glimpse

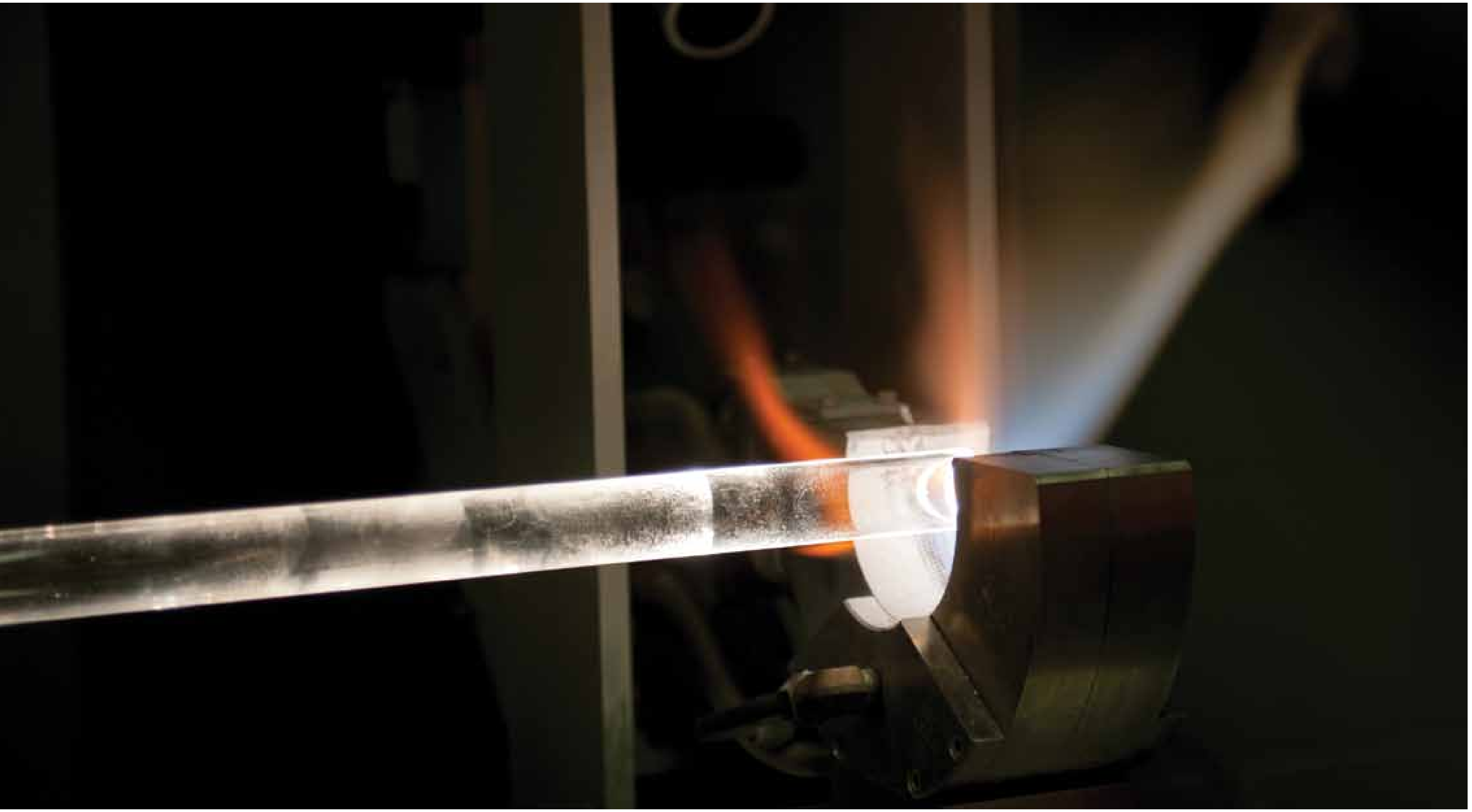
research *and* creative discovery

Clemson University

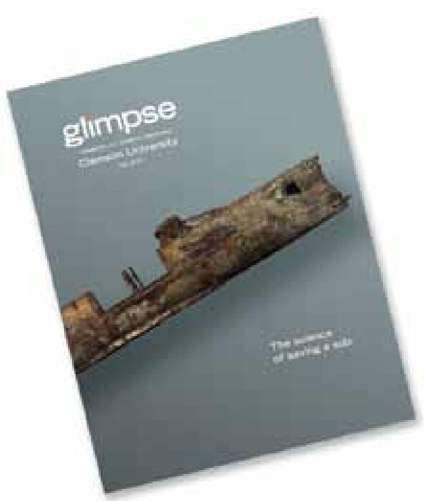
fall 2012

The science
of saving a sub.

Craig Mahaffey



Glowing with light from a gas flame, a glass rod takes shape in Clemson's Advanced Materials Research Laboratory. When the rod is ready, research staff will install it in a draw tower, a behemoth of furnaces and high-precision equipment that will spin the rod into purified optical fiber. Researchers use optical fiber to develop new technologies with applications ranging from cancer treatment to missile defense. For more, see page 32.



sub surface

The *H.L. Hunley*, raised from the mouth of Charleston Harbor in 2000, was the first submarine to sink a ship in combat. To guide conservation, archaeologists used 3-D scanning technology to document the *Hunley* and its artifacts, measuring differences in surface topography to a fraction of a millimeter. Page 12.

Digital rendering by Benjamin Rennison and Michael Scafuri. Image provided by Friends of the Hunley.

glimpse

Volume 1, number 2, Fall 2012

Glimpse is published by Clemson University's Office of the Vice President for Research. Editorial address is Public Affairs, Trustee House, Fort Hill Street, Clemson, SC 29634-5611.

Find us online: clemson.edu/glimpse
To subscribe, please sign up online or write to the editor.

Editor and Designer
Neil Caudle

President
James F. Barker

Vice President for Research
Gerald Sonnenfeld

Chief Public Affairs Officer
Cathy Sams

Director of Creative Services
Dave Dryden

Faculty Advisors
Steven B. Katz, Department of English
Anderson Wrangle, Department of Art

in this issue

A pattern of connection

Our first issue of *Glimpse*, published in April, filled fifty-two pages with stories about Clemson research and creative discovery. For the fall issue, we've packed sixty-eight pages, and we're just getting started. Research at Clemson is thriving, and we have many more stories than we can possibly tell.

What struck me about this issue was not just the number of stories but the way they revealed a pattern of connection. For example, research and conservation on the *Hunley* (page 24) applied Thompson Mefford's work with iron oxide nanoparticles (page 38). It's astonishing to realize that the same basic knowledge used to conserve a historic submarine can be applied to killing cancer cells.

Mefford also works with Tamara McNealy, a microbiologist studying the effects of nanoparticles on bacteria (page 10), and with Brian Powell, an environmental engineer, to learn how nanoparticles move in the environment. The team is using techniques Powell developed to track radioactivity ("After Fukushima," Spring 2012 *Glimpse*, page 12).

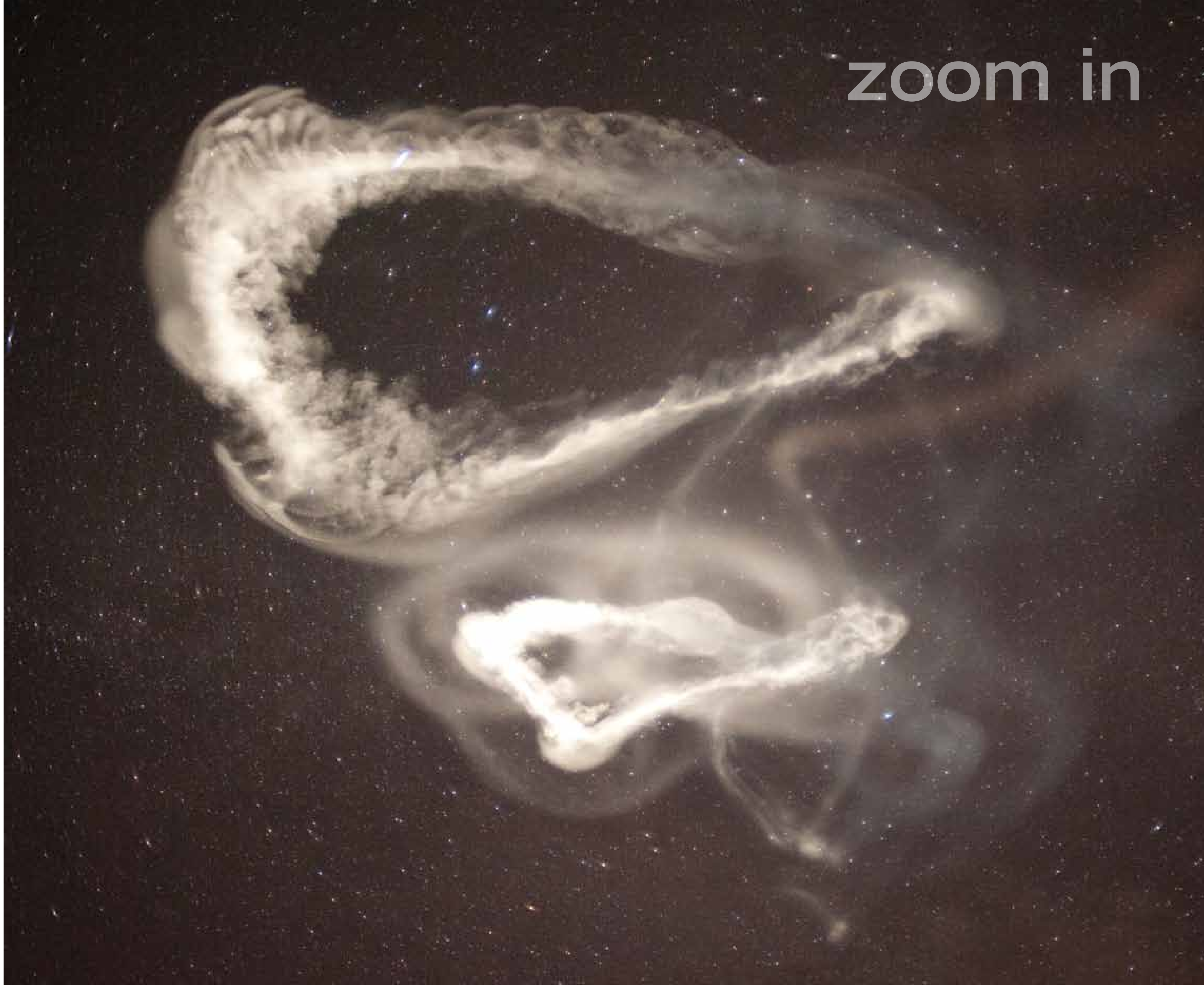
In story after story, we also find students and faculty members reaching beyond their disciplines to grapple with knowledge from other fields. Stephen Foulger, a polymer chemist (page 42), learns cancer-cell biology from his collaborator Michael Sehorn in genetics and biochemistry. Carly Drew, an artist (page 28), and Jillian Weise, a novelist and poet (page 64), both explore the influence of modern genetics, which is the domain of Leigh Anne Clark (page 43) and Brian Booth (page 26).

Booth is one of four researchers named in this issue who pursue treatments for cancer, using tools as varied as nanoparticles, lasers, plasmas, and advanced genetics. Can Clemson, which does not have a medical school, succeed in a field as competitive as cancer research? Yes, we can. We have strong collaborations with hospitals and medical schools. And on our own campus, advances in science and engineering are providing new tools for fighting cancer—tools more precise and less toxic than conventional chemotherapy. So the next big breakthroughs in cancer research may well come from places like Clemson.

The pattern of connection tells a story of its own. At their best, modern research and creative endeavors are constantly reaching out, building teams, sharing knowledge. One of the goals of *Glimpse* is to foster such connections, and to celebrate our culture of discovery. We hope you enjoy this issue.

Gerald Sonnenfeld
Vice President for Research

zoom in



Miguel Larsen

Sixty-five miles above the earth, a ghostly swirl of chemicals reveals a mysterious current of air.

Probing a mystery at the edge of space

On a clear night in March, five rockets pierce the sky above the coast of Virginia. As the roar of their departure fades, they grow ever smaller and disappear into darkness. Seconds later, streaks of glowing white clouds spiral downward. Monitored by cameras in New Jersey, Virginia, and North Carolina, these chemical tracers reveal patterns of winds and turbulence at the edge of space.

By tracking the clouds' movement, physicists Miguel Larsen and Gerald Lehmacher can analyze a high-altitude jet stream approximately sixty-five miles above Earth's surface. Because this jet stream lies at an altitude in which the atmosphere should become relatively calm, its presence and strength present an enigma. In 2002, after reviewing previous experiments on upper atmospheric winds, Larsen noticed that winds in this upper jet stream were three to four times stronger than theory predicted.

"From the experiment history, it was clear that there was a pattern," he says. "These winds were persistent, ubiquitous, and faster than they were supposed to be. We wanted to find out why."

The Anomalous Transport Rocket Experiment (ATREX) provided an opportunity to closely monitor these winds and track their growth patterns. At the NASA Wallops Flight Facility near Chincoteague, Virginia, scientists equipped five sounding rockets, each approximately ten meters long and fourteen to seventeen inches in diameter, with payloads of trimethyl aluminum (TMA), a chemical that glows when it interacts with oxygen. The rockets were launched approximately eighty seconds apart, and each emitted a stream of TMA on its ascent and descent. Scientists at vantage points in three different states photographed the spiral patterns formed by these emissions.

Lehmacher also outfitted two of the rockets with instruments to measure the density and temperature of the atmosphere. Larsen, Lehmacher, and a team of roughly sixty NASA engineers designed the rockets, each equipped for payloads of three hundred to six hundred pounds, so that they would spin at five revolutions per second to make their flight more stable. Several of the rockets also had gas jet systems to control the rocket orientation and optimize measurements. Data generated by the ATREX experiment are well worth long hours of preparation, as the atmospheric regions at the edge of space reveal a lot about planetary atmospheres throughout the solar system and satellite communications here on Earth. To understand why, it helps to know how the atmosphere stacks up.

Keith Koehler/NASA Wallops Flight Facility

Mixing it up

The high-altitude jet stream occupies an atmospheric region called the turbopause, which lies roughly sixty miles above the Earth's surface and marks the boundary between the well-mixed lower atmosphere and the heterogeneous upper atmosphere. The troposphere, stratosphere, and mesosphere lie below the turbopause. High levels of turbulence in these regions allow atmospheric chemicals to remain well mixed.

Above the turbopause, the atmosphere becomes too thin for this mixing to occur, and chemical compositions begin to vary. The atmosphere becomes thinner and presumably calmer as altitude increases, since large wave motions cancel each other out. Because of this, the strong winds of the high-altitude jet stream defy scientific expectations.

Keith Koehler/NASA Wallops Flight Facility

Miguel Larsen

Miguel Larsen looks on as the rockets make their ascent. Spiral patterns created by the rockets' payloads allow scientists to monitor the movement of a mysterious upper-atmospheric jet stream.

Scientists will compare the high-altitude jet stream with a lower stream that is a well-known feature of daily weather patterns and is often cited in weather reports. The ATREX launches will determine whether the turbulence that occurs at the upper jet stream is more two-dimensional or three-dimensional. Characterized by a progression from large- to small-scale motion, three-dimensional turbulence occurs in natural phenomena such as oceanic waves. Large-scale waves gradually break down and eventually dissipate. Conversely, two-dimensional turbulence occurs when small eddies coalesce and eventually become large-scale currents. Two-dimensional turbulence produces the lower-altitude weather jet stream, and scientists hope to discover through the ATREX experiment if the upper jet stream behaves in a similar way.

Keith Koehler/NASA Wallops Flight Facility

The ATREX rockets were about ten meters long, with payloads carefully balanced for stability.

Turbulence aloft

The high-altitude jet stream lies within the ionosphere, an electrically charged region of the upper atmosphere where electrical turbulence occurs. While this turbulence does not affect Earth's surface, it can disrupt satellite and radio communications. The ATREX experiment and subsequent tests will allow scientists a better understanding of the ionosphere's weather and will help mitigate the effects of this kind of turbulence.

Because the ATREX experiment monitors the part of the atmosphere where space begins, its results can be used to better understand the general behavior of other planetary atmospheres, such as those of Jupiter, Mars, and Venus. For example, each of Jupiter's stripes represents a high-speed current in the planet's atmosphere. While Jupiter's currents are oriented on an east-west direction, Earth's jet stream meanders from north to south as well as laterally. These differences reveal variations in the planets' rotations and can illustrate general principles of atmospheric motion for different planets.

"While there are many practical aspects to this experiment, our biggest question at this point is why this jet stream is there," Larsen says. "We don't have a complete answer to that yet, but an understanding of these winds will help us discover a lot about our own and other planets' atmospheres."

To aid in this understanding, Lehmacher is collaborating with mechanical engineers to create numerical models of the upper atmospheric wind patterns observed in the ATREX experiment. These models will demonstrate the behavior of the jet stream and also help predict what happens above it. Larsen, Lehmacher, and their team will assess the results of the ATREX experiment throughout the summer, fall, and spring before determining if follow-up experiments are necessary. They would begin planning these experiments in the summer of 2013.

"Our overall focus is on the classical understanding of how our atmosphere works," Lehmacher says. "We are still discovering the natural processes of our world, and that kind of knowledge generation is exciting because it connects physical theory with dynamics at the edge of space."

Miguel Larsen is a professor of physics, and Gerald Lehmacher is an associate professor of physics, in the Department of Physics and Astronomy of the College of Engineering and Science. This research was funded by the National Aeronautics and Space Administration.

– *Taylor Reeves*

Making cars lighter, stronger

With gas prices soaring, the auto industry is looking for ways to save fuel and cut emissions. One solution: a lighter car.

