common antibiotic, had been used in a different study where it was shown to inhibit the enzymes that degrade

GAGs. What if they introduced the valve to neomycin before the GLUT? Would it have a similar outcome? Vyavahare set off to find the answer and, sure enough, the neomycin increased GAG and elastin binding and decreased the degradation of the valve during *in vitro* testing. If the experimental tests are successful, neomycin could have an immense impact on BHVs in the future. With added cushioning and limited calcium buildup, a valve would be able to withstand enormous amounts of stress and operate for an increased number of years.

Experimental valves were constructed and placed in sheep during the summer of 2012. The devices are scheduled to be removed soon and Vyavahare is eager to see the first round of results. But as with any research study, the goals and questions are always changing.

"A lot of optimizations in concentrations and timing are required to stabilize tissue structures without making them too stiff," Vyavahare says, "so we're constantly modifying our goals in order to make the best heart valves."

Protecting hearts

Because of the risks and complications, open-heart surgeries are a last resort. Another area of Vyavahare's research focuses on improving BHVs that are used in procedures that access the cardiac muscle through the patient's skin. When a person's health prevents them from safely undergoing open-heart surgery, doctors can use a catheter to implant an animal-tissue derived valve. Although these structures have to be compressed to the diameter of a catheter, they must also possess the ability to retain their shape upon insertion. So the valve must have a combination of strong collagen and resilient elastin fibers to survive this drastic transformation.

Today, most of these devices are fashioned out of cattle pericardium. But Vyavahare's studies determined that tissue from a pig's vena cava, a large vein connected to the heart, would be more suitable for the job. The thin tissue consists of highly aligned fibers and an abundance of elastin, both factors lending to its ability to regain its shape after extreme stress. Additionally, the vena cava tissue showed less calcification than did the pericardium tissue. In 2011, these results were published in the journal *Biomaterials* and are currently being tested.

Everything takes time.

According to Vyavahare, research on bioprosthetic heart valves is a very slow process. With the extensive testing required before any structures are placed in humans, it will often take ten to fifteen years before researchers know if their technology works accurately and effectively. As Vyavahare puts it, "Everything takes time." Even after a successful field test, a new instrument may not be readily accepted by the medical community. Doctors may be comfortable with current practices and reluctant to embrace change. In addition, the research is expensive, requiring substantial, steady funding to develop the chemical treatments and new devices, with no guarantee that the technology will function correctly in the end.

But with a new, five-year, $1.2 million grant from the National Institutes of Health (NIH), Vyavahare, in collaboration with Michael Sacks from University of Texas at Austin and Joseph Gorman from the University of Pennsylvania, is working to improve degeneration and calcification issues for BHVs, as well as find new biomaterials related to these structures. Vyavahare's goal is to create a bioprosthetic heart valve that will continue to operate thirty years after insertion in a patient.

Building the science

In addition to his work with bioprosthetic heart valves, Naren Vyavahare serves as the director of the Center of Bioengineering Research Excellence (COBRE). The center, funded with a highly competitive grant of $9.8 million from the National Institutes of Health (NIH), is the first and only bioengineering center of excellence in the nation.

The main focus of the center's research is tissue regeneration. Vyavahare is a mentor for other faculty members, currently overseeing eight projects. New investigators use the center's resources to establish their research programs and compete for their own grant funding. As they succeed, they move on and make room for additional faculty members in the COBRE center. Vyavahare says that the center is an ideal way to build the scientific community of Clemson and the state of South Carolina.

Passing the knowledge along

Vyavahare originally planned on becoming a medical doctor. But with funding in India limited to specialized schooling, he decided to pursue a degree in chemistry instead. As a young researcher in the cardiology department at the University of Michigan, he was inspired by the work of Robert Levy, his professor and mentor. Now, over twenty years later, Vyavahare strives to have a similar influence on his students today.

Brianna Liberio, a recent Clemson graduate, says she is studying medicine in part because of Vyavahare's example. "During my time working in Vyavahare's lab as an undergraduate, I became more confident in a lab setting, and I am currently pursuing research opportunities as a medical student," Liberio says. "In addition, being exposed to bioprosthetic heart-valve research sparked my interest in cardiology, and I am considering this field in my future medical career."

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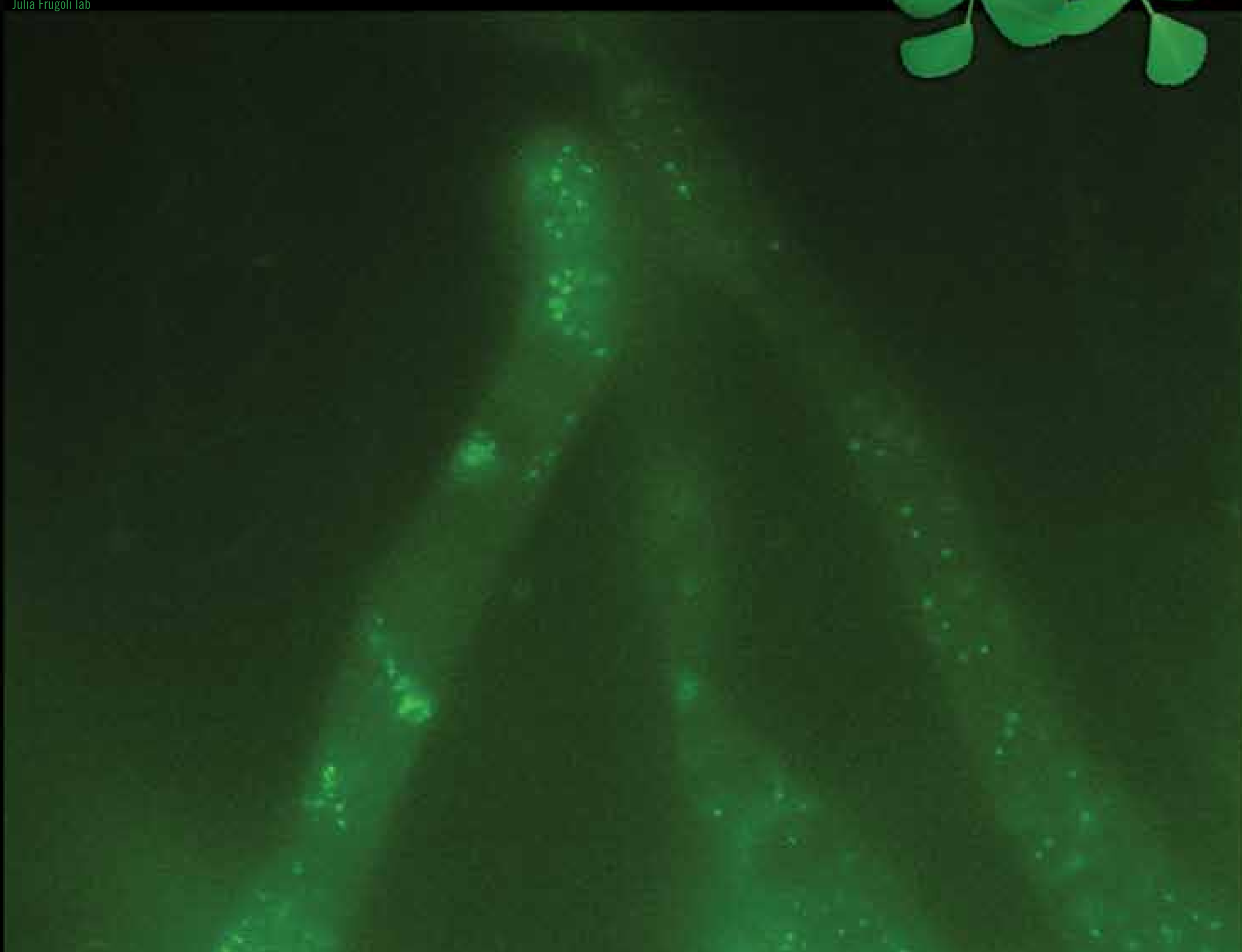
Naren Vyavahare is a professor and Hunter Endowed Chair of bioengineering in the College of Engineering and Science. He is also the director of the South Carolina Center of Biomaterials for Tissue Regeneration, a Center of Biomedical Research Excellence funded by the National Institutes of Health. Rachel Wasylyk, a 2012 graduate and the previous editor of Decipher, *a student-led research magazine at Clemson, is now a marketing coordinator and freelance writer based in Charlotte, North Carolina.*

Vyavahare's work has led to several issued and pending patents that are available for commercialization through licensing. Contact the Clemson University Research Foundation (www.clemson.edu/curf) to learn more.