"The big vision for automotive companies right now is making cars that are lighter weight," says Laine Mears, automotive engineering professor and researcher with Clemson's manufacturing group at the International Center for Automotive Research (CU-ICAR). Mears leads a research project sponsored by the U.S. Department of Energy's Lightweight Automotive Materials Program (LAMP). "The amount of energy it takes to move a car from one point to another is highly dependent on the mass, so the lighter the vehicle, the less energy it takes to move it from one place to another."

While today's engines are more fuel-efficient than those of years past, automakers have been packing cars with new features whose extra weight has kept fuel economy roughly the same, Mears says. More stringent fuel-efficiency standards are on the near horizon, requiring changes in technology to improve efficiency.

To help offset vehicle weight, Mears and his team tested an alternative to steel: titanium. Lightweight but strong, titanium is already common in aircraft, armor, missiles, and laptop computers. For the past two years, LAMP researchers at CU-ICAR have been exploring the use of titanium as a feasible material in automobile manufacturing.

To test the potential, the team worked with BMW to select a part of the vehicle where titanium could both save mass and improve performance: the front damper fork, a suspension component that connects the wheel carrier to the car's body frame. The team redesigned and built a titanium prototype of the fork and tested it both in the lab and in a vehicle, analyzing strength and dynamic performance, which were improved over the stock component. The team concluded that fuel savings achieved over the life of a vehicle with the titanium component—twenty-two to thirty gallons—could be used to justify its higher initial cost.

Phase two of the project focused on reducing production costs. Titanium's capacity to absorb heat makes it difficult to manufacture, as machining tools cannot withstand the temperatures necessary to shape it. This temperature increase in the cutting zone causes tools to wear down rapidly during the machining process. To combat these problems, LAMP researchers used the Clemson high-performance computing system to simulate and analyze a wide range of different manufacturing techniques. The system helped the team identify the main causes of tool wear and learn how to manufacture titanium more efficiently.

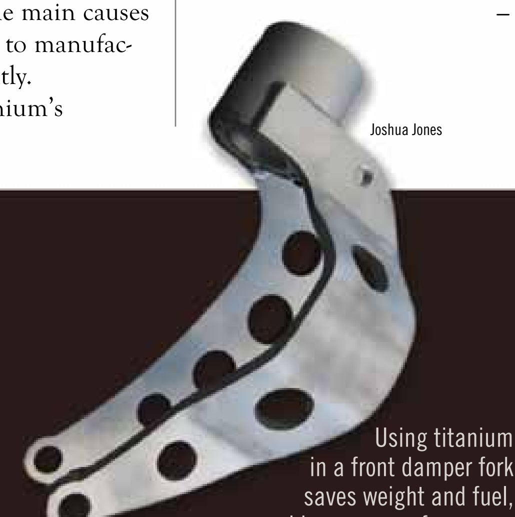
Another barrier to titanium's widespread use is availability: The mineral is difficult to mine and costly to produce. But American Titanium Works plans to build a production facility in Laurens County, South Carolina—an asset to researchers at CU-ICAR as they develop new titanium components and manufacturing methods.

A ten-year veteran of the automotive industry before he joined CU-ICAR in 2006, Mears says that he will keep exploring the potential for using lightweight manufacturing to improve vehicles and increase fuel economy.

"For lightweight manufacturing, there are some fundamental issues we need to get across, not only in manufacturing processes but also in selecting the correct material for the correct function, and bringing different materials together effectively in the vehicle," he says. "That's what this research is all about: getting past those underlying issues so we can see the greater benefit to industry and ultimately to society."

Laine Mears is an associate professor of automotive engineering at the Clemson University International Center for Automotive Research and a member of the Center for Emerging Technologies. Funding for this research is from the U.S. Department of Energy through the National Center for Manufacturing Sciences.

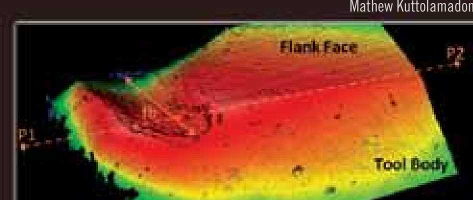
– Taylor Reeves



Joshua Jones

Using titanium in a front damper fork saves weight and fuel, and improves performance.

Wanda Johnson



Mathew Kuttolamadom

Laine Mears discusses a damper fork with graduate student Joshua Jones.

Right: Measuring with white-light interferometry helped the team characterize tool wear when machining titanium.

A bit dense

With high blood pressure, we can miss the emotions in faces or text.

Neil Caudle

Psychologist Jim McCubbin knew last fall that news of his research had gone viral. Still, he was surprised when it made it to Saturday Night Live.

The gist of the story? High blood pressure can cause "emotional dampening," a reduced ability to recognize anger, fear, joy, or sadness in the faces of others. People with this problem can seem a little clueless.

"They're called dads!" quipped SNL's Seth Myers. "Look, maybe if you tell me why you're crying I can help you out."

McCubbin laughs. "I had friends and relatives from all over calling me after that. Our research doesn't often make it into the popular culture."

It's not really a joking matter, though. High blood pressure has long been known to decrease sensitivity to pain stimuli. In fact, this effect occurs in people with a family history of hypertension even before their blood pressure becomes elevated. People at risk for hypertension also have exaggerated stress reactions.

McCubbin and some colleagues wondered if there was an unknown but intimate relationship between blood-pressure control mechanisms and other brain functions. He led a study reporting that subjects with hypertension, and those at risk for hypertension, did poorly at recognizing the emotional meaning of facial expressions, written communications, and other cues.

In complex social situations such as work, McCubbin says, people rely on facial expressions and verbal emotional cues to interact with others. But with emotional dampening, people tend to miss the cues. "If your work supervisor is angry, you may think he's just kidding," McCubbin says. "This can lead to miscommunication, poor job performance, and stress. If you have emotional dampening, you may distrust others because you can't read emotional meaning in their faces or their verbal communications. You may even take more risks because you cannot fully grasp the threats in your environment."

Blunting positives too

His theory of emotional dampening also applies to positive emotions. "Dampening of positive emotions may rob you of the restorative benefits of close personal relations, vacations, and hobbies," he says.

McCubbin's study of 106 adults from a healthy, middle-aged African American population was followed by a project in Creative Inquiry, Clemson's program of undergraduate research. If emotional dampening reduces appraisal of threat, the students wondered, could it also dampen perceptions of risk?

Eight undergraduate students on the team studied this relationship in forty-five young adults. They found that higher blood pressure was associated with higher reported benefit of risky behaviors, especially in financial decisions. The findings suggest that people with significant emotional dampening may perceive lower threat and thus greater benefit from risky behaviors, and they may engage in those risky behaviors more frequently.

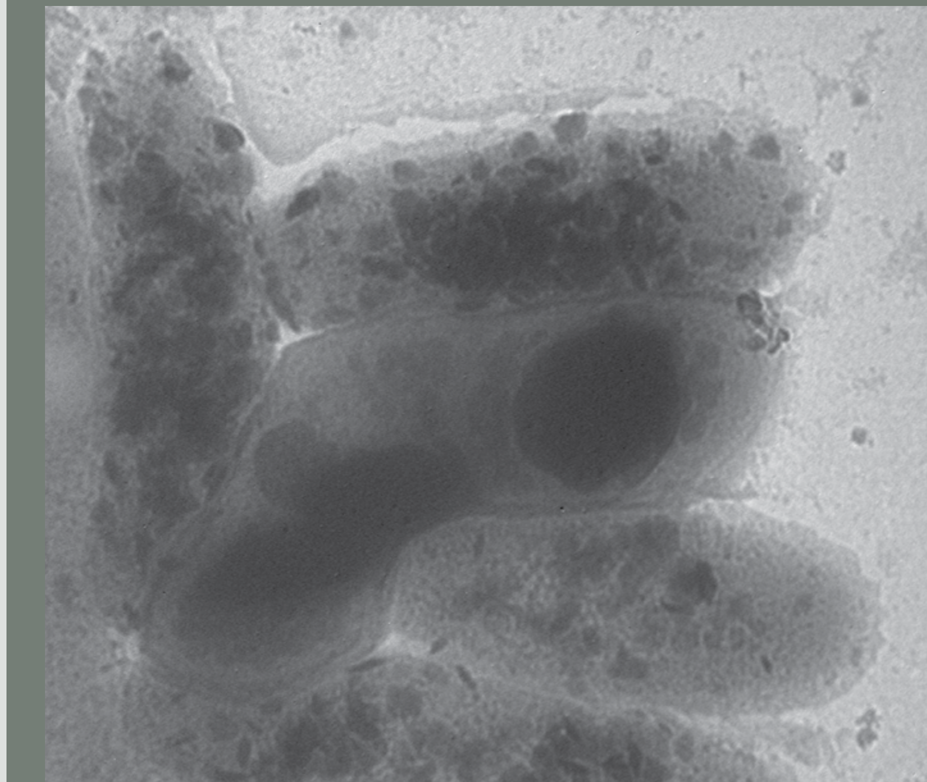
McCubbin is proud that his students were among a handful of undergraduate research teams invited to present their findings to the world's top researchers at a poster session of the annual meeting of the Society of Behavioral Medicine last spring.

"Undergraduates are the new graduate students," he says. "They designed the experiment, performed the research, and did much of the analysis. They are performing at the level of graduate students a decade ago, and it is really a valuable experience for them as they apply to medical and graduate school."

James McCubbin is a professor of psychology in the College of Business and Behavioral Science. The Clemson Creative Inquiry team, mentored by McCubbin, included students Jack Graham, Melissa Hibdon, Brittani Loukas, Danielle Brower-Lingsch, Gracie Ross, Suzannah Isgett, Aaron Nathan, and Ronald Schram. McCubbin was lead author of a study reported in the journal Psychosomatic Medicine *and supported by the National Heart, Lung, and Blood Institute and the National Institute on Aging, both of the National Institutes of Health.*

–Margaret Pridgen

How did *those* get in there?



bacteria with expensive taste

Gold nanoparticles appear as black dots inside the cells of *Legionella pneumophila.* How did the gold get inside? The answer could lead to new weapons against drug-resistant microbes. Electron micrograph by graduate student Amber Stojak, first published in *Nanotoxicology,* February 2011.

Craig Mahaffey

Tamara McNealy (right), with students. From left: Sarah Dusenbury (undergrad microbiology), Jordan Burbage (grad, environmental toxicology), Tara Raftery (grad, environmental toxicology), Zachary Bradley (summer-program student), Brennan Jenkins (grad, microbiology).

The electron micrographs seemed clear enough: Bits of gold had found their way inside living bacteria. But Tamara McNealy could hardly believe what she saw. Sure, the nanoparticles were tiny—only ten to fifty nanometers across—but they were far too large to slip through a cell membrane. If bacteria could take up particles that size, it was news to biologists.

Even after two other labs published similar observations, McNealy was not entirely convinced. She asked Thompson Mefford, a whiz at crafting and using nanoparticles (see story on page 38), to help her sort things out. If their research confirms what the micrographs appear to show, the implications are substantial, not only for science but for human health.

Runaway resistance

Medicine today faces the scary prospect of runaway resistance to antibiotics, also called antimicrobials. Resistant strains of infectious agents such as TB, staph, strep, salmonella, *E. coli*, and various other nasty bugs already pose a serious threat.

"One of the big problems with antimicrobials is the fact that most have to penetrate the cell wall," McNealy says, "and bacteria develop various mechanisms to stop them." Bacteria able to block an antibiotic survive to multiply and spread.

But if bacteria take up nanoparticles naturally, it might be possible to construct a Trojan horse, a particle that could smuggle a dose of antibiotic into the cell. One group of researchers has already shown that combining antimicrobials and nanoparticles seems to overcome certain kinds of drug resistance, but the how and why remain unknown. Maybe—and McNealy emphasizes *maybe*—the experimental treatment worked because the bacteria were taking up the particles, and with them the drug.

The *why* question

Even at a basic-science level, the discovery that bacteria take up nanoparticles is compelling. "Things don't exist in bacteria unless there's a natural reason for it," McNealy says. "Many engineered nanoparticles have a natural counterpart, so there may have been a reason for bacteria to develop some kind of uptake system. Why? I don't know."

McNealy, a microbiologist, is the kind of basic-science researcher who loves to ask the *why* question. But she first began working with nanoparticles for practical reasons—to learn how various types of particles might affect bacteria. She found that nanoparticles of gold or platinum disrupt biofilms, the slick layers of living cells that coat medical instruments and other equipment after use. *Legionella pneumophila*, a pernicious pathogen that causes Legionnaires' disease, forms this kind of tough film, and scrubbing it off abrades the hardware. Conceivably, using nanoparticles to dislodge the film could help extend the life of some medical devices and allow the reuse of others that are now thrown away.

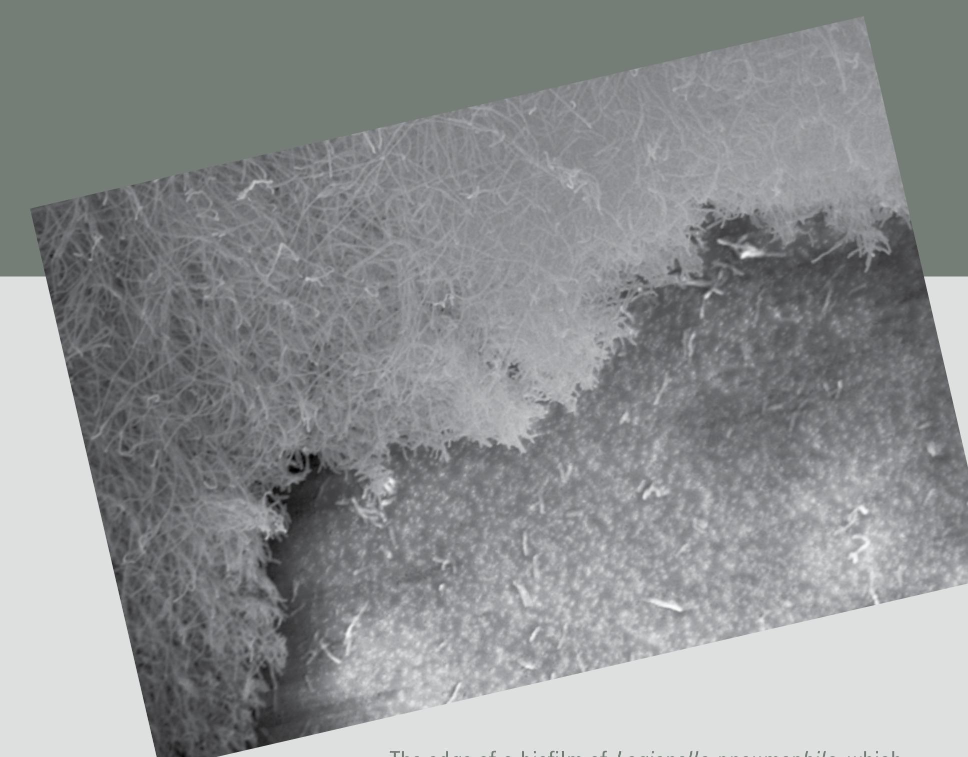
Risks in nature

But in nature, biofilms are not dispensable; they are necessary. Among other things, they cycle nutrients and feed amoeba and other grazers. So a second practical aspect of McNealy's research has been the implication that releasing too many nanoparticles into the environment—from industrial sources, for instance—might damage aquatic ecosystems, and that nanoparticles taken up by bacteria conceivably could make their way up the food chain.

Having pursued these common-sense lines of applied research, McNealy now finds herself facing a fundamental question about the biology of bacteria, which is exactly the kind of basic-science question she is glad to pursue. And she happened on that question by working with scientists and materials from outside her field, pursuing new applications for nanotechnology. "It's allowed us to discover things," she says. "It's allowed us to observe phenomena that we didn't even believe were possible before."

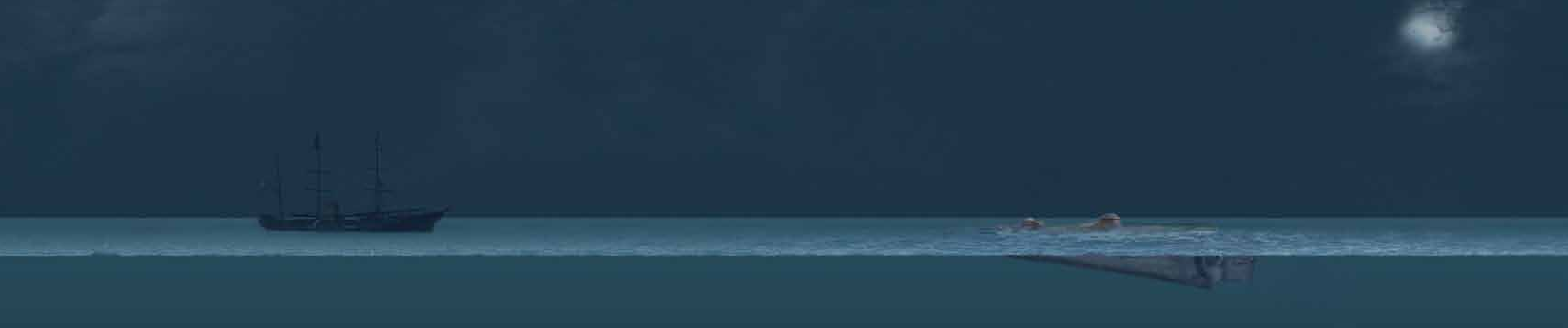
Tamara McNealy is an assistant professor in the Department of Biological Sciences, College of Agriculture, Forestry, and Life Sciences.

– Neil Caudle



The edge of a biofilm of *Legionella pneumophila,* which causes Legionnaires' disease. McNealy has found that applying gold and platinum nanoparticles dislodges the biofilm. Electron micrograph by Tara Raftery.