Ninjatacoshell

Roots and shoots

Julia Frugoli lab



The quest to feed a hungry planet leads Julia Frugoli and her students straight to the root of the matter. BY Peter Kent

That smell, familiar but unexpected in a laboratory: just-cut grass, fresh fodder for livestock, the smell of chloroplasts breaking open.

"It smells like you just mowed your lawn," says Julia Frugoli, a plant molecular biologist. She watches Ashley Crook, a Ph.D. graduate student in biochemistry and molecular biology who works with Frugoli, use a mortar and pestle to pummel plant leaves into powder.

If you've ever done this to herbs in your kitchen, you know that powdered parsley or basil isn't the typical result.

Liquid nitrogen at –80 degrees centigrade makes the difference.

As soon as Crook pours liquid nitrogen over the leaves they flash freeze.

A few more minutes of freeze grinding and Crook collects the powdered cell parts and plant debris and puts them in a test tube containing a homogenized buffer with chemicals to sustain the proteins, DNA, and other research-worthy materials.

Voilà, crude lysate. It's ready to be refined and put on a gel for analysis.

Crook does this three or four times a week with at least nine samples per session. The serrated leaves come from the small plants in trays under grow lamps by the window in a corner. They are mutant plants of an alfalfa, *Medicago truncatula*, the research model plant for Frugoli's studies on how plants communicate, from shoots to roots and roots to shoots.

Challenge of the century

Plant molecular biologists, like Frugoli, along with many other scientists, are participants in the research challenge of the century: how to feed, clothe, and provide fuel for billions more of us without recklessly polluting the planet.

By 2050, forecasters estimate that the population will swell to 9.1 billion people, up from the current 6.1 billion.

Optimistic predictions state that we have barely adequate arable land, resources, and crop yields to make do—but these forecasts cannot accurately account for changes in climate and weather patterns during the next thirty-seven years. Plus, some studies do not address the environmental challenges of a rising global middle class that will want more meat on the dinner plate and more personal vehicles to drive. The pressures on intensive agriculture will increase water demand, dependence on fertilizer, particularly nitrogen, and the pesticides that cause pollution.

Many say that it will be plant scientists, plant breeders, and agrisystems engineers who will offer the greatest innovations for crop-yield advances. Basic research, such as Frugoli does, has the potential to contribute significantly.

Two topics are priorities in the Frugoli lab. One is figuring out how plants select whether to put more resources into what's growing above ground or below it. The work could lead to controlling the process.

"If you could get more roots versus tops in, let's say, carrots, or more tops than roots in lettuce, for example, you could adjust the allocation of energy in the plant," Frugoli says. "If you understand how that decision is made, you can manipulate it."

The second is the legume-rhizobia symbiotic relationship, which enables legumes to have a reliable source of usable nitrogen fixed by a bacteria living inside a root nodule. It's a huge evolutionary advantage for legumes, Frugoli says, adding that it might be possible to activate this process in other plants that cannot make root nodules but could support the right bacteria.

Frugoli's lab works with an alfalfa, *Medicago truncatula*, to study how signals from root to shoot and shoot to root regulate root nodules, unique organelles where bacteria flourish and fix nitrogen.

Nitrogen is essential to life. It's a basic ingredient in amino acids, found in proteins and nucleotides present in DNA and RNA. Plants need it for making chlorophyll molecules, key to photosynthesis. Animals get it by eating plants.

Nitrogen makes up about 80 percent of the atmosphere, but the gas itself is of little use to organisms unless it is "fixed." In nature, microbes fix nitrogen and so does lightning, which has the power to break nitrogen molecules so that their atoms combine with oxygen to form nitrogen oxides. These oxides dissolve in rain, bathing plants and land with nitrates, a source of nitrogen plants can use. To make nitrogen fertilizer, industries break nitrogen molecules using a high-temperature, high-pressure process that yields ammonium.

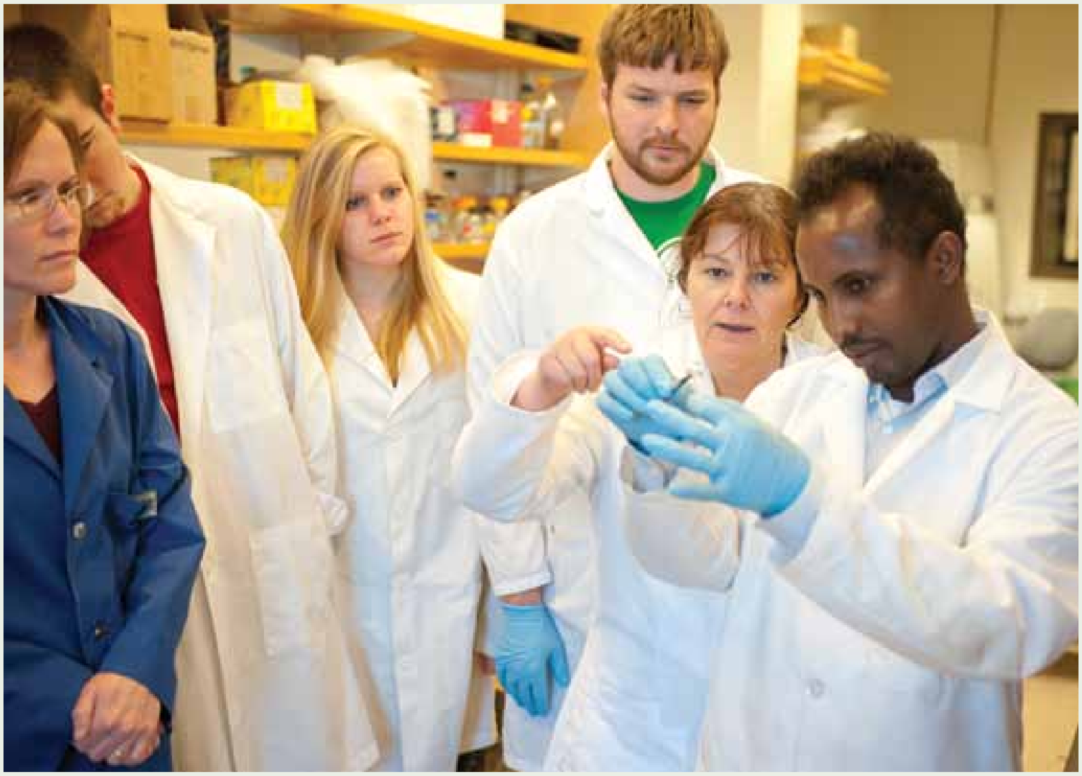
Left: In root hairs of *Medicago truncatula*, an alfalfa-like legume, glowing, microscopic Golgi bodies swarm like insects going about their work. The bodies carry GFP, a jellyfish protein Julia Frugoli's lab uses as a tag to track movement. The tag fluoresces when hit with exactly the right wavelength of light. This is a single image from a movie that shows the bodies in motion (see www.youtube.com/watch?v=ndgyBKFwHFY).

Inset above: Photo of *Medicago truncatula,* also known as barrel medic or barrel clover. The plant is native to the Mediterranean region and is often used in research.

Right: Nodules, like these on the roots of *Medicago truncatula*, are where bacteria take nitrogen from the air and convert it into ammonium usable by the plant.

Julia Frugoli lab

Craig Mahaffey



Julia Frugoli talks with Tessema Kassaw, a postdoctoral researcher (right), about the best way to set up a root graft to study how roots signal to other roots through the shoot of the plant. Listening are (from left to right) Elise Schnabel, a research technician; Ben Flanagan and Katherine Apple, undergraduate students; and Stephen Nowak, a graduate student.

Legumes, the third largest plant family, have evolved another way to get nitrogen. Alfalfa, beans, clover, lentils, peanuts, soybeans, and vetch are some of the legumes able to host bacteria that can take nitrogen from the air and convert it into ammonium usable by the plant. Civilization has benefitted from the symbiotic relationship between legumes and rhizobia for thousands of years. Farmers grow legumes not only for their protein value—legumes make up about a third of the world food supply—but also as "green manure." Left to die in fields, legumes release their nitrogen into the soil, where it becomes nitrates, making the nitrogen useful to other plants.

Each legume has an exclusive rhizobium. Alfalfa's is *Sinorhizobium meliloti.* In a complicated sequence of steps, bacteria in the nodules fix nitrogen that is converted biochemically into ammonium, which the plant moves up the shoot to make chlorophyll, proteins, and seeds.

For the plant, establishing and maintaining root nodules takes significant energy. The plant does it out of necessity, not convenience.

Signs of starvation

When a legume lacks nitrogen, growth slows or stops and the leaves turn yellow. If the condition is sufficiently dire, it can activate a "stringent response," which usually indicates starvation. Then the legume has to make a decision. Root nodulation puts a strain on the plant, enough so that legumes resist starting up the process. The plant's regulation of nodulation is a "negative feedback inhibition system," as Tessema Kassaw wrote last year in *Plant Methods*. Kassaw, also a Frugoli lab grad student, completed his Ph.D. in December.

"It's like having a roommate," Frugoli says about the plant's decision. "If you can't pay the rent, you need a roommate, but if you can pay, it might be nicer to be by yourself and not have to share. That's kind of how the plant looks at the interaction. It has to decide, 'Do I need nitrogen or not?'"

The result is observable: Either the plant makes root nodules or it doesn't. But nodulation is a complex process, and researchers have a long way to go to explain it.

Like genetics researchers everywhere, Frugoli breaks things to study them. She uses mutagenesis, treating a plant with radiation or chemicals that jumble the DNA code, creating plants with atypical characteristics—mutant clones. She and her graduate students look for phenotypes, the observable traits of gene expression.

"Once we have plants that have the phenotype we are looking for, we go through the slow process of what's called mapping, trying to determine what the gene we messed up is," Frugoli says. "Once we find it, that's only the beginning, because we have to figure out what that molecule does and how it does it.

"Sometimes the traits are not observable," she continues. "The signals and the changes that come about are deep in the structure or system."

M. truncatula improves the chances of finding the right molecule. It is a diploid form of alfalfa, meaning it has only two copies of each of its 40,000 or so genes. Other alfalfa varieties, such as the one that is used as cattle fodder, have four copies of each gene. The possible combinations and the search among them becomes a lot more time consuming and harder.

Crook and Kassaw have projects that fluorescently tag proteins so that they and Frugoli can look inside the plant while it's alive. "We see where the protein is, what it's doing, and where it's going—the pictures of glowing plant roots are kind of cool."

In the lab, Crook works with a mutant of a shoot-to-root signaling gene that transmits a message from the leaves of alfalfa to the roots to grow root nodules. Its well-suited name is SUNN, Super Numeric Nodulator. The mutant disrupts the gene expression that stops nodule making. Mutant SUNN causes the

> “If you could get more roots versus tops in, let’s say, carrots, or more tops than roots in lettuce, for example, you could adjust the allocation of energy in the plant,” Frugoli says.

plant to make too many nodules, squandering energy.

Another gene the lab studies is RDN1, Root Determined Nodulator. It goes from root to shoot, signaling when to stop nodule making. When RDN1 is missing, the plant also makes too many nodules, but for a different reason.

SUNN is a protein kinase, while RDN1 is a protein that remains uncharacterized, though it occurs in most plants. Protein kinases are enzymes—biochemical catalysts—that modify other proteins controlling growth and development. Important and ubiquitous, “conserved” kinases can be found in animal, bacteria, and plant genomes. This suggests that, as organisms have evolved and diversified, kinases were useful substances that served many different species. Kinases are particularly important in controlling activities in cells and cell pathways, especially signal transduction, which is a kind of communication.

How a plant makes decisions

All organisms send signals to grow and reproduce, to defend against disease and deal with environmental stresses. Signals can go short distances—inside cells, cell to cell—and long distances—from shoot to root, brain to big toe.

But plants rely on signals in a way animals do not. Plants are sessile, rooted in place. Coping with droughts, poor soil, temperature swings, diseases and insects, plants face a stark reality of working with what’s available. Make do, or die.

“Anytime something happens to plant, it has to change its gene expression essentially to respond,” Frugoli says. “It has to make a molecule that does something to change the way it grows. If a plant wilts, if it gets too much light or not enough light, if it gets hot, if gets cold—even if something bruises it or chews on it—all these things require a response.”

Something happens in a cell to trigger a molecule that begins a signaling process that goes through the plant’s xylem or phloem, from cell to cell.

“Every cell must make a decision based on that signal and passes the signal along to wherever it has to go,” Frugoli says. “So it’s either one cell at a time or it’s through the vasculature of the plant.”

Signaling is not like a light switch; it’s more like a marching band, each member on the move to a location, playing his or her part, creating music in formation. Out of step or off tune, missed notes, the intended result fails to happen.

“In a lot of these communications from roots to shoots, if there’s misstep, there’s a very subtle phenotype, a very subtle thing you can see,” Frugoli says. “Maybe the roots are a little bit shorter, or they are not as fuzzy.”

Legume roots turn out to be sensitive organs. They grow outward more than downward, seeking fast food, as do most annual plants faced with a seasonal deadline to flourish and reproduce. The bigger, thicker root parts mainly transport food up the stem. It’s the root tip where the action is.

All roots have molecular receptors and membranes on the outside of the root tip to detect chemical concentrations in the soil. Root tips can forage, acting like Geiger counters. When enough receptors measure an attractive level of a nutrient—nitrogen, for example—on one side of the root tip, the root will turn gradually toward the nitrogen if the amount and proximity is worth the energy to make the move. They can also forage for water.

Legume roots can do more. They can send signals out to invite the rhizobia to come and infest a root hair growing in a special crooked shape that leads to infection threads, allowing the bacteria to move across the outer cell layers and colonize the root nodule.

“Every gene we have discovered so far that is involved in nodulation, whether it’s regulating number of nodules or allowing nodulation to happen, isn’t exclusive to legumes,” Frugoli says. They occur in other plants that don’t make nodules. That doesn’t mean the other plants don’t have the right genes; we don’t know how to turn them on and off in a way will allow the rhizobia to interact with the plants.

Nodulation and nitrogen fixation have been a holy grail for plant geneticists and breeders. The dream of nodulation in corn, a nitrogen-intensive crop, has been around for nearly half a century. If corn could make its own nitrogen instead of relying heavily on nitrogen fertilizer, “we would be golden,” Frugoli says.