For more, please go to www.microbesadapt.com.



learning from the *Hunley*

A submarine that made history delivers another potent payload, this time for science.

stories by Frank Stephenson

1864. Strangled by a necklace of Union warships wrapped around its seaports, the three-year-old Confederacy was on its deathbed, and its puny navy could do little about it. From the crucible of desperation, the South forged an improbable secret weapon: a hand-cranked attack boat. Built and tested in Mobile, Alabama, in 1863, and delivered to Charleston by rail on August 12, 1863, the *H.L. Hunley* was designed to do what no vessel in the world had ever done: sink a warship from beneath the waves.

Illustration by Neil Caudle

On the chilly, moonlit evening of February 17, 1864, the *H.L. Hunley* pushed out of Breach Inlet; just north of Charleston Harbor, headed for destiny. In its cramped, clammy hull, seven men led by twenty-four-year-old Lt. George E. Dixon, attached to the 21st Alabama Infantry, sat hunched over at their stations, stoically cranking their craft to sea.

Almost two years before, Dixon had been spared a mortal wound in the battle of Shiloh, thanks to a twenty-dollar gold piece that he carried in the left pocket of his trousers. The heavy coin deflected a Yankee musket ball that otherwise could have shattered his left femur, a wound that most likely would have been fatal. Dixon had carried the bent coin with him as a good luck piece ever since, and this night was no exception.

Around 8:45 p.m., the *Hunley* homed in on her target, the 207-foot, 1,200-ton federal sloop-of-war *U.S.S. Housatonic,* which was placidly riding anchor about four and a quarter miles due east of Breach Inlet. Although it had been designed to attack while completely submerged, the *Hunley* brazenly charged its target on the surface at a speed of no more than four knots. A suddenly alarmed watch crew aboard the *Housatonic* began firing their pistols and big-bore rifles point blank at the approaching menace, but too late. The *Hunley's* seventeen-foot-long iron spar, carrying a heavy keg of black powder, found its mark on the *Housatonic's* starboard quarter. Seconds later, a huge explosion disintegrated much of the great ship's aft quarters. In minutes, the ship sank stern first in twenty-seven feet of water, and then heeled over to port, its surviving captain and crew clinging to its mast and rigging. Five Union seamen lay dead in the wreckage.

It was the first successful submarine attack in naval history, and it became one of the most intriguing and enduring tales of the American Civil War. But soon after the attack, the *Hunley* promptly vanished into a cold sea without a trace.

Reunion

April 17, 2004. In Charleston's Magnolia Cemetery, thousands gathered for a funeral, along with reporters from more than four hundred media outlets from around the world. After one hundred and forty years, all twenty-one men and boys who died serving aboard the *H.L. Hunley* were reunited at last. Fittingly, the country's last commemoration of Confederate dead had come to Charleston, the very place where the Civil War began.

The ceremony capped a long and all-but-abandoned search that had ended in 1995, during an expedition led and funded by famed novelist-cum-marine explorer Clive Cussler. That summer, Wes Hall and Harry Pecorelli, two marine archaeologists groping through the mucky floor of Charleston Harbor, became the first humans to touch the *Hunley* in one hundred and thirty-six years. Five years later, on August 8, 2000, the ten-ton vessel—filled with around thirteen tons of silt burying its final crew—was gingerly plucked from its muddy grave and transported to where it lies today, in a North Charleston water tank the size of a swimming pool. Now into its twelfth year, the project—the likes of which archaeologists had never seen—is run by an international team of specialists. Since January 2007, the team has been under the exclusive management of the Clemson University Research Institute (CURI).

Friends of the Hunley

Lt. Dixon's gold watch stopped at 8:23. A team of conservators including Paul Mardikian painstakingly cleaned and preserved its intricate parts.

Pushing the boundaries

Before stepping down in August, Michael J. Drews directed CURI's Warren Lasch Conservation Center, the *Hunley's* home at a decommissioned navy base on the west bank of Charleston's Cooper River since the sub's recovery. He managed the project and its international team of specialists beginning in January 2007. Formerly on the faculty of Clemson's School of Materials Science and Engineering, Drews directed the center's day-to-day operation. His job was to make sure that the center's work stayed focused on its number-one mission, namely to study and conserve the *Hunley* to the fullest extent possible so that the old vessel's significance to history and culture and to education and science is passed on to posterity.

"Our goal is not just to do conservation and archaeology but to push the boundaries of science in both areas," Drews says.

Drews first connected with the *Hunley* in 2001, when Paul Mardikian, senior conservator at the Lasch Center, made a presentation at Clemson about the conservation project. Among many other artifacts recovered from inside the vessel, Mardikian had found pieces of fabric—shreds of clothing worn by the *Hunley's* crew. These remnants, along with the remains of the crew that wore them, were extremely degraded and required expert analysis. Drews happened to be in Mardikian's audience that day.

"This turned out to be a great example of the fields of materials science and conservation coming together," Drews recalls. "Paul was interested in conserving, identifying, and characterizing the fabric he'd found. We talked and I thought I might be able to help."

Discussions led to Drews coming to the Lasch Center in 2003 on a sabbatical (his first since joining Clemson's faculty in 1972). An expert in using high-pressure fluids to treat and modify fabrics—technology used by industry to dye cloth—Drews began a series of experiments in treating a variety of samples and rivets recovered from the *Hunley.* The work resulted in a patent, filed in 2006, that describes a revolutionary treatment of iron objects recovered from saltwater environments (see story on page 24).

It's a submarine!

On a clear May morning, Mike Drews walks us down the hall of the Lasch Center to a set of bay windows that overlook the floor below. Sunlight pouring through two large skylights brightly illuminates a tank of clear water and the long, dark mass inside.

It's the *Hunley,* all forty-two feet of her, sitting upright with her bow pointed to the northwest, the course that would have carried her and her crew safely home long ago had fate been more kind. Beneath the shimmering surface of the green pool, her crusty brown skin seems to crawl. Ominously, she looks like a stealthy leviathan, asleep perhaps, but no less the lethal creature of the sea she was built to be. Looking down on her fish-sleek frame, one thing stands gin clear: *The thing is a submarine!*

From a closer range below, a tour group leans against a safety rail, gawking, as a volunteer with the Friends of the Hunley, the nonprofit group that spearheaded the first years of the *Hunley* project, explains what they're seeing. Every year, some 40,000 visitors to Charleston put the Lasch Center on their must-see list.

Drews says our visit is well timed. We're among the first to see the *Hunley* in its entirety, sans the eight-ton truss assembly that had cradled the vessel from the day it was raised in 2000. The truss had enabled engineers to hoist the *Hunley* to the surface in the exact position she'd been found—lying 45 degrees on her starboard side. This costly, painstaking move was essential to prevent the vessel's contents from being jostled, an archaeologist's nightmare.

Ray Stanyard

Michael Drews at a tank equipped to keep the *Hunley* intact during archeology and conservation.

In July 2011, some seven years after the ship's insides were excavated, engineers finally rotated the vessel to its original upright position. As a precaution, the truss stayed in place until January 12, 2012. With the truss pulled away, mortals suddenly had their clearest look at the *H.L. Hunley* since it sat, nearly 150 years ago, on a Confederate dock less than seven miles from its current home.

Unexpected marvel

No one has been at the frontlines of the *Hunley* project longer than Paul Mardikian and his colleague Maria Jacobsen. Both were hired by South Carolina's newly formed Hunley Commission almost a year before the vessel broke the surface in the summer of 2000. The pair formed the vanguard of an all-pro team that would lead what everyone from the beginning knew lay ahead—many years of meticulous lab work.

The Danish archaeologist Jacobsen, previously with the Institute of Nautical Archaeology at Texas A&M University, is chief archaeologist at the Lasch Center, the namesake of local businessman Warren Lasch, who served as first chairman of Friends of the Hunley. As did her Sorbonne-trained colleague Mardikian, Jacobsen brought multiple years of globe-spanning experience to Charleston. She's helped excavate old shipwrecks from Turkey to Texas.

Now a dozen years on, Jacobsen and Mardikian's vantage point from the front row of the *Hunley* project has opened their eyes to a fragment of history with dimensions they never imagined. Neither researcher expected to find what they did in an artifact that Jacobsen has called "a technological marvel of its time."

"Everything we thought we knew about this vessel turned out to be flat wrong," Jacobsen says. All that she and her colleagues had read from the few surviving historical records on the *Hunley* –including descriptions written by men who not only served on her but who also helped design her—were found to be fraught with error.

From the full complement of crew thought to be required to operate the vessel—multiple records had indicated nine, yet only eight bodies were recovered—to the way the vessel was built and how its curious manpower propulsion system worked, one revelation atop another made for daily thrills for the *Hunley* team during the project's early years. (For a list of key discoveries, see page 21.)

Well before the boat's mud-packed interior was explored, the vessel revealed its builders' mastery of metalwork and craftsmanship. From its cast iron, knife-like bow to its elegantly contoured conning towers, the *Hunley* is a genuine tour de force of engineering for its time.

"When you consider the fact that this vessel was built out of desperation by people under incredible pressure, with few resources, you'd think they would have slapped something together quickly, just to get it out there," Jacobsen says. "But that's clearly not what they did. Everything about the *Hunley* bears the hallmark of something very finely crafted with a refined design."

In an obvious effort to make the *Hunley* as sleek and efficient as possible, every single one of its thousands of rivets was hammered flush with its outer skin. In a pre-power tool era, this was a herculean job requiring men willing to work in hellish conditions, handling red-hot metal in painfully tight quarters.

The hull itself was found to be made up of a series of three-eighths-inch-thick wrought iron plates built specifically for the purpose, not salvaged from old boilers as legend had it. Typical boilers of the day were built with overlapping iron plates riveted together. On the *Hunley,* the plates' edges are neatly butted up against each other and riveted to iron backing straps on the inside. These were juxtaposed by a series of iron stiffening rings, designed to help the hull withstand pressure at depth, a feature that most likely developed from trial and error (the *Hunley* had at least two precursors).

Adding immeasurably to the *Hunley's* speed and stealth was the care with which its designers shaped every detail of its exterior. The chiseled bow—forged to a thickness of a mere inch—allowed the vessel to cut through water with ease. The vessel's smooth skin gives way to a drastically tapered keel ballasted with custom-made iron blocks, each seamlessly contoured to match the hull.

Once they had a chance to examine the *Hunley's* insides, the team's wonderment vaulted. They discovered levels of ingenuity that continually surprised them.

"When we tried to imagine, to predict, how the designers would have solved a problem, I don't think anyone has been right once," Mardikian says. "Every time, we've been blown away by their creativity and cleverness."

On-the-job training

The men who built the *Hunley*, on Water Street flanking the Mobile River, didn't work from a manual, mainly because none existed. But, they could easily have written one for the world.

Friends of the Hunley

Above: Senior archaeologist Maria Jacobsen works in the *Hunley's* crew compartment during the final excavation of human remains in 2004.

Below: Hundreds of onlookers cheered as the *Hunley* broke the surface of Charleston Harbor on the morning of August 8, 2000, for the first time in 136 years.

Friends of the Hunley

Ray Stanyard

Tending the light: Chief conservator Paul Mardikian examines the *Hunley's* lantern, a whale-oil light used mainly for signaling. The lantern was highly degraded, with some parts missing. Mardikian used X-rays showing the lantern's "ghost" to reconstruct missing parts.

Finished in July 1863, the *Hunley* (the vessel didn't acquire the name until later) was the third true submarine that a team largely made up of well-to-do New Orleans-based engineers and businessmen had built since the war began. The first, *Pioneer,* was built in New Orleans and scuttled when the town fell to Union forces. The second, *American Diver,* built in Mobile, sank during sea trials somewhere off Fort Morgan. Neither vessel survived long enough to see combat.

Given the *Hunley's* appalling track record—before its final (and fatal) mission, it sank twice during practice runs in Charleston Harbor, killing thirteen crewmen including its namesake, Horace Lawson Hunley—its builders' third try was something less than the charm. Still, in the end the vessel did what it was designed to do. Against astounding odds, it pulled off a military feat that opened a terrifying new era in naval warfare that would soon have global, cataclysmic consequences.

Like the *Hunley's* makers, the twenty-first-century saviors of the sub began their work with no manual. No archaeologists on Earth had ever faced as complicated a task as posed by this one-of-a-kind time capsule, essentially a mass gravesite trapped inside a corroding iron coffin.

"From the start of this project, there was no blueprint for how to proceed," Jacobsen says. "There simply was no precedent for what we faced. The team had to come up with every bit of it."

The most critical thing the team did, even before the vessel was raised, was to devise a suitable corrosion-protection system for its new home in the Lasch Center tank. Typically, conservators' first line of defense against corrosion in metal objects is to place iron artifacts in strong alkaline solutions. This option would have been good for the stabilization of the hull but would have destroyed the human remains and fragile artifacts. And working in such a caustic environment would have made the excavation of the vessel extremely dangerous for the scientists. After consulting experts in corrosion, the team installed a system based on a technology known as impressed current, widely used in pipeline industries. The system, which involves the use of anodes powered by electrical current, offered several advantages, not the least of which was a safer working environment for the team.

With a safe, no-chemicals-added system in place, the team began work on the *Hunley's* most important contents—the human remains.

A rare time capsule

"Because the hull was intact, we knew we might be facing a mass fatality site," Jacobsen says. Well before the *Hunley* was raised, the Lasch team had put together a detailed plan for dealing with the human remains that they fully expected to find. The careful approach soon paid off. "The forensic experts who eventually studied the remains were absolutely floored by what they saw," she says.

Relatively soon after it sank, various openings in the hull—possibly including a forward hatch cover later found to have been left unlatched—allowed tons of sediment to enter the sub and eventually bury everything in it. By the close of 2001, the main section of the crew compartment had been excavated, and the team had collected fragments of clothing, including silk, cotton, wool, cashmere, and leather, along with hair, teeth, a cache of roughly 1,600 bones, and boots that contained fully articulated foot bones.

The most unusual finds included remnants of human flesh. Pieces of fatty tissue were recovered from several places, including the insides of skulls. Jacobsen and Mardikian found, in the insert of a shoe, remnants of the human heel that once pressed into it, along with a clear impression of skin. Mardikian's biggest surprise was finding fingerprints embedded in a sample of concretion

Science and the artifacts

The team carefully conserved the ship's artifacts, using X-rays and advanced digital imaging to help guide the work. A few examples: (1) Lt. Dixon's suspender buckle and (2) watch works before and after conservation. (3) Dixon's diamond-studded ring. (4) A silk bandana before and after. (5) The *Hunley's* lantern before and after. (6) A brass oilcan.

1

3

2

4

5

6

Images courtesy of Friends of the Hunley

Friends of the Hunley

Righting the ship: After its recovery from the sea in 2000, the submarine was kept at exactly the angle (roughly 45 degrees) at which it was found to protect its contents and structural integrity. In June 2011, a crew of scientists and engineers rotated the *Hunley* to its original position using carefully coordinated adjustments. Tension sensors mounted above each station fed information to a computer monitored by Vincent Blouin, assistant professor in the School of Architecture and the School of Materials Science and Engineering, who made sure the rotation was smooth and even, to avoid stressing or breaking the fragile sub. Before the rotation, Blouin and graduate student Aditya Choragudi used multiple computer-based models to calculate potential stresses on the hull. The photo above shows an early stage of the rotation. Later, fifteen people tended the port side.

found on the sub's floor. Basically, a hard crust that forms when carbonates in seawater combine with iron, concretion can essentially fuse organic material to an iron substrate. In this remarkable case, the process recorded the only fingerprints of a *Hunley* crewmember known to exist.

The question that had been on the minds of archaeologists from the start—whether the remains held any recoverable DNA—was soon answered. The team successfully recovered DNA from all eight skeletons. (The project's forensic panel represents multiple fields of science and forensic specialties. Doug Owsley, head of physical anthropology at the Smithsonian Institution, leads the study of bones; Jamie Downs, regional medical examiner of the Georgia Bureau of Investigation, is in charge of the pathological investigations; and Linda Abrams, U.S. Army forensic genealogist, heads the genealogical research.) Work to date has identified and named five members of the eight-man crew and established the origins of some of them. Four were found to be native Europeans.

Aside from what chemistry revealed about the *Hunley's* last crew, their skeletal remains speak volumes about the men, Jacobsen says. Scholars have suggested that all of the men who served aboard the vessel likely were picked mainly because of their stature. It was thought that only short men could manage to squeeze into the sardine can that was the *Hunley*. The story told by the bones found by the Lasch team proved otherwise.

"These men were taller than the average men of the Civil War, and in fact two of them were nearly six feet tall," Jacobsen says. "They were clearly not picked for their stature. And in looking at their profiles, we realize that these were handpicked men who were seasoned. This was *absolutely* a special ops team."

The final phase

For all of the attention, drama, and exciting science that the discovery of the *Hunley's* last crew brought to the Lasch Center's lab, the inescapable fact is that it put the conservation of the vessel on a vastly different timetable. Mardikian believes that had human remains never been found, in all likelihood the *Hunley* would have been put on public display in its own museum years ago, and displaying the vessel remains the preeminent goal.

"The presence of human remains added enormous constraints to the overall project's timeline," he says. "Because of this, using chemicals was not an option. I'm pretty confident that had the vessel been found empty of remains we could have finished conservation in less than seven years. And if it had been found in freshwater instead of saltwater, three."

Equally vexing is the way the *Hunley* is constructed and its condition after lying in saltwater for well over a century. The vessel is a veritable medley of metals, each with its own chemical characteristics, which often overlap or otherwise come in contact with each other, making standard treatment protocols extremely tricky. Moreover, the vessel overall is highly corroded, but not uniformly so. Extremely fragile sections often are found right up against solid ones. Even after all the human remains and other organic materials were removed, switching to a one-step, fast-track approach to stabilizing the vessel would have posed risks to the ship, Mardikian says. In 2006, Mardikian submitted to the U.S. Navy a conservation plan for the *Hunley*, and the plan was approved by several federal agencies, the Smithsonian Institution, and international leaders in the fields of conservation, underwater archaeology, and historic preservation.