The hope was that it would take only a few added genes to create a super corn. It is, of course, more complicated, and researchers have yet to identify all the genes involved or to know with certainty how nodulation is regulated in plants.

Frugoli is a fan of another crop being the first to nodulate. “I would choose rice, because there are some things rice can do that are very close to nodulation, but not exactly.”

In the lab, Frugoli’s researchers have taken a rice gene and inserted it into an alfalfa mutant they created, and the combination behaves normally. “That means the rice gene is restoring the trait. We call it ‘rescuing the phenotype,’” Frugoli says. “When we put it in the plant in the right place and at the right time, it works. That suggests to us that it may be a problem of timing in rice.”

While rice looks to be a better fit than corn, nodulation in rice won’t happen today or tomorrow and may never come to be. But the basic knowledge Frugoli contributes may eventually help to grow more food or to pollute less by minimizing fertilizer use. And for a world facing the prospect of hunger, that kind of work sends all the right signals.

Julia Frugoli is an associate professor of genetics and biochemistry in the College of Agriculture, Forestry, and Life Sciences. The National Science Foundation supports Frugoli’s research. In 2012 she received a $600,000 four-year grant toward developing a model of the pathways plants use to pass messages back and forth from cell to cell. Peter Kent is a news editor and writer in Clemson’s Public Service Activities.

Don't be afraid.

by Neil Caudle

ONE DAY LAST SUMMER, Bria Dawson walked into a clinic in Singapore and watched a patient take a needle in the eye.

"He was an older man, about sixty, and he was in a lot of pain," she says. "He let out a cry that was awful to hear. I didn't want to see that happen to anyone ever again. I didn't want to see a needle go into somebody's eye again. For me, it was motivation."

Motivation because Dawson and several of her classmates from bioengineering were in Singapore looking for a way to replace the needle with something much gentler—a clear film of thin, biodegradable plastic that could deliver the right kind of drugs to the eye.

Building toward a career

Clemson's collaboration with NTU in Singapore helps students prepare for a job market that is increasingly international, says Frank Alexis.

"A lot of companies have offices overseas, so knowing something about other countries can give you an advantage," he says. "Also, if you work in a big company today, there's a good chance you will work with people from China or Singapore or somewhere else. If you've worked in other countries, you're a more valuable employee."

The program is especially useful for students interested in medicine, Alexis says. "We have many students going to medical school, and research can make a difference. Our students have had good success on the entrance exams, and medical schools are looking for the kinds of experience we provide."

The Clemson/NTU collaboration, which began in the summer of 2011, has landed a number of student fellowships and scholarships from outside sources such as NTU and the Howard Hughes Medical Institute. Several students from the program, including Bria Dawson, have received awards for student research and for poster presentations.

"Students get more out of this experience than a course credit," Alexis says. "They are broadening their perspectives and building their résumés."

"You could think of it as a kind of contact lens," she says. "The goal was to have it gradually release the drug over a six-month time span."

The two drugs involved, known as Val and Gan, control retinitis, an inflammation of the eye caused by human cytomegalovirus (CMV). People infected with HIV are especially susceptible to CMV when their immune systems fail to suppress it. Without treatment, patients with severe CMV retinitis go blind.

So the goal was clear, the motivation was strong, and the stakes were high. But creating a lens to deliver a controlled dose of Val and Gan was no small task. And the team of scientists assembled to work the problem? Four undergraduate students in bioengineering at Clemson. They had only eight weeks to get the job done.

"When I was in high school, I loved math and science, and I wanted to be a doctor, but I never imagined that I would ever go to Singapore and do anything like this," Dawson says. "Once you're there, and you start seeing results, you realize, hey, maybe this can work. And then you can do things you never thought were possible."

Dawson was part of a summer research program led by Frank Alexis, assistant professor of bioengineering. Last summer, Alexis took Dawson and eight other students to Singapore for research at Nanyang Technological University (NTU), where he had earned his Ph.D. Using his contacts there, Alexis arranged for teams of students to work on three projects in one lab under the supervision of NTU scientists. The goal was not just to let students conduct biomedical research; it was also to shift their learning into high gear.

"When we take the students overseas, their level of learning increases rapidly," Alexis says. "They have to adapt very quickly, which is what usually happens with graduate students when they move to a new campus and work in a new environment. Our students are getting this experience as undergraduates."

Soon after they landed in Singapore, Dawson and her three teammates— Kali Luffy, Cheryl Jennings, and Even Skjervold—went to work in the lab. First, they had to figure out how detect the presence of each drug in the film by determining the wavelengths of the drug compound's fluorescence. This involved multiple experiments with various chemical buffers and drug solutions. Eventually the team found the right wavelengths for excitation and transmission—reliable markers of a compound's reaction to light.

The sweet, not the sugar

The experiments were a success, and the team moved on, testing various polymer solutions and doses of the drugs. They used a device called a knife caster to flatten the mixtures into very thin films, dried the films, punched out the lens-like circles, and tested rates of drug release. But as the team tried to suspend both drugs evenly in the polymer, they ran into trouble. One of the drugs, Gan, precipitated out of the polymer, leaving cloudy white patches on the surface. None of the solvents the team tested kept Gan in suspension. Because of the problem with the solvents, Dawson says, the lenses released the drugs too rapidly, over fifteen days rather than six months.

"The drug should dissolve in the solvent the way sugar dissolves in your tea," she says. "You want to taste the sweetness, but you don't want to see the sugar."

With more time, the team would have tested other solvents, and Dawson feels certain that researchers will find the right one. Alexis plans to take another group of students to Singapore this summer, and Dawson expects the next team to pick up where hers left off.

"We set up the foundation for the project," she says. "We feel good about what we accomplished in such a short time."

Not just one guy alone

She also feels good about the experience of working as part of a team. "I used to think science was one guy alone in a lab coat watching a Bunsen burner all day," she says. "But science is more about the team. I think a lot of women like to work in teams. We don't say, 'Hey, I'm this macho guy who's going to do everything himself.' We know our strengths and weaknesses, and when you find a team with different strengths, you can put them together and accomplish a lot. And when you get frustrated, you have a partner there to help you, a companion to keep you focused."

Dawson also got a chance to test herself in cultures very different from her own. Venturing out into Singapore streets, she marveled at the people's fascination with technology. Everyone she passed was operating a high-tech gadget. And yet people were friendly, she says, and she felt safe and welcome. From Singapore, the team made side trips to Thailand, Malaysia, and Indonesia. Dawson thinks of herself now not only as a scientist but as a citizen of the world, with a responsibility to serve. "As scientists, that's one of our jobs," she says, "to help others—in Asia or wherever they are."

The combination of science and travel has emboldened her, she says, to strive for bigger goals. She plans to earn a Ph.D. and work as scientist, first in industry and then in academe. Asked how she would advise a high school student considering a study of science in college, Dawson sums it up this way: "Don't be afraid. It was my first time abroad and my first time conducting research, and the experience changed my life. My confidence is much higher now. I feel like I can do anything."

Bria Dawson is a senior majoring in bioengineering. Frank Alexis is an assistant professor of bioengineering in the College of Engineering and Science.

Cheryl Jennings

Bria Dawson checks lab notes at the Nanyang Technological University in Singapore, where she and eight other Clemson students worked on a treatment for retinitis, an eye disease. Scott Cole, a senior bioengineering student from Clemson, works alongside her on a separate project.

Wrapping up food safety

Edible communion cup or a pathogen-sensing film, the goal is saving lives.

BY Anna Simon

Paul Dawson rummages through a desk drawer and finds, in a plastic sandwich bag, an edible communion cup made mainly of wheat flour. The cup is a prototype developed in Clemson research labs about seven years ago, after missionaries working in anti-Christian areas asked for a self-contained package that included bread as a cup with wine or grape juice sealed inside. The idea: Leave no evidence behind after taking communion.

Anna Simon

Even here at home, lives can depend on the right kind of package. The Centers for Disease Control reports about 1,600 cases annually of listeriosis, a food-borne illness caused by the deadly *Listeria monocytogenes* bacteria. A 2002 outbreak associated with turkey deli meat caused fifty-four illnesses, eight deaths, and three fetal deaths, according to the CDC. An outbreak in 2012 associated with an imported ricotta cheese caused twenty hospitalizations and at least two deaths. The right package, Dawson says, can block contamination and help prevent illness and death.

"Packaging's role in food safety has been primarily as a barrier to prevent contamination, but that role has been evolving," Dawson says. "This includes the label, which now gives proper handling guidelines and cooking directions. The package label has an expiration date that roughly informs the consumer of product shelf life. In the future the package will become more interactive with the food, actively eliminating microorganisms or signaling to consumers that harmful toxins or pathogens are present or have formed in food."

Dawson is nationally known for debunking the five-second rule about eating dropped food (don't risk it) and for warning that "double dipping" with shared chips and dip is a practice that spreads germs. At the moment, Dawson and his collaborators—Clemson chemistry professor Bill Pennington and Furman University chemistry professor Tim Hanks—are working on smart food packaging with embedded sensors that change color to warn of contamination by bacteria such as *Salmonella* or *E. coli*, both of which can cause food-borne illness. The team is also developing smart bandages that monitor the condition of wounds.

Canary in a coal mine

The smart bandages and packaging use liposomes, which are tiny bubble-like vesicles made of lipids (natural molecules that include fats). The liposomes, which measure about 150 nanometers in diameter, are far too small to be seen with the naked eye, but, like a canary in a coal mine, they can warn of pathogens in food or of infection in wounds.

To use liposomes as sensors, researchers embed the hollow spheres in gels or films and design them to change color in the presence of a specific threat.

"Looking five or ten years down the road, there are several ways these could be used," Dawson says. Rinse water used in processing salad greens could be passed through a filter to instantly monitor sanitation of the product, Dawson says. Or cotton swabs could be impregnated with liposomes that change color like litmus paper to check the safety of food and the cleanliness of food preparation areas at home, in stores, and in restaurants.

Dawson, Pennington, and Hanks are excited about the possibilities. "We can incorporate the sensors into packaging or use them to test food-preparation services or food-processing instruments," Pennington says. He's already talking to industry about bandages containing liposomes that change color to warn of infection or other changes in wound condition.

The researchers start with a synthesized fatty acid mixture processed so that it forms a membrane. An ink-jet printer sprays the fatty acid into water and the mixture curls up into hollow balls as it hits the water. The synthesized compound can be designed to change color in the presence of specific substances. For example, it can be designed to interact with *E. coli* but not *Salmonella*.

"We can build specificity into the color-changing process," Pennington says.

Similar technologies are already on the market but are not widely used or recognized because of the expense and difficulty of making the product, Pennington says. He is working on ways to make the process more cost effective on the industrial scale.

Film school

As Dawson and company work on their sensors, other Clemson researchers and their students develop new films that could extend shelf life, reduce spoilage, and eliminate bacterial invasion in packaged foods. Kay Cooksey, an expert in microbe-fighting films, hopes to see the fruit of her graduate students' labor on grocery shelves in five years or so. Cooksey's team coats film for packaging meats with natural antimicrobial materials such as nisin, which is produced by bacteria and is already in commercial use by the dairy industry to extend the life of cheese.

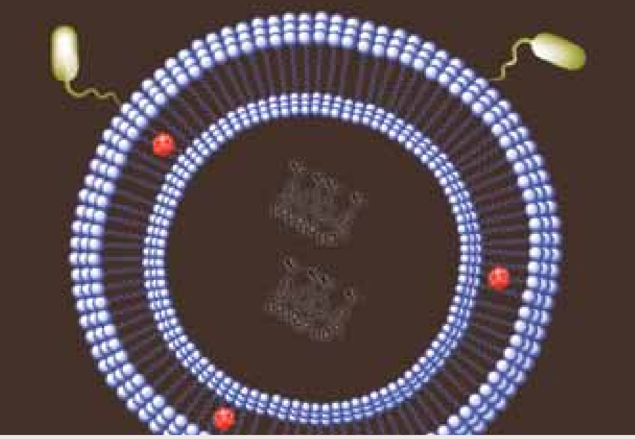
Some film samples Cooksey pulls from the cardboard boxes feel nubby; others are slightly sticky to the touch. Some are fairly transparent; others are cloudy. The texture and appearance must

Detecting a threat

Paul Dawson's lab uses liposomes as sensors that can react to food-borne pathogens and other threats by changing color. The vial on the left contains a phenylalanine liposome treated with *Salmonella.* On the right, the liposome has been treated with *E. coli.* The vial in the middle was not treated.

The liposome's structure (diagrammed below) gives it potential as a multifunction device, Dawson says. Fluorophores (shown in red) are fluorescent chemical compounds that can re-emit light when excited by a cell-disrupting intruder, an imact, a temper-ture shift, or various other changes.

Images: Bill Pennington, Clemson University, and Tim Hanks, Furman University



be refined to be acceptable to consumers, she says. And the cost of production must be economical so that the packaging doesn't add to the cost of the food product inside.

"We know we have material that works. The question is making it commercial," Cooksey says.

Cooksey is targeting industries that produce ready-to-eat sandwich and deli meats. Slicing meats can introduce contamination, Cooksey says. Antimicrobial packaging adds an extra measure of protection to reduce spoilage, extend shelf life, and eliminate pathogens such as *Listeria*. The packaging would also reduce waste as less spoiled food would be thrown away, she says, and that could save money for consumers and producers.

Green chicken

Cooksey's research has spanned a decade, and, like most scientists, she learns as much from what doesn't work as from what does. An early experiment using chlorine dioxide did a good job of eliminating bacteria but turned chicken green. Disappointed and a little grossed out, the team went back to the drawing board. "Negative results aren't bad," Cooksey says. "They just tell you what you can't do. You have to change the focus a little bit, but don't quit."

The current challenge is heat. Making coated film takes heat. Nisin breaks down under heat and becomes less effective. Students working under Cooksey and Amod Ogale, the director of Clemson's Center for Advanced Engineering Fibers and Films (CAEFF), are seeking the optimal combination of heat and other factors in processing the product.

Ogale likens chemical engineering to working in a kitchen. The quality of a batch of brownies depends on the combination of ingredients, amount of heat, baking time, and even the type of baking pan used. But lab conditions are far more extreme than those in the kitchen at home, Ogale says. Equipment in the CAEFF labs is a smaller version of that found in industry and can use heat and pressure as much as ten times greater than those of home ovens and pressure cookers.

Not all of packaging science is directed toward food. Ogale's group also makes fiber for use in absorbent, disposable hygiene products. By mixing soybean flour and plastics, the team creates a fiber that combines the beneficial properties of both materials. "That's what smart materials are," Ogale says. "Smart materials have to serve several functions."