Now that the ship's hull has been rotated into its correct position, the team plans to bathe the *Hunley* in a dilute solution of sodium hydroxide, a caustic chemical used to leach out the salts from corroded metal. No matter what process is used, pulling chloride ions out of a complex iron structure that spent more than a century in seawater can take years.

"We may never be able to extract all the salts in a reasonable amount of time without taking the submarine completely apart," Mardikian says. The Navy's priority, he says, is to maintain the integrity of the submarine during conservation and to prepare it for display in a condition that minimizes corrosion and the need for future conservation.

After the submarine has bathed in caustic chemicals for about three months, the team plans to drain the *Hunley's* tank, and conservators armed with both manual and pneumatic chisels will begin chipping away at the brown encrustation that conceals the surface of the sub. Only when they gaze upon the original skin of the *Hunley* will Lasch researchers be able to draw final conclusions about what happened on its famous mission.

"We must look at the surface," Mardikian says. "That's where we believe some of the best clues lie."

Into new waters

The Lasch Center itself is a converted warehouse that once was part of the famed Charleston Naval Yard, a base for tens of thousands of military personnel who served the nation through four wars. As a cost-cutting measure, in 1996 Congress shut the base down. In 2005, Clemson announced big plans for reviving the area. A donation of eighty acres of land by the City of North Charleston, along with $10.3 million in state matching funds, gave the university a green light to proceed with plans to turn the property into a research park and home for the newly formed Restoration Institute. The country's economic malaise slowed progress, but the project finally is taking shape, with a mission in renewable energy research. Last summer, a $100 million wind-turbine testing facility, reported to be the largest of its kind in the world, cranked up there, bringing eighty jobs to the area. With its foot in the door of materials science, the Lasch Center has positioned itself to become a full partner in the park's energy research.

Since assuming control of the *Hunley* project, administrators recognized the remarkable potential that the *Hunley* project held for advancing the fields of archaeology and conservation. Given its worldwide fame, the project was seen as a natural candidate for research that could have a lasting impact on technologies ranging from corrosion control to materials fabrication and preservation.

Today, the team's innovative work has reached the attention of scholars the world over. Since 2007, the center has published dozens of papers and made presentations at professional groups around the world. In 2010, the attention made the center host for Metal 2010, the largest gathering of metal conservators in the world, sponsored by the Paris-based International Council of Museums. The team is excited by some of the ideas already taking shape as direct spin-offs of the center's work (see sidebar, page 25). But they are mindful that the most pressing task at hand is the *Hunley* itself, and getting it ready for its final home. "We have to finish what we started," Drews says.

Exactly how the submarine will be presented to the public involves details yet to be worked out, Drews says. But he already knows that it will involve putting the vessel in a special place where people can see but never touch it.

"I envision it being in something like a Plexiglas terrarium

"I've got the coin."

In March 2001, researchers probing the muddy interior of the *Hunley* found the first bones.

From the start, all knew that this was inevitable, yet the moment was no less poignant. From then on, the work at the Lasch Center proceeded with a solemn new appreciation.

Kneeling in the sub's forward compartment, the evening of May 23, Maria Jacobsen was carefully working her way through a mound of mud that contained the upper torso of a crew member thought to be the *Hunley's* skipper. Suddenly, she touched something inexplicably familiar. Withdrawing her hand from the muck, she stared at something shiny. Jacobsen turned to her colleagues and said simply, "I've got the coin."

It was a Liberty Head 1860 twenty-dollar gold piece, showing obvious damage. The coin was caved in from the front. Flipping it to tails, Jacobsen read an inscription, written in cursive:

Shiloh
April 6, 1862
My life Preserver
G.E.D.

Nothing could identify the jumble of bones before Jacobsen any better than this. She had found Lt. George E. Dixon's good-luck charm, the heavy coin that had saved him from the hell of Shiloh, Tennessee. Legend had it that as Dixon headed off to war he carried the coin given to him by a sweetheart, one Queenie Bennett of Mobile, Alabama, whom he planned to marry as soon as the war ended.

Scant evidence has turned up to support the story, or to refute it. But it nonetheless makes for a romantic tale irresistible to Hollywood, which has made it part of the *Hunley* drama in several films and TV specials.

Ray Stanyard

Lucky coin: This warped 1860 twenty-dollar gold piece, recovered from the remains of Lt. Dixon, sits on display at the Lasch Center. Thought to have saved Dixon's life in battle, the coin adds a note of poignancy to the *Hunley* legacy.

and kept very dry," he says. "The air would be replaced with some inert gas, preferably argon, which is heavy and tends to stay in place."

By keeping tight controls on temperature, humidity, and exposure to oxygen, the *Hunley's* corrosion could be held in check to a level that would be "almost imperceptible" after a century, Drews says.

Peaceful legacy?

Each year, upwards of 10,000 visitors find their way to the sylvan grounds of Charleston's oldest public cemetery, Magnolia. Founded in 1849, the cemetery earns its listing on the National Register of Historic Places in large part by being the final resting place of hundreds of Confederate dead, including five generals and all three crews of the *H.L. Hunley.*

Cards, letters, hastily written notes, and other memorials commonly adorn the graves of Hunley, Dixon, and their comrades. We found a handsome printed tribute left by an international submariners group who obviously went to considerable lengths to pay their respects.

Such far-flung attention underscores what others have said and written about the legacy of the *H.L. Hunley.* The story transcends borders, politics, ideology, race, age, and gender. Yet some critics can't get past the legacy's unshakable ties to a renegade government hell-bent on protecting a venal economic system built on slavery. To their mind, the only lesson worth remembering is that the *Hunley* fought on the wrong side of history. Revering the old vessel and keeping its memory alive is impolitic at best.

While conceding the point on slavery, others argue that history is rarely this simplistic. Historians generally agree that the *Hunley* represents one of the most important milestones in the evolution of modern warfare that, for better or worse, fundamentally altered the course of history. Supporters argue that this fact stands independent of, and untarnished by, the sins of man, no matter how egregious, and therefore easily merits Clemson's investment at the Lasch Center.

Civil war historian Paul Anderson, associate professor of history at Clemson, says that people who would bury the *Hunley*—again—essentially are saying that they don't want to learn anything about the South's painful past. The project, he argues, represents a core mission of Clemson or any other university, namely, the pursuit of knowledge.

"Our job is to discover the past, not ignore it," he says.

Drews sees the university's role in a purely academic light as well. To him, the *Hunley* project is education, research, and service—the three-legged stool upon which any university worthy of the name rests. Clemson happens to be in the enviable position of helping to make a rare cultural treasure available to science and the world, he says.

"To a scientist, engineer, or naval historian the *Hunley* represents a nineteenth-century technological marvel that, unknown to those who built or manned it that night, changed the world in February of eighteen sixty-four."

The Hunley Project is conducted through a partnership of the South Carolina Hunley Commission, the Clemson University Restoration Institute (CURI), the Naval Historical Center, and Friends of the Hunley. CURI's executive director is John W. Kelly, Clemson's vice president for economic development.

Friends of the Hunley

Submerged in its tank, the *Hunley* slowly releases an accumulation of salt that would destroy it, if the ship were left exposed to air. Once it has been treated with a mild solution of caustic chemicals, the sub may be stable enough for the conservation team to begin removing the concretions that cover its surface. Will that reveal the secret of what sank the *Hunley?* No one knows for sure. But once the job is done, visitors will view the sub much as it appeared 150 years ago.

For more information about the *Hunley*

Friends of the Hunley
1250 11th Street
North Charleston, SC 29405

Tour information:
843-743-4865, ext. 10
www.hunley.org

Ray Stanyard

Setting the record straight

Much of what people believed about the *Hunley* turned out to be flat wrong, according to the project team. She was not, for one thing, a crude contraption built like a glorified boiler. She was a marvel of engineering and a warship ahead of her time. Here's a summary of some of the team's key discoveries so far:

Key findings about the vessel itself

- The vessel carried eight crewmen instead of nine, as records and testimony had indicated.
- The vessel's true dimensions were established:
  - length over all: forty-two feet
  - beam: forty-two inches
  - distance between conning towers: sixteen feet
- The vessel may not have been built from the scraps of old boilers, as was previously thought, because the hull reveals exceptional design and engineering skill employing abutting plates (as opposed to overlapping plates, the standard in boiler construction of the period) riveted to a series of backing straps on the inside.
- All rivets (thousands of them) are sunk or hammered flush to the outside, an obvious means of reducing drag.
- The crankshaft was not connected directly to the propeller but was instead offset to starboard and tied into a system of reduction (differential) gears (ratio still unknown) and a large flywheel. This helped sustain the crankshaft's rotation and propeller's momentum.
- A wooden bench for the crew was discovered mounted on the port side. This painted bench, measuring twelve inches wide and eighteen feet long, is made of pine.
- The design of the vessel's propulsion system reveals the secret of how engineers solved the problem of balancing the craft with seven crewmen sitting on the same side (the port). The cramped interior forced the crewmen to hunch over the crankshaft, thereby putting their collective center of gravity amidships.
- To date, no evidence has been found that definitely establishes how the vessel's weapon system was either constructed or deployed. The spar was attached by a bolt that was easily removed, allowing the spar to be raised separately.
- The vessel's plumbing system is ingeniously designed. Two pumps in the sub were found to have triple functions. They served as ballast pumps (to add or remove seawater) and as bilge pumps. By the twist of a valve, either pump could control the water level in either of two ballast tanks.
- Nine discovered valves controlled the vessel's network of pipes attached to two ballast pumps. Because of obscurity from concretion, the team has not yet determined the exact position of all valves.
- The inside of the vessel was painted white, possibly to magnify any illumination.
- The dive planes were connected to a dive-plane control rod that is not attached to their centers. A dive-plane control handle was counterbalanced to help move the large dive planes and thus make it easier to control the vessel during descent and ascent.
- The captain used a joystick-like lever to control the rudder, not a wheel as was previously thought.
- Two large holes, both on the starboard side, occurred long after the vessel sank and most likely were the result of corrosion and erosion.
- The hatches of both conning towers reveal fittings that include brass valves for equalizing internal air pressure. No historical records of this feature on the vessel exist.
- Researchers found a total of eighteen glass ports in the hull, including ten "deadlights" for admitting sunlight or moonlight into the dark interior while running on the surface. The other ports were mainly for navigational viewing from the conning towers.
- The vessel was composed of at least two different kinds of wrought iron as well as various cast iron parts. The narrow bow and stern sections, along with both conning towers and their hatch covers, are made of cast iron, whereas the hull is made entirely from wrought iron. Construction materials included wrought iron, cast iron, brass, copper, glass, wood, and rubber (for watertight gaskets).
- The vessel's forward hatch was unlocked and partially open. The aft hatch was securely locked.
- The vessel is equipped with a series of contoured iron blocks that form its keel. These blocks are secured to the vessel by T-shaped bolts, three of which could be undone by crewmen in emergencies. No evidence was found indicating that any effort was made to drop these blocks.
- A single "bull's-eye" whale-oil-burning lantern contains a clear lens, with no evidence of any artifice that would have given the lantern's light a blue tint.
- Because of concretion on the outer skin, there's no evidence the sub had a lanyard reel, which was previously thought to be the device used in detonating the vessel's torpedo from afar.
- Loose pieces of pig iron ballast were found on the floor of the vessel, most of which were iron plates that originally may have been used for building ironclads.
- All evidence suggests that the vessel rapidly filled with water upon sinking, although there may have been air pockets trapped inside the hull.

Key findings about the crew

- All eight crewmembers died at their stations, with no evidence of panicked escape attempts.
- The sediment that eventually entered and filled the interior did so from the bow first, as evidenced by the fact that Lt. Dixon (the ship's captain whose station was at the bow) was buried first.
- Fingerprints from a crewmember were imprinted into the concretion inside the hull.
- The insides of a shoe revealed the impression of skin atop a heel section.
- Shreds of various fabrics included pieces of leather, silk, cotton, wool, and cashmere.
- Remains found include bone, teeth, hair, and remnants of brain tissue.
- Personal or ship artifacts found and preserved include the captain's pocket watch, his legendary twenty-dollar gold piece, his gold diamond ring and diamond brooch, his binoculars, a brass compass, the broken remains of a glass depth gauge, various buttons and buckles, a medicine bottle, an identification ("dog") tag from a Union soldier, four smoking pipes, two pocketknives, seventeen canteens, and assorted wooden toothpicks and matchsticks. No sidearms or other weapons were discovered.

What really happened to the *Hunley?*

It took two full days after the *Housatonic's* decks were swimming with fish before the Confederacy's top brass in Charleston asked the obvious question. Nearly 150 years later, it's still the mystery that a dozen years of studying the *Hunley's* bones has yet to solve.

When the vessel was raised in the summer of 2000, optimism was sky-high among legions of *Hunley* fans that one of the most curious mysteries of the Civil War was on the brink of being solved. Twelve years later, the mystery has proven impervious to an unrelenting, point-blank barrage of some of the best archaeology and conservation talent in the world, largely because the submarine itself is still hidden under heavy concretion.

When cameras flashed the first pictures of the vessel as it was hauled aboard the deck of a barge on August 8, 2000, two large holes on the starboard side instantly caught the attention of onlookers. To many, here was the smoking gun. True to legend, here was proof that the luckless sub had been hit and fatally damaged by the *U.S.S. Canandaigua,* the ship that sprang to the rescue of 150 sailors clinging to the wreck of the *Hunley's* victim, the *U.S.S. Housatonic.*

Holes explained

Research led by Maria Jacobsen, head archaeologist on the *Hunley* project at the Lasch Center, soon proved that the holes occurred long after the *Hunley* sank and were a product of the twin forces of erosion and corrosion. The *Canandaigua* was a 1,400-ton war sloop, larger than the *Housatonic,* powered by sail and a huge, steam-fired screw. "If it had hit the *Hunley,* it would have cut it in two," Jacobsen says.

Did small arms fire from the *Housatonic* play a role? Eyewitness testimony described how panicked soldiers aboard the doomed ship opened up with rifles, pistols, and even shotguns at the *Hunley* as it approached its prey, illuminated by a near-full moon. (Ironically, at the critical moment of its history, the *Hunley* abandoned its biggest element of stealth—underwater navigation—and, on orders of commanding Confederate General P.G.T. Beauregard, attacked on the surface.)

At point-blank range, a round from a .58 caliber, black-powder rifled musket—the typical long gun carried by federal troops in 1864—can do a great deal of damage. Did a lucky shot knock a hole in the forward conning tower, or find one of its small viewing ports and thus kill or wound Lt. George Dixon, the *Hunley's* skipper?

One of the first examples of damage seen by the divers who found the wreck in 1995 was a softball-sized hole in the forward tower. How it got there is a puzzle. Jacobsen says that it could have been a result of either the explosion that took the *Housatonic* down or firepower. But no bullets were found in the bottom of the vessel, and the skulls of Dixon and all his comrades showed no telltale signs of bullet wounds.

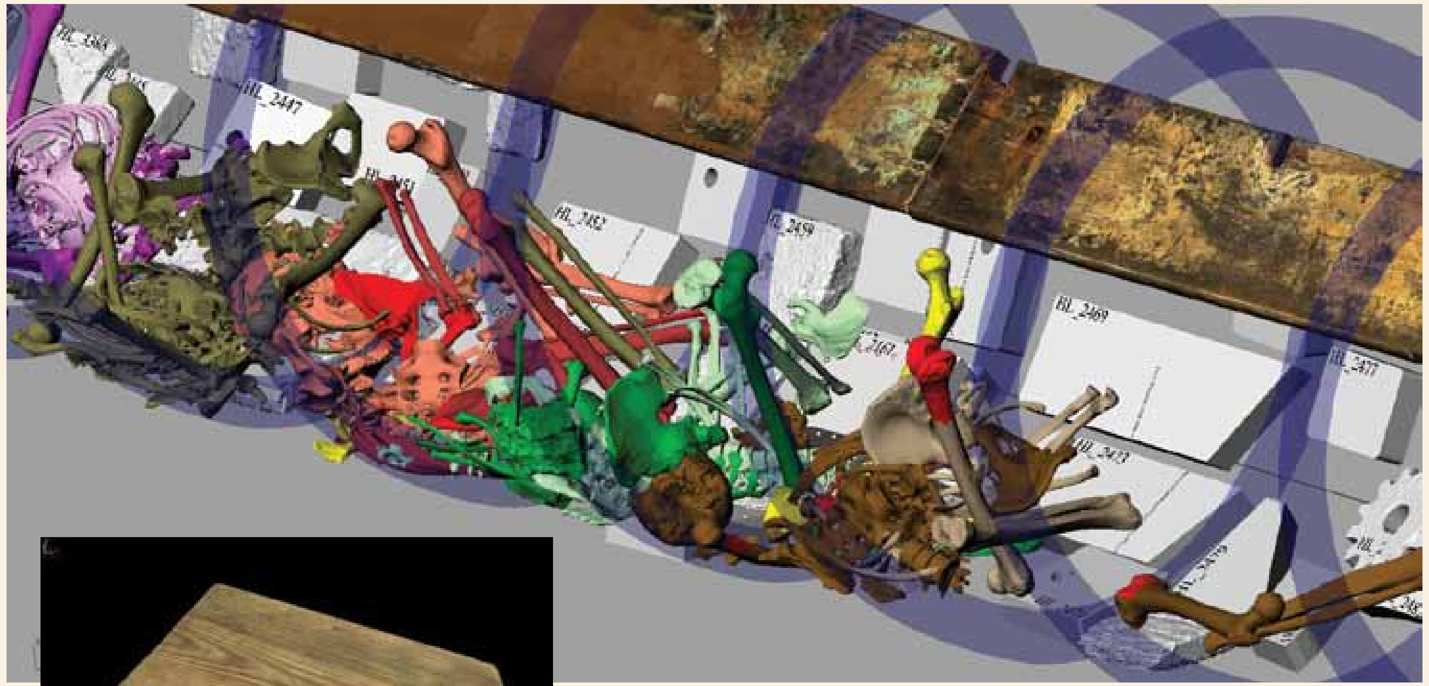
But the hail of fire from the ship may very well have played a role. Intrigued by the possibility, the Lasch Center team had an exact copy of the forward conning tower cast in iron and subjected it to a field test using period weaponry. The rifles succeeded in cracking it, a finding that may factor into subsequent discoveries when the *Hunley's* skin is finally freed from its heavy mantle of encrustation, a process slated to begin later this year.