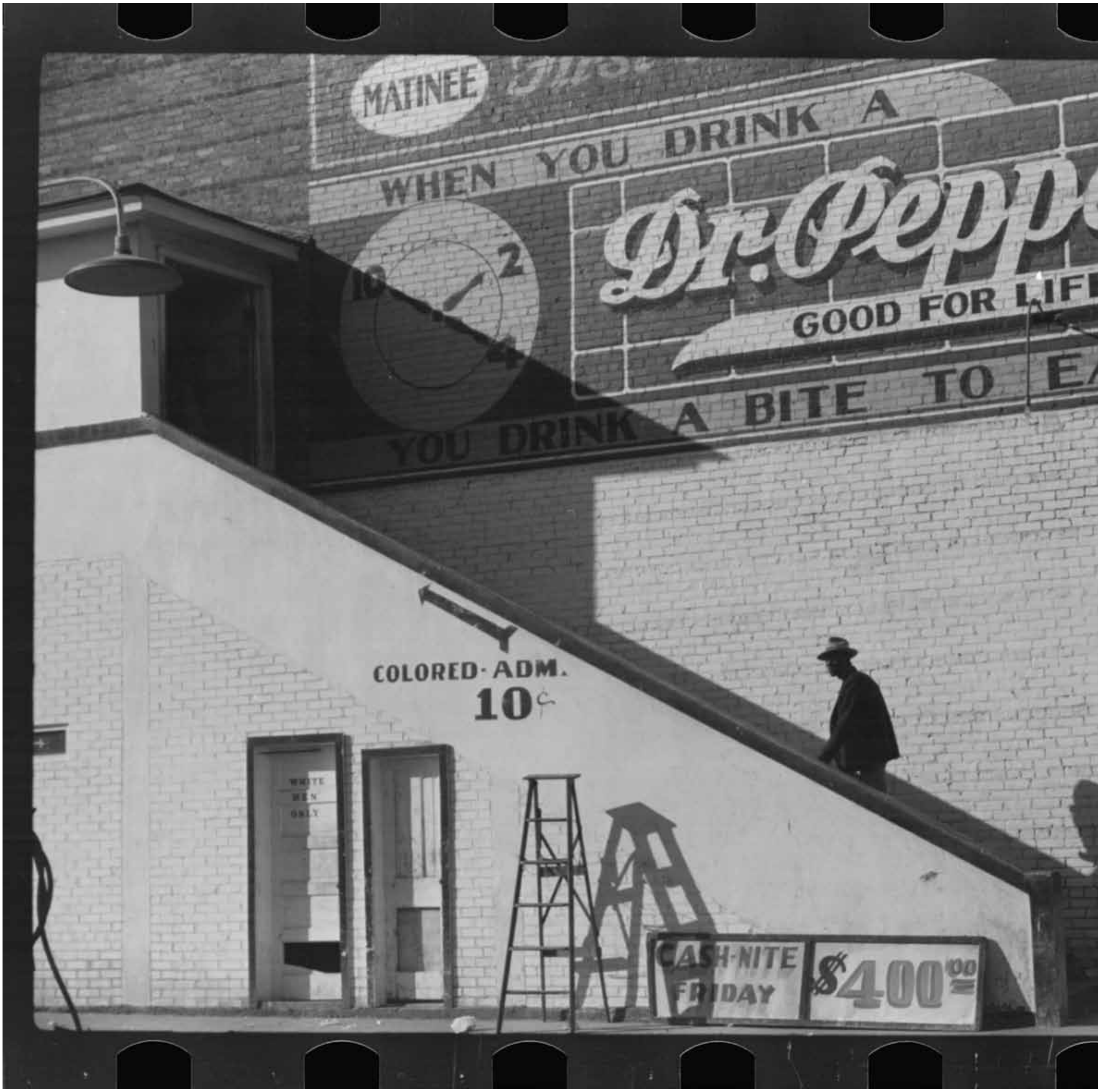
Like his colleagues in packaging science, Ogale starts small in the lab but aims for a much larger, industrial scale. The goal is not just a new material but also a practical process for manufacturing it successfully. "Otherwise," he says, "so many research ideas are born and die."

Transferring knowledge developed in university labs "into something that changes people's lives is a pretty complex process," says Jack Miley, a chemist and retired director of research and development for the chemical division of the Spartanburg-headquartered Milliken & Company in South Carolina. The division has helped its customers develop numerous food-packaging applications using Milliken additives and has a small but growing medical products group.

Milliken is "monitoring a lot of different things at Clemson because some of it is pretty close. We would love to have something come to fruition that would work commercially for us," Miley says.

"There are lots of kinds of innovation," Miley says. "The breakthrough ones that matter to somebody a lot are what you want to buy. That's what you are looking for, but it's really hard to find."

Paul Dawson is a professor of food science in the Department of Food, Nutrition, and Packaging Sciences, College of Agriculture, Forestry, and Life Sciences. Kay Cooksey is a professor and the Cryovac Endowed Chair in the Department of Food, Nutrition, and Packaging Sciences. Amod Ogale is the director of Clemson's Center for Advanced Engineering Fibers and Films and a professor in the Department of Chemical and Biomolecular Engineering, College of Engineering and Science. William T. Pennington is a professor in the Department of Chemistry, College of Engineering and Science. Anna Simon is a freelance writer based near Pendleton, South Carolina.



Selling soap and saving souls

How white filmmakers misread black audiences in the early days of film.

by Jeff Worley

On a Saturday afternoon, a man climbs the back stair to a balcony seat at a movie house in Belzoni, in the Mississippi Delta. Photo by Marion Post Wolcott, 1910-1990. Library of Congress; The Crowley Company.

close focus

> *"African Blacks don't understand film language. This means that if you show a guy going into a house, you have to show him coming out as well. If you cut from the house to a car on the highway, your audience won't know what the hell's going on."*

This caution to filmmakers interested in producing motion pictures for black African audiences comes from South African director Rudi Meyer in a 1986 interview. And according to history professor James Burns, this belief about the inability of Africans to understand movies dates from the early twentieth century, when British filmmakers brought movies to their African colonies.

But first things first: Why make films for black African audiences at all? Were the British keen on entertaining the colonials?

Burns laughs at this question.

"The films, beginning in nineteen-twenty with *Unhooking the Hookworm,* were strictly educational," he explains. "They were funded by the Rockefeller Foundation and focused on trying to eradicate disease (encephalitis, venereal disease, malaria), instruct the Africans in modern farming techniques, and teach women to do small-scale manufacturing projects so that the household economy wouldn't be entirely reliant on crops."

In bringing these films to African colonials, the British Home Office in London was part altruistic and part capitalistic, Burns adds. The colonies were huge and easy sources of revenue for the British, partly because of the low capital investment in these far-flung land holdings. The challenge was to educate the peasant farmers without spending much to do it. Movies, the government thought, might be the answer.

But did African audiences get the message?

"Since the nineteen-twenties an army of filmmakers, academics, journalists, missionaries, and educators have attempted to measure the abilities of Africans to make sense of motion pictures," says Burns, a specialist in African history and the social history of film, "and these groups have focused on several key questions. Could Africans be taught to understand the 'language' of the cinema? Were they particularly susceptible to motion-picture images? Did African audiences inevitably accept action on the screen as a literal depiction of reality or could they be taught to distinguish between truth and fiction?"

The answers to these questions involved high stakes, Burns points out. "These analysts represented groups committed to nothing less than transforming African societies and, though their agendas ranged from selling soap to saving souls, they shared the common hope that motion pictures might prove an efficient and potent tool for influencing the thinking and behavior of African audiences."

Burns says that the first recorded experiment into African film literacy was conducted in the early 1920s, when William Sellers, a medical officer with the Nigerian government, studied the reactions of Africans to British documentaries. Sellers produced a film called *Anti-Plague Operations in Lagos*, to show Nigerians how rats spread contagion, and over the next seven years he made fifteen similar films.

Through his observations of Africans who watched these films, Sellers concluded that African audiences were clearly confused by the sophisticated

In *Tropical Hookworm*, a 1936 British film, a barefoot African man learns how worms spread disease. Director Leslie Notcutt largely endorsed William Sellers' arguments that illiterate African audiences required a different set of rules from those of Europeans.

techniques employed in most motion pictures of the time. So he instructed the actors in his films to move very slowly and make their actions simple, to basically dumb everything down. Sellers also used the most direct camera angles and as few potentially distracting characters and props as possible.

The chicken incident

"Because Sellers' work influenced a generation of filmmakers, it's worth examining how he arrived at these conclusions," Burns says. "And we start with what African film scholars call 'the famous chicken incident.'"

Burns says that Sellers determined one of his rules after several members of an African audience expressed an intense interest in the activities of a chicken in one of his early productions. Sellers did not remember filming the creature, but after a second viewing, he found it running off camera, startled by one of the actors.

"From this incident Sellers deduced that the audience noticed the chicken because of its position at the base of the screen. African audiences, he decided, 'read' the screen from bottom to top, rather than focusing on the projected image as a whole. He concluded from this one incident that the eyes of illiterate people fasten their gaze onto any movement in the scene to the exclusion of everything else in the picture."

A second incident similarly added to Sellers' developing "grammar" of colonial cinema, Burns says, this one starring a giant mosquito.

"Sellers recounted some Africans' reactions to his malaria film, which included full close-ups of mosquitoes in the act of sucking blood, but when the film was shown, the results were disastrous," Burns says. "Viewers became alarmed and inquired about the country where the people had to contend with such wicked-looking, gigantic monsters and remarked that they themselves were very fortunate to have mosquitoes which were quite small and comparatively harmless."

From this incident Sellers concluded that African audiences accepted what they viewed literally and, therefore, filmmakers should avoid any tricks that might confuse or disturb them. Sophisticated techniques such as panning, flashbacks, and quick cuts were out for African audiences, he concluded.

Though Sellers was the most prolific and influential filmmaker during the early days of movies in Africa, other filmmakers were quick to posit various filmmaking principles based on scant evidence.

"Along with educational films about disease and hygiene, the

Moviegoing here at home

On the entertainment page of a February 3, 1924, newspaper from Aiken, South Carolina, readers could find an ad for *Enemies of Women,* a 1923 silent film directed by Alan Crosland and starring Lionel Barrymore, alongside an application for membership in the Knights of the Ku Klux Klan.

Craig Mahaffey

James Burns outside the old Clemson movie theater, now a sportswear shop. In communities across the country, the local movie house was once the hub of popular culture. By studying the films, the venues, and their history, Burns and his students investigate the values and beliefs of the time.

British made quite a few films focused on farming techniques because, well, it was in their financial interest that the colonials be successful farmers," Burns says. "During one of these films, which stressed the importance of what was clearly onerous contour-ridge digging, several of the men watching the film got up and left. The filmmaker's conclusion: Their primitive minds couldn't understand it. But the Africans understood exactly what the British wanted them to do; they just didn't want to do it. That's why they walked out."

The consensus among at least two generations of filmmakers—that Africans didn't and couldn't get the language of cinema and that they were simpleminded as well as literal-minded—emerged from small sample sizes and a lack of understanding of the moviegoers' cultural history and beliefs, Burns concludes.

It's extremely likely that some of the stories about Africans' failures to understand film are apocryphal, he adds, particularly since the specifics of the incidents are rarely given. And even if true, he believes they are certainly open to alternate interpretations.

"In discussing the reaction of the audience to the mosquito on the screen, Megan Vaughan, a historian at King's College in Cambridge, pointed out that Sellers and his successors never considered that such comments might have been meant ironically," Burns says. "My own experience in Zimbabwe suggests the strong likelihood of this possibility."

A major reason why these assumptions about African audiences became so entrenched is because they carried such heavy political freight, Burns says.

"The belief that African audiences had limited capabilities reinforced a broader colonial stereotype regarding the intellectual state of Africans," he explains. "Especially in southern Africa, where white minorities sought to cling to power forever, these assumptions remained solid and unshakable because they served to legitimize the perpetuation of settler control. In questioning the abilities of Africans to comprehend modern media, it's a short step to conveniently conclude that these Africans were incapable of participating effectively in a technologically sophisticated, democratic society."

Jump cut to Clemson

Burns came to his research into African film through his study of African history in graduate school.

"In grad school in the mid-nineties I read a story about how the government in Southern Rhodesia had been making movies strictly for African audiences since the nineteen-twenties, and the focus of the article was the challenge of making movies for people who'd never seen a movie before." Burns, who admits to a lifelong love affair with movies, then got a Fulbright Grant to study the history of moviemaking for African audiences in Zimbabwe (Zimbabwe gained its independence from Southern Rhodesia in 1980).

In 1998, after earning a doctorate in African history at the

University of California, Santa Barbara, Burns joined the faculty at Clemson.

"When I moved to South Carolina, I started doing research on early moviegoing by blacks in this state and was struck by how similar their experiences were in the nineteen-twenties and nineteen-thirties to those of Africans in Southern Rhodesia. Both operated with a rigid racial caste system where blacks were relegated to the status of second-class citizens. In order to see a movie, blacks in South Carolina were made to sit in a 'Colored Only' balcony or in a segregated part of the theater. And in South Carolina and Southern Rhodesia, blacks faced identical forms of censorship."

A case in point was the early, jerky footage of the 1910 World Heavyweight Championship fight between Jim Jeffries, "the great white hope," and Jack Johnson, a highly touted black boxer. Johnson won, and this outcome triggered race riots that evening in twenty-five U.S. states and fifty cities, from Texas and Colorado to New York and Washington, D.C. Eight blacks and five whites died in the riots, and hundreds more were injured.

"Some of these so-called riots were, in actuality, simply joyous celebrations by blacks, who felt Johnson's great victory was a victory for racial advancement," Burns says. "But there's no doubt many whites felt humiliated by the defeat of Jeffries. A number of states, including South Carolina, banned the Johnson-Jeffries film for viewing by blacks, thinking it would be self-congratulatory or incendiary. In Southern Rhodesia, Africans were also not allowed to see this film." Other films, most notably D.W. Griffith's *Birth of a Nation*, were also banned for blacks in South Carolina and Southern Rhodesia, though, as Burns points out, the film was promoted to white audiences.

"Until after World War II, blacks faced these obstacles in participating in what was clearly the most important communications media ever invented," Burns says.

Sending students to the movies

In addition to his own scholarship on the history of moviegoing in South Carolina, Burns began offering a research seminar at Clemson last spring that focuses on this topic. His students choose a city or town in the state and work to reconstruct its moviegoing history through a variety of primary sources that include old newspapers, maps, journals, and interviews with elderly members of the community.

"The idea is to use the then-new and unique form of urban space, the picture palace, as a window into the important social and economic trends that swept the state between nineteen-hundred and nineteen-forty," Burns says. "The students will end up with a local history of moviegoing that is a microcosm of a much larger story."

A key part of the story is the experience of African-American audiences, Burns says. Conventional wisdom says that blacks didn't go to see movies in great numbers before World War II, but this was the same assumption scholars made about African audiences in the colonial era, which Burns' research has shown was inaccurate.

"So this is where my research dovetails with the research projects of my students. But finding evidence of early black moviegoing is challenging. There isn't much of a paper trail to follow—very few black theaters advertised—and oral histories are sometimes hard to come by since movie patrons from the early days of moviegoing are now in their eighties and nineties."

Although his current students haven't completed their projects yet, there have been some interesting and surprising findings.