Shockwaves

Perhaps the most plausible explanation for the *Hunley's* demise is that it was too close to the death blow it dealt the *Housatonic.* Shockwaves from a huge underwater concussion, even without causing lethal structural damage to the *Hunley,* could have either killed or knocked unconscious her entire crew. After drifting with no power for a few minutes in a choppy sea—and with the forward hatch cover curiously left open—the sub simply filled with water and sank. One hundred thirty-six years later, the sub was found lying less than a thousand feet due east of the *Housatonic* wreck.

Several findings support this and similar explosion-related theories. For one, none of the surviving drawings of the *Hunley* give details of exactly how its weapons system worked. Other than it was mounted on a seventeen-foot iron spar bolted to the bottom of the keel at the bow, little is known about the rig. Was the spar simply holding a contact mine, or was it tipped with a barb designed to be driven into a target's hull, leaving a charge to be detonated at a distance? A reasonable assumption, but so far no proof has turned up to support it.

Friends of the Hunley



Above: Before they were removed from the sub in 2004, the crew's skeletal remains were carefully documented with a 3-D scanning device. The digital image above, color-coded by individual, shows the *Hunley's* tilted position on the ocean floor, the bench seat higher than the crew's remains. Iron ballast blocks, shown in pale gray, could be moved to adjust the pitch and trim of the hull. **Inset:** The wooden seat occupied by Lt. Dixon.

Legend has it that the charge was attached to a lanyard installed on the *Hunley,* which ostensibly would play out from a reel, attached to the sub, which would be at a safe distance before tension pulled a trigger. So far, Lasch researchers have found no evidence for such a lanyard reel but remain hopeful that the deconcretion process will turn up something.

No mad scramble

Interestingly, witnesses aboard the *Housatonic,* testifying in a federal inquest, all agreed on one thing: The explosion occurred when the *Hunley* was very close to its victim. Exactly how close, no one will likely ever know. The Confederates also left no record of what size black-powder charge they installed on the *Hunley* that fateful night; undocumented reports give a range of ninety to one hundred and thirty-five pounds. Such a detail would be helpful for computer simulations of the explosion's impact.

A somber finding associated with the remains of the *Hunley's* men is a telling clue about their last moments. Researchers spent months poring through hundreds of bones, scraps of clothing, and personal effects. Instead of being scattered willy-nilly about the vessel, the remains lay in discrete places arranged sequentially along the ship's crankshaft where the men worked.

"It's clear that there was no mad scramble for the exits. They all died at their stations," Jacobsen says. "Whatever happened, it was so fast that they couldn't move or maybe they were already dead or unconscious."

Hunley timeline

10 Years

- **July 1863** Construction completed and sea trials run (Mobile, Ala.)
- **Aug. 12, 1863** Arrives by rail at Charleston
- **Aug. 29, 1863** First sinking (loss of five crew)
- **Oct. 15, 1863** Second sinking (loss of eight crew, including namesake Horace L. Hunley)
- **Feb. 17, 1864** Attack on *USS Housatonic;* submarine vanishes with all hands
- **May 3, 1995** Discovery by Clive Cussler expedition team
- **Aug. 8, 2000** Raised and installed at the Lasch Center
- **Apr. 17, 2004** Burial of last *Hunley* crew, Magnolia Cemetery, North Charleston
- **Jan. 2007** Clemson assumes management of archeological project
- **June 2011** Righted to original ninety-degree position
- **Jan. 12, 2012** Truss removed, revealing the complete hull

Ray Stanyard

Nestor Gonzalez-Pereyra, a chemical engineer with the Lasch Center, and conservator Liisa Nasanen open the top of a canister where salt-impregnated metal artifacts undergo treatment in the center's patented subcritical reactor.

Ridding metal of salt

Museums throughout the world groan beneath the weight of iron artifacts recovered from the sea. Everything from cookware to cannon sit soaking in various solutions awaiting the day they'll be cured from the saltwater poisoning that threatens to tear them apart from the outside in.

The process isn't for anyone in a hurry. Even a twelve-pound cannonball can take years in the bath before it's stable enough to be put on display.

Of all the countless conservation labs in the world, only one has the capability of curing iron artifacts in a fraction of the time typically required. In 2006, Michael Drews filed a U.S. patent, which was issued in 2011, on what could be a revolutionary method for treating archaeological iron.

After more than 150 successful treatments of various artifacts, Drews' process is turning skeptics (conservation pros are wary of magic bullets, and for good reason) into advocates the world over. While the device they've developed at the Lasch Center isn't yet big enough to treat something the size of a cannon (much less the size of a *Hunley*), for small objects the results are a conservator's dream.

Recently, his team "cured" a sixty-pound Civil War cannon shell recovered from Charleston Harbor's Fort Sumter in two weeks, a task that using traditional methods would have taken years, says Liisa Nasanen, a research scholar who helps run the treatment process. "Not only did we finish this shell in two weeks, but it still had almost all of its surface left intact. In the traditional way, we could have risked losing some of that."

The new process uses a super-hot, dilute alkaline solution (weak sodium hydroxide, or lye) under high pressure to basically cook embedded chloride ions out of saturated metal. Seawater is loaded with chlorides, the most viciously corrosive agent that iron-bearing objects face in a marine environment. The Lasch Center treatment rapidly and efficiently removes chlorides and transforms the iron corrosion products into their most stable forms.

Taking a lesson from textiles

In 2002, Drews, a professor emeritus of Clemson's Department of Materials Science and Engineering, got the idea of treating *Hunley* iron artifacts with a process he had experimented with during years of research on textiles and other materials. He specialized in studying processes that used super-heated fluids under high pressure and temperature. For decades, industry has used such techniques in applications ranging from decaffeinating coffee to dying cloth.

The twist on the industrial process used at the Lasch Center is that the sodium hydroxide bath is used at what chemists call "subcritical" conditions. By pressurizing the reactor first and then raising the temperature, researchers generate very hot liquids that do not boil. Lasch Center scientists and engineers typically use baths heated to around 350 degrees Fahrenheit and kept in liquid form by pressures of up to 800 pounds per square inch.

In 2003, Drews borrowed a supercritical water oxidation device—called a reactor—from a campus colleague and converted it to running subcritical experiments at the center. The results were so promising that in 2007 the Lasch Center designed and built its own subcritical reactor. The machine has a reaction chamber big enough to treat an object measuring as much as a foot in diameter and two-and-a-half feet long.

Word spreads

The word about the Lasch Center's subcritical extraction method is getting around the world's conservation community. Ian Macleod, executive director for collections management and conservation at the Western Australian Maritime Museum in Perth and consultant on the conservation of the Civil War ironclad *U.S.S. Monitor*, says, "I believe that this is the most significant advance in metals conservation in more than eighty years. It is without doubt the most efficacious and non-destructive method of conserving archaeological iron that has ever been developed."

Both the Lasch Center team and MacLeod hope the process can be scaled up to treat much larger pieces, such as whole cannon and entire sections of ship hulls. Technically, there's no reason this can't happen, Drews says. Economics will heavily dictate any scale-up, the first feasible stage of which likely will be designed to accommodate an average cannon from the Civil War.

Today, the most efficient traditional methods can treat such a field piece in about seven years. Drews believes the Lasch method could finish the job in a month.

faster conservation

Friends of the Hunley

Ballast block before conservation | **Ballast block after conservation**

Using a pressurized chamber to extract corrosive salts, the subcritical technology speeds conservation. A batch of five blocks took only seven days of treatment. Conventional treatments take much longer—an average of one year of electrolysis and two to three years of soaking in fresh water.

spin-off science

In addition to the subcritical treatment of archeological iron, Clemson research on the *Hunley* archeology project has produced two other promising spin-off technologies:

• **Greener Silicon Etching:** Before silicon wafers can be used to build photovoltaic cells for solar panels or for use in microelectronics, their surfaces must be etched. Etching is commonly done using a wet process whereby silicon is bathed in a corrosive liquid of some kind. While highly efficient, the process typically generates large quantities of toxic waste. Using the Lasch Center's know-how on subcritical technology, a team led by chemical engineer Nestor G. Gonzalez-Pereyra has developed an application for wet etching silicon that uses only a fraction of the volume of chemicals normally required.

Gonzalez-Pereyra worked with Thompson Mefford, a Clemson assistant professor of materials science and engineering, who is an expert on the chemistry of rust (see related story on page 38).

• **Protection and Conservation of National Monuments:** Thanks to an agreement with the National Park Service, Lasch Center researchers are transferring some of the cutting-edge digital imaging and corrosion-fighting techniques to help protect and conserve the grounds and artifacts at nearby Fort Sumter and Fort Moultrie. Last year, archaeologist Ben Rennison and Michael Scafuri, the center's 3-D scanning specialists, in collaboration with Clemson civil engineers Sezer Atamturktur and Peter Messier, began analyzing the forts, inside and out, as part of a comprehensive structural assessment. The forts may be threatened by a federal plan to deepen channels at major ports in anticipation of an expansion of the Panama Canal. Concurrently, the center's chief research scientist, Stéphanie Crette, is coordinating research on determining the most effective industrial coatings for protecting the large collection of iron artifacts at both forts.

The Office of Technology Transfer in the Clemson University Research Foundation manages inventions described in these pages.

Ray Stanyard

Stéphanie Crette, an expert in protective coatings used for artifacts found in marine environments, is the Lasch Center's chief research scientist.

as close as someone you care about

by Peter Kent

Brian Booth is looking for a way to tame a wild child. Cancer is genetics' wild child, relentless, growing from cell to tumor, restless, reaching from brain to bone, reckless, destroying even the body it makes home.

Actually, it's not just one wild child; it's a bunch of them.

Booth studies breast cancer, which killed about 40,000 women in the U.S. last year. Some 20 percent of breast cancers involved a signal for cell growth called HER2—human epidermal growth factor receptor 2. A cell biologist at Clemson's Institute for Biological Interfaces of Engineering (IBIOE), Booth wants to know how to control HER2, which plays a major role in how cells grow and divide. Being HER2 positive means a greater likelihood that some of your cells are growing and dividing as if the accelerator pedal on a car were stuck stomped to the floor, the brakes broken and no mechanic aboard. That's the tried-and-true analogy many physicians and scientists use to describe the spread of cancer.

The breast is a prime location for a cellular car crash, and breast cancer has been with us for a long time. An Egyptian papyrus describes eight cases of breast tumors cauterized by surgeons.

"The breast is the only organ that goes through about ninety-five percent of its development after birth," Booth says.

When a girl reaches puberty, the hormone estrogen and other chemical signals, including growth factors, initiate and spur cell growth and proliferation. It's a time when cells are working very rapidly and the risk of DNA damage and cell mutation is higher than normal. In a newborn, breast tissue is made of a single duct to the nipple. At puberty, the single duct branches out, creating a network as cells proliferate, grow, divide, and differentiate to make the parts of the breast.

Until a woman gives birth for the first time, the breast is more vulnerable to cancer than it will be afterward. Carrying a child to term, a woman's breasts get different hormonal signals: immature milk-making cells respond, making milk, and the change makes the cells less vulnerable.

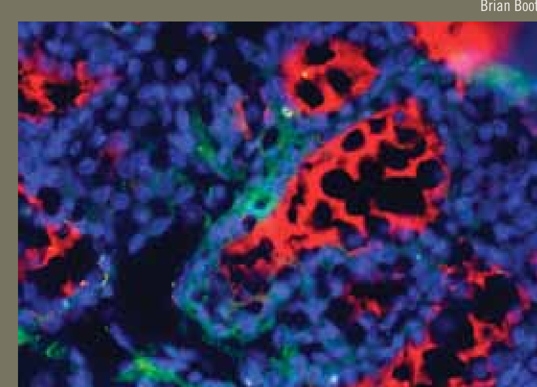
The two most common types of breast cancers are ductal tumors, which develop in the lining of the milk ducts, and lobular tumors, which begin where the milk is produced.

Only primates have breasts, but all mammals have mammary glands, the distinctive attribute giving our mammalian family its name. Booth uses mice, which begin puberty three weeks after birth. He inserts breast cancer cells in specially bred mice, waits for the cells to grow, euthanizes the mice, and looks at the results. Most of time the cancer cells flourish, growing, overwhelming the normal cells and spreading…but not always.

Neil Caudle

Brian Booth pursues the mystery of redirected tumor cells: For example, human male cancer cells introduced into lactating mice can form a mouse mammary gland and make human milk. In the image below, the blue stain indicates the cell nuclei, the red stain mouse milk, and the green stain human milk.

Brian Booth



"When we mix cancer cells with normal cells, depending on the ratio of cancer cells to normal ones, we will either get a tumor or get tumor cells that incorporate into the outgrowth of mammary cells in the mouse," Booth says. "The incorporated cells will not make a tumor. They will just become part of normal growth, become part of the cellular structure; they will even make milk."

Why do some turn normal?

So far, these redirected tumor cells are a mystery. Why do some cancer cells begin to behave normally?

This is the question that moves Booth forward in his seat, breaks him out of his just-the-facts monotone. This is the question he thinks about all the time, even when he takes the kids to Disneyworld. "We are trying to find out what is the mechanism; why do we get tumors with some and not with others?" Booth asks. "What are the signals and what do they turn on or turn off in the tumor cells or in the normal cells that keep the tumor cells in check?"

Outside the IBIOE labs on the fourth floor of Rhodes Hall are stools, some of drab gray metal, others wooden with painted seats. They hold umbrellas, water bottles, and food containers—student stuff banished from the lab and offered like sacrifices. "We keep things out that could contaminate the experiments or the students," Booth says, walking into the lab to a bench he shares with Jang Park, the postdoc who works with him. Another room has a fluorescent microscope the researchers use to look for markers, such as green fluorescent protein, that guide their search.

Like other researchers in the IBIOE, Booth is doing translational research, which means translating and applying information learned in the labs to clinics, surgery suites, and pharmaceutical makers. The tools are bioengineering and biotechnology. In the IBIOE, bioengineering can include, for example, biocompatible materials for scaffolds used in bone and tissue repairs. Biotechnology can include drug development with three-dimensional cell tissue models.

The institute and its director Karen Burg have developed a strong reputation for breast cancer research and breast reconstruction materials and techniques.

"If we are successful, we see our work not as a cure but a treatment, another tool to treat cancers," Booth says. "I have a hunch that what we will discover will not only be useful for breast cancers but other cancers, too. HER2 plays a role in cancer growth, not just in breast cancer."

The research still has a long way to go, but Booth's lab has isolated the redirected tumor cells and soon will begin analyzing them genetically. To do this, Booth works with Alex Feltus, a colleague at Clemson. Feltus is designing software that will rapidly sort through thousands of genetic code combinations, looking for proteins that could trigger the cellular responses Booth hopes to find. It's a big job because cancers do not develop identically, act the same, or grow the same. There are more factors involved than oncogenes—the growth accelerators—and tumor suppressors—the brakes. Booth studies the timing and sequence of gene mutations and the messengers that carry signals inside and outside the cell. The biochemical basis for these factors is largely unknown. Booth expects that his breast cancer research will lead him to explore other cancers, because pathways involved in one cancer often are used by others.

"From the genetic and molecular profiles, we can backtrack to locate the messengers that signaled the cell, its DNA, to turn on or off the cancer cell's growth," Booth says. "We want to be able to do it on purpose. I believe it could be useful as either a way to reduce the need for surgery and chemotherapy or to supplement it, helping to neutralize cancer cells that may have been missed in surgery."

HER2-positive breast cancers tend to be more aggressive than other types. There are HER2 specific drugs, such as Herceptin and Lapatinib, that kill cancer cells and lower the risk of recurrence, but 40,000 women still die from the disease and a nearly a quarter million more are diagnosed each year in the U.S. alone.

The human factor

Booth knows that cancer research can be isolating, shifting the focus from the patient to the disease. Controlled experiments, culturing cancer cells, injecting them into specialized laboratory mice, observing the tumor growths, staining slides, looking at the results through high-powered microscopes, using computers to locate and identify genes—it all but removes the human factors, which may begin with finding a lump, having it checked, and hearing a doctor say "cancer."

"When I was doing a postdoc at the National Cancer Institute in Bethesda, there was a hospital for kids with cancer," Booth says. "We would go to the cafeteria for lunch, and sometimes you would see the patients, the kids and their parents there. You wouldn't eat as much; you wanted to get back to work, try a little bit harder—okay, a lot harder."

Booth was recruited to Clemson in 2009, and there was no clinic here to remind him of the human cost of cancer. But he is a husband and a father of two girls. He doesn't let the question finish before answering, "Absolutely, I think about them all the time, with what I do."

"Cancer is as close to you as someone you care about," Booth says. His father, a retired General Motors worker, died of brain cancer in April.

As motivators, some people put up words of wisdom, others pictures of a frog or kitten hangin' in there or a poster of a famous scientist. Booth has a newspaper clipping pinned to his office carrel wall.

The 2007 obituary tells of the life of young woman in Connecticut who died of breast cancer. Phoebe Jones Foster. Booth knew her as Phoebe Jones, two decades ago, during high school in Rochester, New York.

"She was my prom date."

Brian Booth is a research assistant professor in the Institute for Biological Interfaces of Engineering, which spans all five Clemson colleges. Karen Burg, who directs the Institute, is the Hunter Endowed Chair and professor of bioengineering. She is also professor of electrical and computer engineering in the College of Engineering and Science. The Institute funds Booth's research.