"One student found a promotion in the May twenty-four, nineteen-twelve edition of the *Newberry Observer* that promised: 'The Arcade will give to the one holding the lucky number, next Wednesday night, a Real Live Baby. This baby has black hair and brown eyes, and it's a boy. The one who gets this baby will have to give us a bona fide guarantee that they will take good care of it until it is the age of 21. It is from a good family. Remember, if no one wants the baby after winning it, we will buy it back for $2.50.'"

Kathleen Brand, who was in Burns' fall seminar, says among her early findings in Camden, South Carolina, is that to get people to come to their theater, owners would advertise raffles in the town newspaper, or various contests with prizes.

"My favorite is the contest for the prettiest girl," Brand says. Another interesting and popular event at the Camden theater was "bank night," a cash giveaway that built up until the name of a person in the audience—you had to be present to win—was drawn. Yet another trick to get people to the theater was that local filmmakers would shoot footage of people in Camden and then show the films in the local theater so that people could see themselves on the big screen. "Apparently these creative strategies, promoted in the local paper, worked," Brand says.

"The theater advertisements are interesting," Burns says. "While white theaters advertised an array of 'quality' films, the black theater ads featured almost exclusively B-movie Westerns and serials. This is consistent with what I found in Africa—that the high cost of renting first-run movies, combined with the familiarity of the Western genre, made the cowboy film a staple of black moviegoing until World War II."

Some of the students are uncomfortable with what their studies are revealing to them about their hometown histories, Burns says. "They are shocked to learn about the marketing of *The Birth of a Nation* in South Carolina towns, the banning of that film and others for black audiences, and the segregation of movie audiences, which continued long after it had been made illegal."

In her research, Alli Lane, who was also in the fall seminar, discovered a racial incident that took place at the segregated American Theater in her hometown of Charleston during the civil rights era.

"During a movie being shown to a mixed-race audience, with whites on the first floor and blacks in the balcony, racial slurs were made and fights broke out," she says.

The students' discoveries so far are unique to the cities and towns they've chosen to research but, Burns says, there's one common result.

"All of the students who have done this detective work have discovered how much more significant and central moviegoing was to social and cultural life in the first half of the twentieth century as compared to today. For me, the fun of this project has been to watch the students get excited about the history of their hometowns. The movies are their window into this history, and these students have used a remarkable combination of ingenuity and energy to go deep into their community's past."

James Burns is an associate professor in the Department of History in the College of Architecture, Arts, and Humanities. Jeff Worley is a freelance writer and poet who lives in Lexington, Kentucky.

Digital breakthrough

Stop-action photos of a bullet shattering glass? No, the bullet and the glass are digital, and the images are frames from an experimental production created by a faculty-student team in computer science.

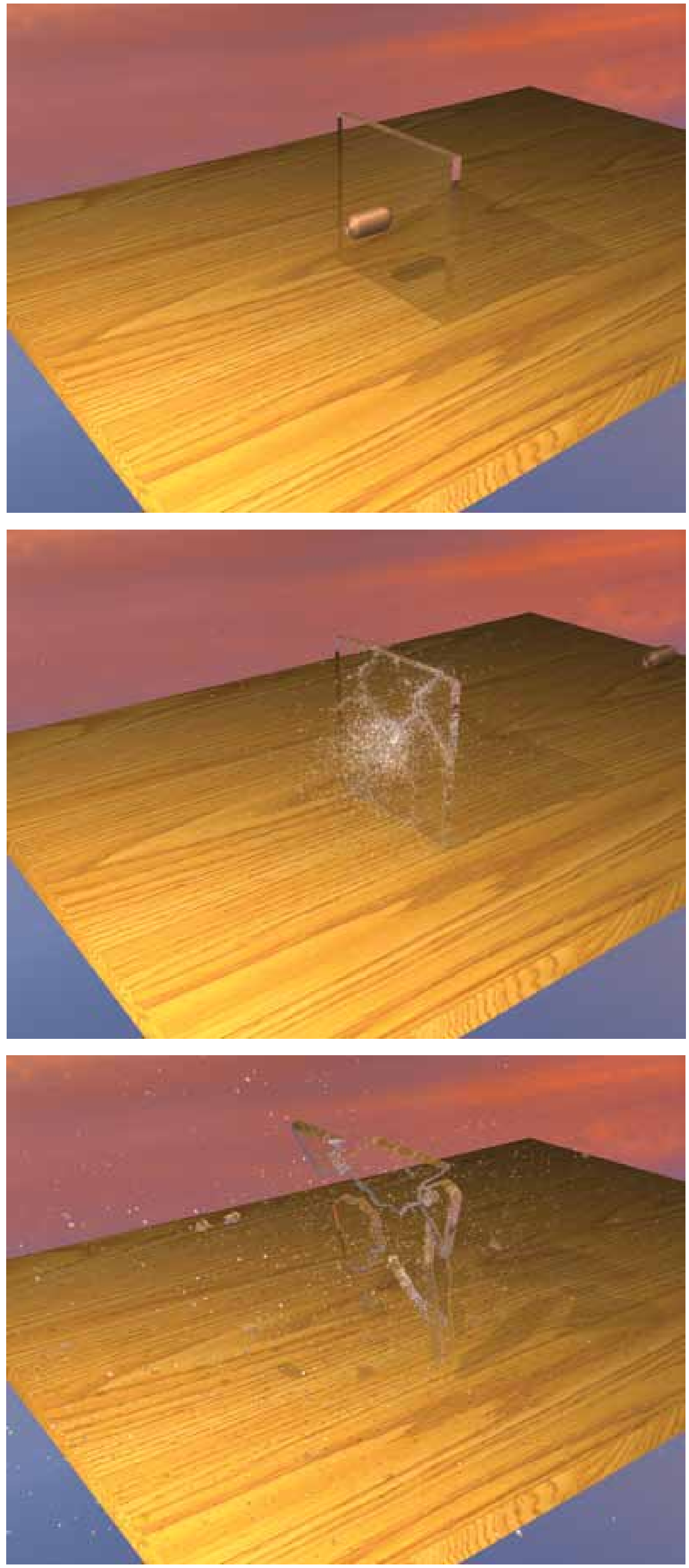
If you've been to the movies much lately, you've probably immersed yourself in spectacular digital effects, some of them pioneered by research-and-development teams that included Jerry Tessendorf or Robert Geist, colleagues in digital production arts in the School of Computing. Tessendorf's development of a software tool that mathematically captures the dynamics of water—as well as other fluids and gasses—earned him a 2008 Oscar for technical achievement and a credit in *Life of Pi,* which this year won an Oscar for visual effects.

Geist has received research-and-development credit for his work on *The Hobbit: An Unexpected Journey*, by Weta Digital. In 2011, Geist spent eight weeks of sabbatical leave with Weta Digital in Wellington, New Zealand, where he worked on normal map filtering—techniques for rendering textures and shadings. The film this February won an Oscar for scientific and technical achievement and was nominated for its visual effects as well.

Both Tessendorf and Geist have brought their experience with commercial productions into Clemson labs and classrooms, exposing their students to the latest techniques. Geist says his work at Weta Digital "caused me to completely change the contents of the graphics course I teach."

To create effects like those shown here, the team uses a relatively new approach to modeling called peridynamics, which is based on integral equations. Peridynamic modeling is useful for creating cracks, breaks, deformations, and other irregular forms.

The team working on shattered-glass simulation includes Jerry Tessendorf, professor and director of the Digital Production Arts Program; Robert M. Geist III, professor; Joshua A. Levine, assistant professor; and Christopher Corsi, an undergraduate computer-science major, all in the School of Computing, College of Engineering and Science.



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Boxed, from the series *The Nabakov Index,* 2013, *by Christina Hung.* Fragmented and contained *Papilio glaucus.* For more on Hung's work, see page 20.