Pinned above his desk, a reminder.

the cabinet of curiosity

works by Carly Drew

Queen Anne's Lace is the story of a plant that came over from England as an ornamental for the English garden, a way for people to remember their homes (left panel). Later, farmers used it as a companion plant for crops such as tomatoes, to draw the pests away (center panel). Today, Drew says, modern agriculture has made the old ways almost irrelevant (right panel). The letters are part of the genetic code of a commercially grown tomato plant, Drew says.

Chris Campbell

Carly Drew grew up on the red clay of South Carolina but spent her summers on a family farm in the community of Indiana, a rural borough in western Pennsylvania. A couple of years ago, after her grandparents died, Drew's relatives began to feud over family land, she says. At the same time, energy companies were moving into the region with renewed interest, probing the bedrock for natural gas.

Drew began to see the landscape in new ways. It could still be personal and lovely, but now there was also conflict, powerful new technology, and layers of documentation: data sets and scientific symbols, lines on maps. Online, she found gas-company records that listed people by latitude and longitude, "transposing personal relationships into another, more rigid structure," she says.

It was this counterpoint of old and new, personal and technical, that began to shape her work and open up what she calls "the cabinet of curiosity," an allusion to eclectic Renaissance collections of artifacts, specimens from natural history, and objects of art tailored to the curator's history and identity. She grew interested, she says, in "the topographies of ideas."

As a child, Drew was constantly drawing on sketchpads made of leftover paper from her grandfather's printing press. She still works mostly on paper, using watercolor washes in muted earth tones, incising them with charcoal or graphite symbols and patterns—topographic lines, blocks of terms or data, cursive quotations, snippets of code. Here and there, lines from nature converge and blend with the symbols of technology.

Drew has been influenced by her teachers and by artists such as Anselm Keefer and Walton Ford, but her father remains her first critic. An accomplished designer and craftsman, he also makes frames for her work. "If he can look at a piece and really get into it, then I kind of know that I'm on the right trail," she says.

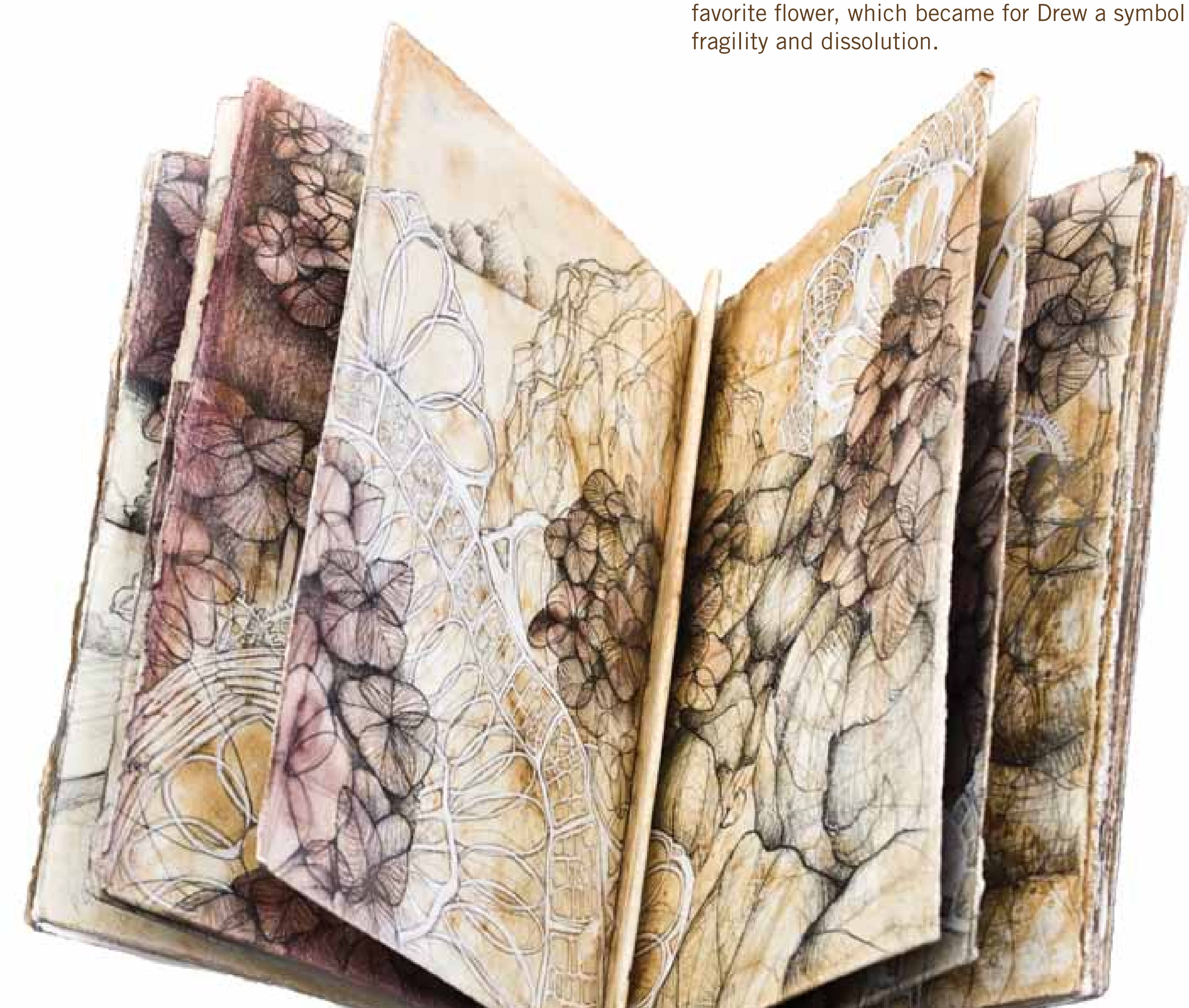
Carly Drew is working toward a master of fine arts degree at Clemson. Her major professor is Todd McDonald, a painter and associate professor of art. Drew has exhibited her work in the Kentucky National Juried Biennial, the McNeese National Works on Paper Exhibition in Louisiana, the annual upstate visual arts exhibition in Greenville, and at the Hub-Bub Showroom Gallery in Spartanburg, South Carolina.

– Neil Caudle

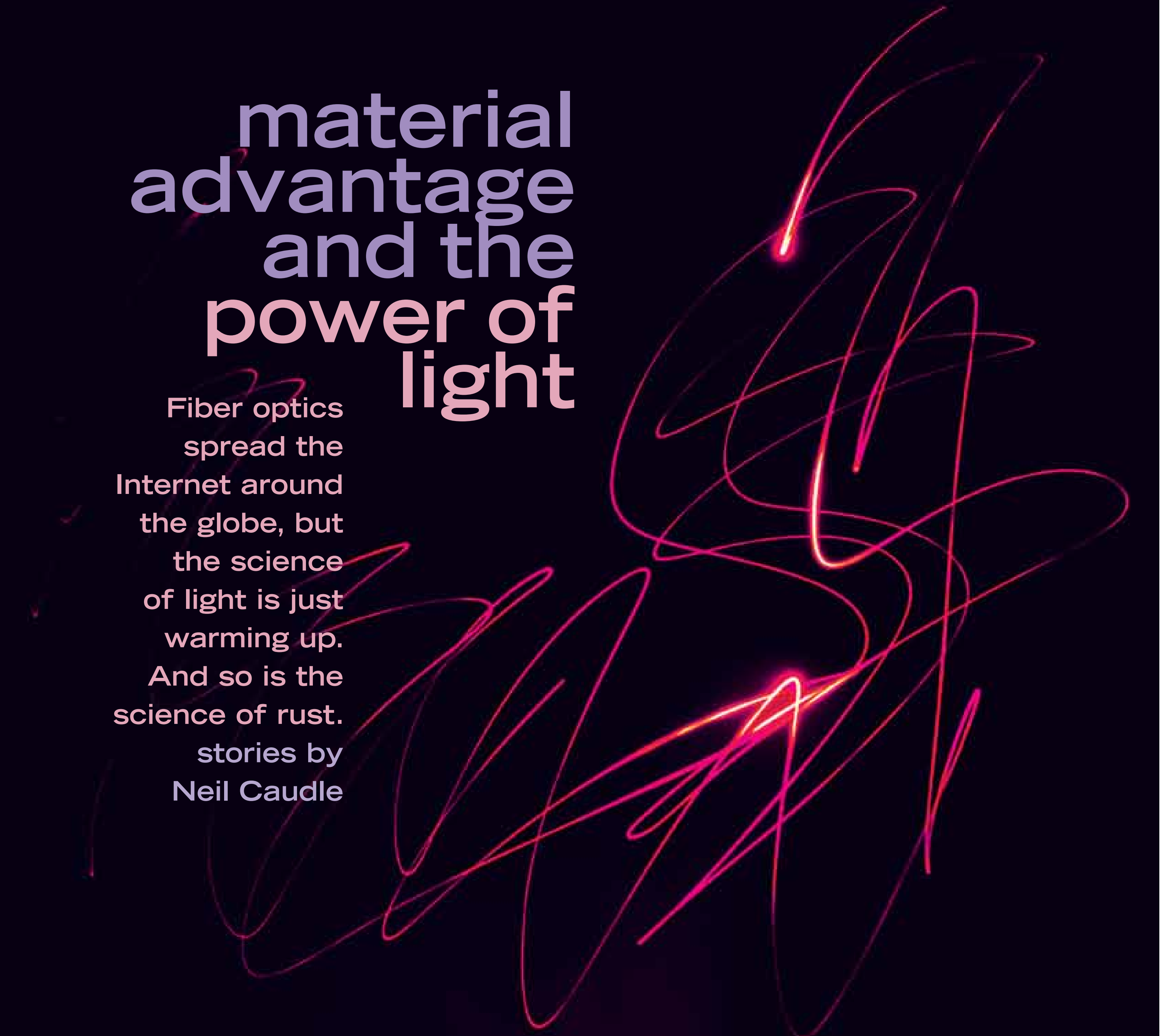
Reverence began with a snapshot her cousin took after a deer hunt. "The hunters had dragged the deer up and made a circle on the ground in front of a house my grandfather built," Drew says. The cursive text in the image is from one of her grandfather's old books, about trees. "It's a loving, tender introduction from the late eighteen-hundreds," Drew says.

Above: ***Manifest Destiny and Christmas Tree Farms*** incorporates the lines of a topographic map, one of the ways we "push and pull the landscape to fit our own visions," Drew says. The lines connect the unmanaged trees on the left with the order of farmed trees on the right.

Below: ***Hydrangea*** is an artist's book, a handmade hybrid of sculpture, drawing, and bookmaking. "You can pick it up and go through it," Drew says, "so you get that tangible feeling that's missing in a work of art that's on a wall or behind glass." The book tells a story about her grandmother's favorite flower, which became for Drew a symbol of family fragility and dissolution.



material advantage and the power of light



Fiber optics spread the Internet around the globe, but the science of light is just warming up. And so is the science of rust.

stories by Neil Caudle

When Maeve Budi hasn't been home for a while, her father will say she's been playing with rust.

"No," she says, "I've been working to cure cancer." As excuses go, this must rank among the all-time best.

But Dad, for once, was right; she was playing with rust. Tiny bits of it. Brownish, sludgy slurries of it. This is iron oxide, like the rust on the scissors you left in the rain. Now it stains the white sleeves of her lab coat. And yes, it is fun.

Neil Caudle

Just four years ago, when she was a freshman, Budi had never imagined a future in rust. And the idea that rust would fight cancer? No way. Rust is a cancer, right? A cancer of metal?

But take a few bits of that rust, form them into tiny particles, coat them with precisely the right chemical concoction, and direct them toward a tumor, where they penetrate the cells and do not assail the patient's body with toxic drugs or risky radiation. Instead, pass a mild wave of radio-frequency magnetic energy through the tumor to excite the iron atoms and heat the particles just enough to kill the cancer cells, and only the cancer cells, with zero damage to the healthy tissues around them. You would kill cancer with rust. And for an undergraduate student keen on doing something real with her life, that possibility was too cool for words.

Holding her own

My first contact with Budi was her voice, as I passed in the hall. She was inside an office, making her case to a couple of men who weren't ready to buy it. Someone would reel off a series of numbers; someone would *hmmm*; all would go silent a moment, then riff on *what-ifs* and *yes-buts*. No one was angry; no one was tense. But I knew there was plenty at stake.

So I crashed the party, leaned against a wall in a second-floor office of the Advanced Materials Research Laboratory (AMRL), and listened. Budi's professor, Thompson Mefford, was propped back in his chair, a foot on the rim of his desk, lobbing questions. Steven "Moose" Saville, who is finishing his Ph.D. under Mefford, stood nearby with his arms crossed, genial but imposing, like the second cop in a tough interrogation. Budi held her own, walking them through an experiment, reporting what she'd found, venturing an explanation.

The team, which also uses nanoparticles to develop new optical materials, had been testing two methods for coating iron oxide particles with chemicals that could anchor a polymer to their surfaces. Eventually, if things went according to plan, the polymer and its chemical payload would help guide the particles into cancer cells. One of the anchors, nitro dopamine, had worked as expected, but the other, a phosphate, had performed better than was theoretically possible. The team did not trust the data.

In the chair beside Budi, Mellissa Stimson, a rising senior, was tracking the debate. Stimson, who's in line for more rust now that Budi has graduated, plans a career in science policy. She was in the lab to learn, firsthand, how science works. Today, she was learning how scientists gang-tackle a problem and wrestle it to the ground.

Not much of their talk about the phosphate-anchoring problem would have made sense around the dinner table, back home. Budi and Stimson had come away to college and stepped inside a strange new world, a world with its own special language, and it suited them both. Budi is headed next to Florida to work on a Ph.D. She aspires to be a scientist. Here is a clue about her chances: School is out for the summer and she is still in the lab. She has finished her classwork, bagged her diploma. But she is not at the beach with her friends. She is not at home with Mom and Dad. She is playing with rust.

Trouble is, not enough students like Budi and Stimson are finding their way to the lab. Every day, we read about the critical shortage of American scientists and engineers. Somehow, the youth of today, agog in the digital dreamscape of futuristic marvels, are not yet awake to the fact that they themselves could make these dreams come true.

The idea, around here, is to wake them.

If you build it, they will come.

From Clemson's main campus, take a two-lane blacktop south through a patchwork of cropland, woods, and fields. Several turns later, your GPS may send you to the loading dock, as mine did. Find your way around a wooded slope and park in front of Clemson's field of dreams, a LEED silver building (certifying its sustainable design) that houses, among other things, eight thousand square feet of optics labs. There was no voice from a cornfield, but an ultramodern laboratory building and research park have materialized, here in the middle of nowhere.

For a time, some people thought Clemson was delusional to gamble on a research park with an optics lab at its core. Around the nation there were already hundreds of research parks, many with optics labs, and the most successful of these were usually near high-tech hotspots such as Boston and Silicon Valley. Was Clemson ready to play in that league?

Apparently, yes. Now, twelve years after its formal inception, the Center for Optical Materials Science and Engineering Technologies (COMSET) includes thirty faculty members publishing sixty to seventy journal articles a year. Breakthroughs from COMSET make the covers of high-profile journals. Better yet, from a scientist's point of view, citations of COMSET papers may soon top a thousand—per year. Because citations indicate influence, this is a sizeable claim in the marketplace for knowledge.

Coffee, beer, and light

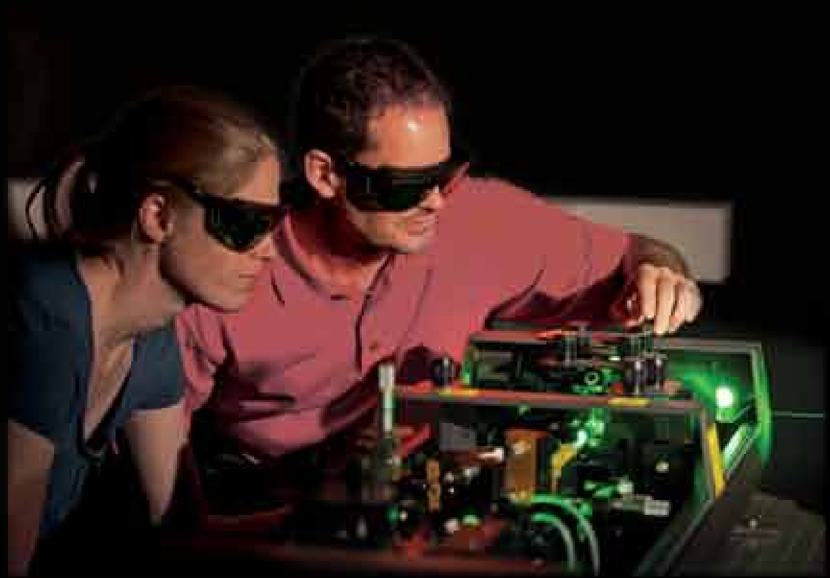
John Ballato seems too young to serve as the resident historian of anything, but today he fills that function for COMSET, which he directs. In 1997, Ballato, a brand-new assistant professor in materials science and engineering, showed up for orientation at Clemson and settled into his seat beside another newcomer, David Carroll from physics. In the course of that session he and Carroll discovered, Ballato says, "a common passion for coffee, beer, and light." (The order of priority changed with the time of day.)

Very soon, Ballato and Carroll were crossing departmental borders, sharing equipment and know-how. "I needed lasers," Ballato says; "Dave knew how to run them better. He needed chemistry; I knew how to do the chemistry better. I would buy something and put it in Dave's lab; he would buy something and put it in my lab, and our students would come back and forth."

They laugh about it today, but at the time their disregard for turf unsettled a few senior colleagues. "We would do," Ballato says, "unheard-of things."

Carroll eventually moved on to direct a research center at Wake Forest University, but not before he and Ballato had accumulated a cohort of like-minded insurgents who also valued coffee, beer, and light. Unlike most people working in optics, this group was not inventing gadgets for the telecommunications industry; they were interested in something more fundamental. They were studying light, yes, but light in relation to materials.

"The nice thing about materials is that you may design them for one thing, but you may be able to tweak them and make another thing," Ballato says. This is why the lab's research in optical materials has led to technologies with diverse applications in



Craig Mahaffey

John Ballato and Ph.D. student Stephanie Morris tweak a high-power laser in a COMSET laboratory.

defense, telecommunications, and medicine—from killing cancer cells to stopping missiles. The team's expertise with materials has given them an edge.

"There's a ton of competition out there," Ballato says, "but the vast majority of these programs have physicists or electrical engineers and don't know anything about materials. So they came to us."

During the 1980s and '90s, telecommunications had claimed the big money and many top optical scientists and engineers. For a time, the military had trouble finding the talent it needed to develop new optics-based hardware. The Clemson team saw an opening and made a name for itself at the Pentagon before the telecommunications boom began to wane.

"The military had an unmet need," Ballato says, "and if you're working with the military, you have to be domestic. So the foreign competition goes away. The military and security niche is still very competitive, but it's easier to get ahead once you're established. We had good people, and we had good contacts, and we were able to jump ahead of lots of other programs."

Glass slippers

Materials science is a field that has sometimes toiled in obscurity. Practically speaking, this makes no sense, because the material we use to build a thing can dictate its performance. The information age, for example, might never have dawned without silicon for making semiconductors, or without silicon's oxide, silica, which mediates the flow of electrons on computer chips and also happens to be the main ingredient in sand and glass. By learning how to purify silica and form it into long, hair-like fibers, scientists and engineers developed the fiber-optic cables that crisscross continents and oceans, connecting billions of people. The Internet dances in slippers of glass.

But the dancing has only begun. If the world's second industrial revolution harnessed the electron, the third may be driven by photons. In every corner of the new economy, from manufacturing to medicine to military weapons, people are grasping the power of light. But applying that power means finding new materials and new ways to use the ones we have.

In this quest, COMSET offers a material advantage. Ballato's own research, for example, was finding ways to improve the optical properties of glass fibers by reducing impurities and by "doping" glass with properties that amplify or tailor light. But in Ballato's view too much of the research funding, public and private, still went elsewhere—toward the devices themselves and not toward the stuff from which the devices were made.

"The money is usually downstream, with the devices," Ballato says. "You're making something you can put on a program manager's desk, press a button and zap a wall."

To compete, COMSET had to zap a few walls. It formed partnerships with institutions and companies that made lasers and other devices. This worked fine, but the money was still leaving Clemson. "We were shipping out well over a million dollars a year," he says. "We went to our administration and said, 'Wouldn't you rather that the money stay here, to create a structure, educate students, and build visibility—all the things research can do?'"

The administration said yes and invested in four new positions for what Ballato calls "devicey" people. And the first of those hires would bring plenty of zap.

A bigger pipe

When Liang Dong was a boy in China, he knew that he wanted to do something technical when he grew up. Like every little boy, he played in the sunshine and read by the light of a lamp, but he never imagined that he would one day take up the light in his hands, concentrate it, guide it, and send it blazing with such force that it could blast through an incoming missile, destroying it in flight. Now it's his job to help make that possible. And he begins with one deceptively simple material: glass.

The skinny glass threads in a fiber-optic cable are adept at piping photons for thousands of miles to beam our emails and spreadsheets and viral videos around the globe. But if you want a

Whether the target is a cancer cell that doesn't move or a missile traveling several thousand miles an hour, the goal is the same: Destroy the threat and only the threat.

Coming to terms...

In these stories, we'll go easy on technical terms, but you may find an unfamiliar word or two. A few definitions:

Nanoscience, nanoparticles. A nanometer is one millionth of a meter, useful for measuring stuff as small as atoms and molecules. So any time you see the prefix "nano," think very, very small.

Micron. This term is short for micrometer, one thousandth of a meter, useful for measuring things larger than atoms but too small to see. The smallest particle visible to the naked eye is about forty microns in diameter.

Optics and photonics. Optics is a branch of physics that studies the properties of light. Photonics is a science of light emphasizing photons, light's elementary particles and energy carriers. While optics and photonics are closely related, scientists draw distinctions between them. For our purposes in these stories, both terms refer to work involving light.

fiber laser strong enough to stop a missile, you will need a bigger pipe—one that can carry not a few watts but thousands.

For a half century, the U.S. Department of Defense (DoD) has been searching for that kind of power. But conventional lasers relied on mirrors and crystals, and bulky mechanical parts that had to be perfectly aligned for the laser to work. This was not a technology you could mount in a spacecraft or fighter jet. The advent of fiber lasers, coincidentally by Ballato's former advisor and frequent collaborator, Elias Snitzer, suggested a way to jettison some hardware and simplify the system. In a fiber laser, a small "pump" converts electricity into concentrated light and sends it down a fiber that can guide the beam towards a target. The fiber laser's slender geometry allows excess heat to move quickly to surface and away—a key to high-power operation.

During the 2000s, factories began using beefed-up fiber lasers as machining tools, slicing and piercing metal at high speed, and the tools were often mounted several feet or yards away, never touching the materials.

In his corporate job making optical fibers, Liang Dong could see that the DoD wanted something that closely resembled what industry already possessed: a remote machining operation. The time seemed right to leave industry and go after the long-elusive laser. So two years ago Dong joined the faculty in electrical and computer engineering at Clemson, built a team at COMSET, and went to work on a new generation of optical fibers.

"For me, this is a technical challenge that is way beyond what the commercial world is looking for," Dong says. It is, however, exactly what the DoD is looking for: a powerful, long-range laser that strikes with the speed of light.

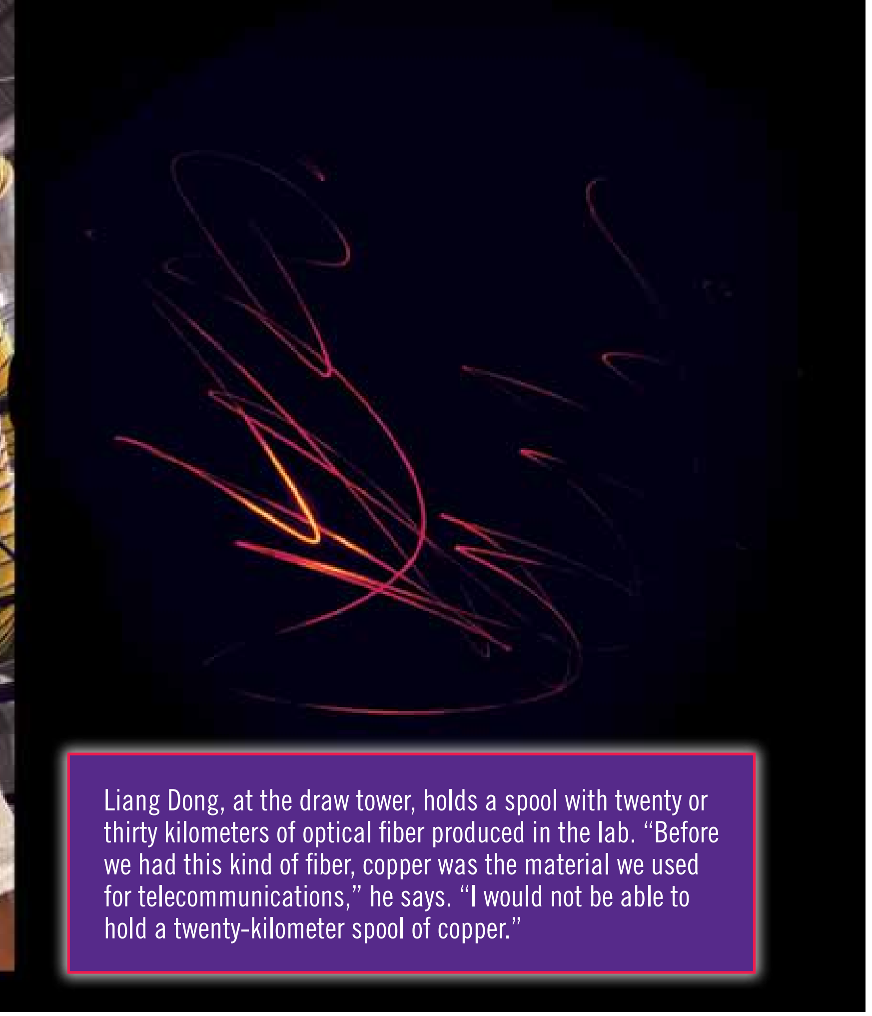
Pulling matter apart

To understand how such a laser would work, it helps to recall a bit of basic physics. Light is electromagnetic radiation, like radio waves or microwaves, but its waves wiggle faster. A laser beam is highly concentrated light. When you direct that light against a surface, its electromagnetic field can rip apart the electrons that bind matter together. This is called ablation, and it is the same process that reshapes a human cornea during laser eye surgery.

In combat, lasers mounted on military platforms could intercept and destroy rocket-propelled grenades and heat-seeking missiles. But the potential for using lasers is even greater in space-based missile-defense systems, Dong says, because space has no atmosphere to interfere with the beam. A laser beam could travel thousands of miles and open a hole in a missile traveling several thousand miles an hour.

But ablation, which would make the laser a devastating weapon, also makes a big fiber laser hard to build. As the power level rises, photons begin to pull silica's electrons out of orbit, degrading the light. And various other bugaboos, including sound waves, disturb the flow. Dong had to solve these problems, if he hoped to succeed.

Dong has an instinct for isolating, with laser-like precision, a



Liang Dong, at the draw tower, holds a spool with twenty or thirty kilometers of optical fiber produced in the lab. “Before we had this kind of fiber, copper was the material we used for telecommunications,” he says. “I would not be able to hold a twenty-kilometer spool of copper.”

Neil Caudle

technology’s core issue. As he saw it, the fiber itself was the core technology, as the CPU was the core of a computer. Everything else was peripheral. The power supply, the pump, the hardware for mounting and firing—DoD and its contractors could handle all of that. The limiting factor was fiber. “There’s a lot of people working on lasers in the DoD labs, and they are limited by the fiber they have,” Dong says. “If this works for them, they can deliver a lot more power. So that’s the goal.”

No single fiber could handle the power a weapon requires, and neither could the simple concentric patterns of fibers the telecom industry used in its bundles. Dong began to design experimental bundles with various types and sizes of carefully crafted glass rods to merge multiple channels to create a uniform beam. This was a very different problem from what he’d faced in telecommunications.

“We’re not making kilometers of this stuff,” Dong says. “We’ll just be using a few meters. That means we can have a much larger core size while keeping the beam quality good.”

On his computer, Dong shows me the kind of pattern he prizes in a laser beam: an intense but uniform glow at the center, dimming neatly at the margins. The beam of light itself shows a radiant simplicity, but Dong’s team cannot achieve that simplicity without technical complexity and near-perfect clarity—in the work and in the glass. The fibers he makes are so different from the standard that he had to create a completely different fabrication process for it. “You cannot get this kind of fiber commercially anywhere,” he says. “In fact, this is the only place in the world where we can make the kind of glass we want.”

Knobs to tweak

For Dong, the process of creating new optical fiber must be managed as a whole, with each step informing the rest. “We have people looking at designs; we have people looking at material and a whole new process for making the fiber itself and pulling the different glass structures together. And the testing of those fibers is also very different, because the guiding principles are different from commercial fibers.”

To make new fibers, the team uses a twenty-foot industrial monster—a draw tower—available in only three other U.S. university labs, though none is like the one at Clemson. With three interchangeable furnaces capable of up to four thousand degrees Fahrenheit, the tower can produce a continuous thread of highly purified glass.

Purity is key, Dong says, because even tiny flaws would compromise the light. “We start with a liquid and purify it multiple times, but even with those steps you still get parts per million of impurities, and we really need to keep those impurities to the parts-per-billion level,” Dong says. In a final step analogous to distilling water, the team heats the liquid and captures its purified vapor to make the glass that ultimately gets drawn in the tower.

The biggest fibers require a slow buildup of glass. In a room near the draw tower, the team uses a high-tech lathe to deposit layer after layer of material from gases and liquids bubbling into the device. The resulting concentric rings of glass confine and guide light in the fiber.

Dong shows me one of the team’s schematic designs, a sectional diagram with a pattern that seems organic, like the specialized cells in the stem of a plant. The center will contain a glass doped with rare earth ions that intensify light. Another glass in the array is black, an anti-guide from which no light can escape.

“These are all derived from silica glass, but with small alterations that enable us to do what we need to do,” Dong says. “So we do have, on the materials side, some knobs we can tweak.”

The next wave

To create a new design, Dong trusts his experience and the principles he has internalized over many years. In the 1980s when in England working on his Ph.D., he studied the early development of optical fibers for telecommunications, which in those days meant landlines for telephones. “A professor told me, ‘This is a dead end. Soon everybody will be able to talk on the telephone twenty-four hours a day, and one single fiber will carry all of that information for the whole country.’” But then the Internet came along and changed the whole picture. Now the demand for bandwidth is so high that it pushes the limits of a capacity that once seemed almost unlimited.

Today, Dong is working once again in the early surge of fiber’s next big wave. “My experience has been both in fabrication and design, and the way I see it the two have to interact closely,” he says. “So when I’m looking at a design I am thinking about a range of things: Can this be made? Can this be used practically? Can this be made easily with the tolerances we need? Are there simpler ways of doing this? Once we have a concept, that’s when we go to a computer and say, ‘Okay, how well will this work?’ And the computer can help us identify the precise parameters.”

Neil Caudle

Graduate student Guangcheng Gu assembles a large fiber laser using a pattern designed by Liang Dong.

For now, Dong’s team will design, fabricate, and test fiber lasers up to several hundred watts of power, and the prototypes will go to DoD labs and defense contractors such as Northrup Grumman. After that, the next step will be to make a much larger core capable of handling kilowatts of power. Dong is already conducting theoretical studies to sort out the baffling physics at that level of power. U.S. military labs will do the testing of the kilowatt-size lasers, when the time comes.

Dong says that no other organization, in industry or academia, offered him the tools and opportunity to pull all of this together in one place—the theory, design, fabrication, and testing of very high-power fiber lasers. “We’ve gone where nobody else has been,” he says. “It’s not the typical university approach, but if you can get this to work, that gives you a very strong competitive advantage, because it would be very difficult for someone else to duplicate this whole chain of technology.”

As a natural teacher who rewards each question with a patient, thoughtful answer, Dong wants young people to know just how bright the future is, not just at COMSET, but in optics and photonics, fields in which demand for talent far exceeds supply, in which many of the best discoveries are yet to be made. “We have these technologies,” he says, “and we know some of what they can do, but we don’t yet know everything they can do. There are many opportunities, and many new problems to solve.”

Not just washing beakers

Which brings us back to students. Maeve Budi continued to work in Thompson Mefford’s lab in the AMRL until her apartment lease ran out at the end of May. By then the team had solved the mystery of the suspiciously perfect results, turning up an error in the data. “We ran the procedure again and managed to attach the phosphate just fine,” Budi says. “I would like to have done this multiple times, to make sure, but I ran out of time. We’ve set it up so that Melissa or someone else can continue the work.”

Budi and Stimson, who have both been tour guides for incoming freshman interested in engineering, urge new students to give research a try. “When I first came to the lab, I thought I’d be washing the beakers,” Budi says. “I was really surprised when I was actually handed things to do, and told, ‘All right, I want you to make this.’ Not only can you figure out a problem and solve it; you can decide what *you* think is a problem. That is very rewarding.”

John Ballato is a professor of materials science and engineering and a professor of electrical and computer engineering in the College of Engineering and Science. He is also director of the Center for Optical Materials Science and Engineering Technologies (COMSET), which is a South Carolina Research Center of Economic Excellence. Liang Dong is an associate professor of electrical and computer engineering.

The Office of Technology Transfer in the Clemson University Research Foundation has filed patent applications for several of John Ballato’s inventions and for a Liang Dong design of a large-core, high-power laser.

For more than a glimpse…

For now, we can introduce you to only a few of the people at COMSET, and we’ll have to save a number of researchers for issues to come. For a list of COMSET faculty members and descriptions of their work, please go to:

www.clemson.edu/centers-institutes/COMSET/faculty/

well-dressed particles

Thompson Mefford's group gets down and dirty with rust. They like it that way.

As any teenager might guess, what a particle wears affects its game. Thompson Mefford's lab turns out designer wardrobes for nanoparticles that can, for instance, target a receptor site or smuggle things inside a cell. Starting with what Mefford calls "glorified rust," he and his group of five graduate students and eight undergraduate students create iron oxide nanoparticles as small as molecules—cubes and rods and spheres and more—and dress them up for work.

"We're a materials chemistry group in hiding," Mefford says.

Why would a chemistry group hole up in an optics lab? Mefford needs advanced optics to track and analyze the particles he makes, and many new technologies marry particles with optics. Mefford's lab, for example, uses nanoparticles to form a diffraction grating—a patterned surface that splits light into several beams heading in different directions. Mefford is excited about a grant he received from the National Science Foundation to develop methods for making various optical materials on an industrial scale.

Mefford's knack for creating designer particles has made him lots of friends outside his field, which is materials science and engineering. Biologists use his nanoparticles to test treatments for Legionnaire's disease, clean away biofilms, and infiltrate bacteria (see the story on page 10). A physicist programs an old-style hard disk and bathes its surface with Mefford's nanoparticles, which are attracted to the magnetic poles; the particles and program can then be fixed in a polymer film and peeled away like adhesive tape—a step toward computing with flexible fabrics. And a collaboration with Clemson's Warren E. Lasch Conservation Center (see the story on page 24) has produced a method for etching the silica surface of computer chips or photovoltaic cells with hot, mildly caustic water instead of the usual method, which applies very hazardous hydrofluoric acid.

With the heat of a fever

But the bulk of Mefford's work is biomedical, and his group devotes much of its attention to killing tumor cells with heat, imitating the natural fevers that fight infections. German clinics have already begun to test an early version of this technique in human patients, but the nanoparticles in those trials are rudimentary, Mefford says, and the technology faces serious hurdles. His lab is refining the particles to make them more effective, so that fewer are needed.

Nanoparticles are flowing into medicine from multiple directions and are already widely used as magnetic agents for high-contrast images in MRI diagnostics. Steven Saville, a Ph.D. student in Mefford's lab, has discovered that the contrast agents sometimes begin to "crosstalk," interacting in ways that suppress the contrast. By changing the particles' coating, he can manage the conversation.

All such studies require a steady supply of nanoparticles, which are not easy to make or dispense. This year, undergraduate students on a Creative Inquiry team designed and built a plumbing system that pipes nanoparticles through a stainless steel coil to a high-tech faucet, where researchers can tap them at will. "Some people can't believe that undergraduates could make something like this," Mefford says. "They can."

The idea of free-flowing nanoparticles—even those confined to a lab—can worry those of us who wonder how nanoparticles might threaten our health or the environment. The truth is, Mefford says, we do not know what the risks might be. He and two colleagues—Chris Kitchens in chemical engineering and Brian Powell in environmental engineering—are studying the fate of various nanoparticles in soil, using a device called a lysimeter. Powell has used the same device to track the radionuclides associated with radioactivity (see "After Fukushima," Spring 2012 *Glimpse*).

"Our hypothesis is that the surface chemistry of the particles basically dictates where these things go," Mefford says.

If that's the case, we can ask his chemistry group in hiding to tell us what a responsible nanoparticle should and should not wear.

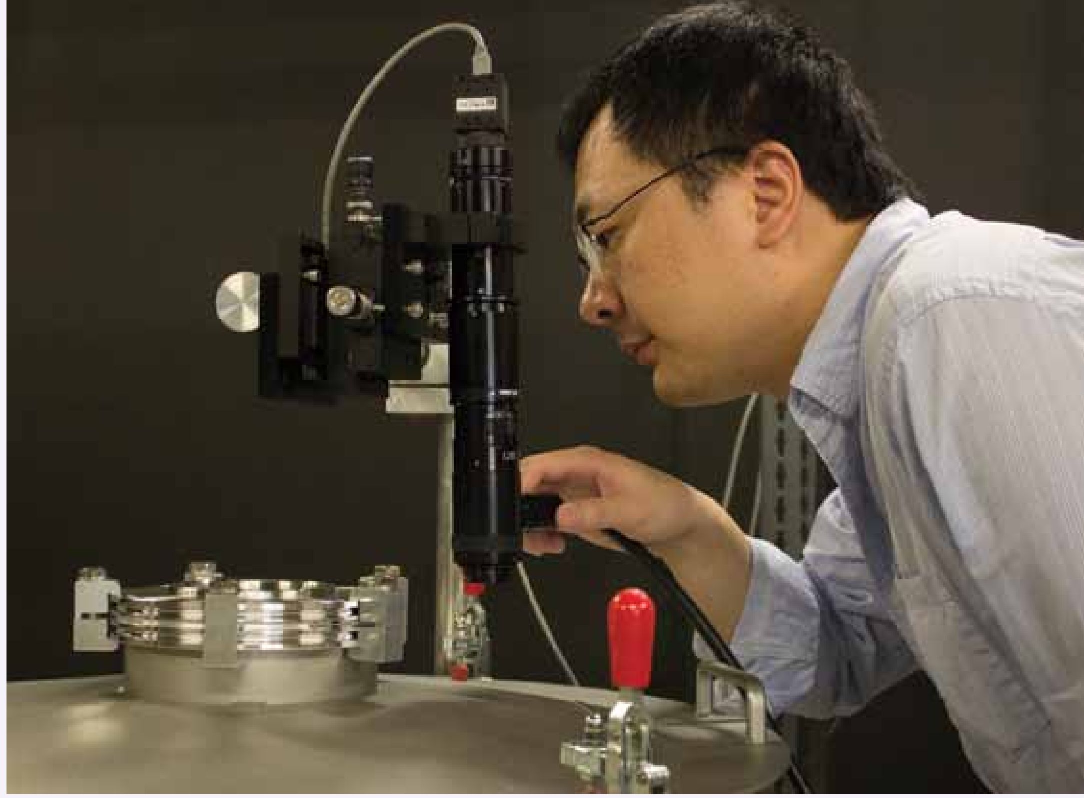
O. Thompson Mefford is an assistant professor of materials science and engineering in the College of Engineering and Science.

nanoparticles and the environment

One of the big questions in nanoscience is: What happens to nanoparticles released into the environment? Thompson Mefford (left) and Brian Powell have been tracking the movement of several kinds of nanoparticles by using containers of natural soil exposed to weather. Early results indicate that the coating on a particle influences its movement. **Below:** Samples await analysis.

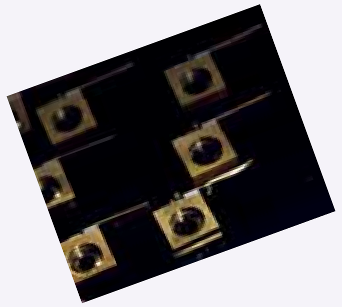
Neil Caudle

Neil Caudle



how to stop an atom

To make his cool tools, Lin Zhu thinks small as an atom and big as the reaches of space.



In his quest for tiny devices, Lin Zhu explores ways to control an atom by freezing it, not with cold but with lasers. **Left:** Zhu's diode lasers protrude like tiny needles from their mounting hardware. The lasers are about 1 millimeter long and 0.1 millimeter thick.

Sooner or later, technology's pursuit of ever-smaller devices leads it down the rabbit hole and into the realm of quantum mechanics, where the hot dance of atoms makes assembling tiny structures iffy. Theoretically, you could stop the atoms cold at absolute zero (minus 459.67 degrees Fahrenheit) and configure them as needed, but doing so appears to be a practical impossibility. Even if you could a find a freezer with that kind of chilling power, moving anything around inside it would excite a few atoms and set them to dancing again.

Oddly enough, the solution may turn out to be lasers, which most of us associate with heat, not cold. In the right conditions, an atom, like a deer in the headlights, will freeze in the beam of a laser. This is a virtual freezing—the effect of absolute zero without its big chill. And the use for such a thing? Lin Zhu imagines, for example, the tiniest of engineered bridges, a nanobridge, holding a single photon. Bridges can also become switches, open or closed—the makings of a circuit.

Zhu, a quiet, unassuming man, is reluctant to talk about this part of his work, because it involves fundamental science too theoretical to have an obvious application, at the moment. He does not expect us to follow him down the rabbit hole. But he keeps an eye on the quantum realm as he develops his devices, which are mostly diode lasers.

Watch where you shine that thing.

If you've ever used a laser pointer to tease the cat or highlight a bit of data in your slide presentation, you aimed a laser diode, a compact and highly efficient technology for converting electricity into light. The typical laser pointer is rated at about five milliwatts, five one-thousandths of a watt. But it is potent enough, if flashed into the sky, to distract a pilot, which is against the law.

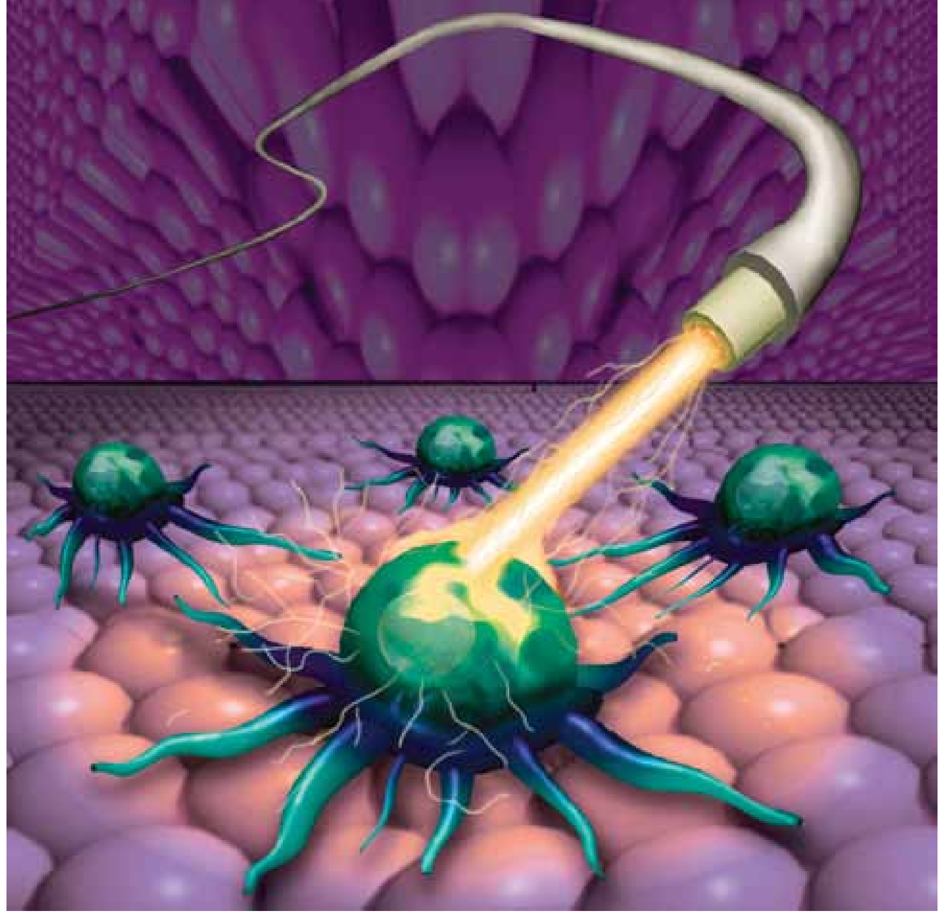
Zhu is working on diode laser arrays that could reach several watts for a single emitter or up to two hundred for an array—intensely bright lasers strong enough to pump other lasers, cut metal, power a laser radar system, or beam information from satellites in space. To approach that level of intensity, Zhu assembles several emitters, each about the diameter of a human hair, onto a tiny bar and merges their beams into one. He also battles one of the diode laser's most notorious limitations: the loss of beam quality as the power goes up.

"At high power the beam quality is not very good because there are too many modes being generated inside the optical cavity of the laser," Zhu says. The modes are diffracted waves of energy inside the cavity, and they can bounce around out of control. Engineers have tried to correct the problem by using lenses to focus the light as it comes from the diode. Zhu hopes to eliminate the need for a lens by improving the optical cavity itself. He and his students design and fabricate gratings—zigzagged microstructures designed to corner and control the diffractions.

But increasing the power of diode lasers is not Zhu's only goal. He is also finding ways to build biodetectors. Imagine a device, perhaps built into your cell phone, that could alert you to contaminants wherever you went. People already use lasers for biodetection in laboratories, where the sweep of light through a sample of liquid creates wavelengths a sensor can read like a fingerprint. But the setup is bulky, because the lasers are separate from the sample and detector.

"What we're trying to do is to integrate the laser, the sensor, and the detector on a single small chip," Zhu says. "This would let you take the detector almost anywhere." In this case, the technology would be measured not so much by its wattage as by the smallest possible space required to hold a big idea.

Lin Zhu is the Warren Owen Assistant Professor of Electrical and Computer Engineering in the College of Engineering and Science. His research is funded primarily by the Department of Defense and by the National Science Foundation.



Using a hollow optical fiber to direct microplasma, Sung-O Kim's lab demonstrated the ability to kill an individual cancer cell. (Illustration first published in *Small,* July 19, 2010, Wiley-VCH.)

aiming plasmas at cancer

The hottest thing in medical science may be the gas-like stuff we see in stars.

Sung-O Kim came to COMSET to work on displays and wound up taking aim at cancer.

Not that cancer is the lab's only target. Kim and his students use plasmas to make all sorts of things. They make plasma thin films to sterilize wounds or medical equipment, or to shield the densely packed circuits on microchips. They make nanomaterials for flexible and transparent displays, solar cells, and batteries. And they conduct research in plasma physics, including plasma jet arrays that work under atmospheric pressure, eliminating the need for costly vacuum chambers.

But nothing grabs people's attention like a brand-new therapy for cancer. And Sung-O Kim is almost there.

Before we talk specifics, let's consider what a plasma is—the gas-like state of matter we see in stars or neon signs. Scientists and engineers make plasmas by heating a gas to ionize its molecules, or by exposing it to a strong electromagnetic field. A plasma television screen uses small cells of ionized gas to illuminate the image.

So the idea is to take that glowing, gas-like stuff, pipe it down a slender tube, and kill a tumor with it. Doctors have already used such plasmas on the outside of the body, to treat skin cancers. But Kim plans to take the treatment deeper.

"We want to develop an endoscopic plasma device using optical fibers," he says.

Scoping out a cancer cell

Endoscopes, which have tubes, lights, and lenses designed to probe around inside us, are already useful for examining organs and bodily cavities. But Kim's endoscope would not just find the cancer cells; it would shut them down.

In the lab, Kim has shown that he can build a plasma device with such precision that it can snuff a solitary cancer cell—a feat that in 2010 and 2011 earned him the cover of *Small*, a leading journal in nanoscience. That sort of precision is possible because Kim's lab has developed very slender tubes—some with an inner diameter of only four microns, much smaller than a cancer cell. In most cases, a surgeon would want to treat clusters of cells, and Kim's device could do that too, he says.

"Sometimes in cancer treatment, doctors cannot use open surgery," Kim says. "They could use our endoscopic device to treat the specific place where a tumor has grown."

A similar technology has been tried in Europe, but the endoscope tubes there have been made of polymers that could degrade in contact with plasmas, Kim says. In fact, plasmas are very good at taking polymers apart. At COMSET Kim found ready access to glass-making equipment and expertise, and his collaborator, John Ballato, and he began to fabricate flexible tubing made of quartz glass, which Kim says is a much safer, more stable material for use in the body.

Kim's collaborators at the Medical University of South Carolina have tested his technique in cell cultures and laboratory mice, and the team is working with a company in South Carolina to fabricate the endoscope for cancer treatments. Kim expects to see a device on the market "very soon," he says.

Flipping a switch

Meanwhile, he and his collaborators have plenty of science to do. Because plasmas themselves are complex—a swarm of ions, electrons, photons, and phonons with various electrical and magnetic properties plus heat—it is difficult to understand them completely, especially when they interact with the complex biology of a cancer cell.

"We don't know exactly why the plasma is killing cancers," Kim says. "But we do know the most important thing: The plasma is initiating apoptosis."

Apoptosis, also known as programmed cell death, is a normal process in cells that tells them when to die. When apoptosis fails, cancer spreads. Conventional chemotherapy kills cancer cells but usually inflicts collateral damage. Somehow, the plasma treatment flips a switch that tells a cancer cell to die in a couple of days but leaves normal cells alive.

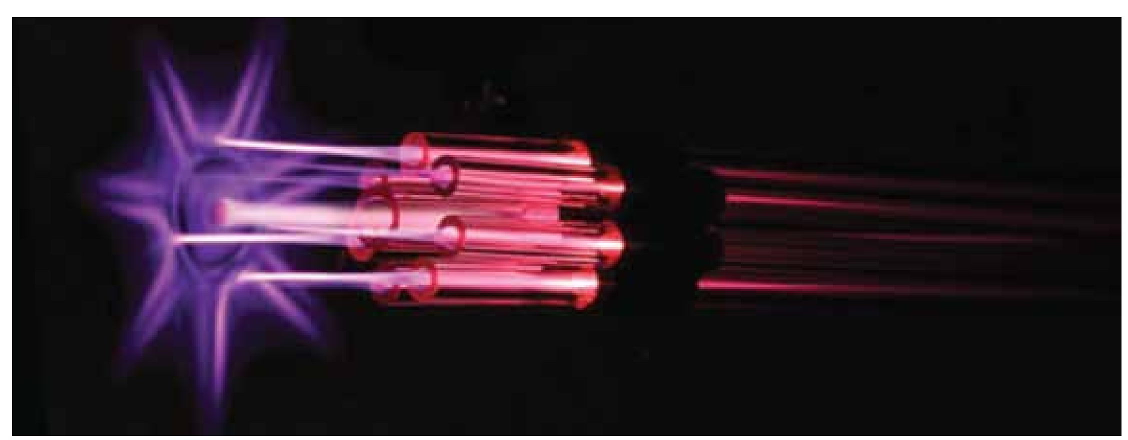
"That's why we don't see any side effects from the plasma right now," Kim says; "it's based on apoptosis."

At Clemson and other places, recent strides in plasma medicine and nanoscience are making people wonder where to look for the next generation of medical breakthroughs. Are new drugs the answer, or will optics and materials science yield a better set of tools? Could the next big breakthrough in cancer therapy really come from Clemson?

Kim has thought about this question and the answer makes him smile. "Yes," he says, "it could."

Sung-O Kim is an assistant professor in the Holcombe Department of Electrical and Computer Engineering in the College of Engineering and Science. His research is funded primarily by Samsung Advanced Institute of Technology and South Carolina Bioengineering Alliance.

The Office of Technology Transfer has filed a patent application for Sung-O Kim's microplasma jet devices for biomedical applications.



Working with John Ballato, Kim's team overcame the limits of atmospheric plasmas by coupling several jets into one powerful discharge.

(Image first published in *Plasma Processes and Polymers,* March 2012, Wiley-VCH.)

No, we don't make eyeglasses.

This is what Eric Johnson has to explain, outside of work. But what he does make, with his team of savvy students, takes vision.

If you look across the country, what's one of our biggest challenges?" Eric Johnson asks. "We don't make things anymore." Johnson would like to help reverse that trend. He and his students make things. They design and build the sort of devices that could give homegrown industries a fighting chance against foreign competition. Infrared lasers. Silica mirrors for high-precision optics. Imaging systems. Optical transceivers that transmit and receive data. Etched glass for solar cells and semiconductors. Devices so tiny they could fit on a chip in your cell phone.

The optics industry, as Johnson sees it, sits on a mother lode of untapped potential. But the very diversity of materials and possible applications that gives optics its vast potential also complicates its industrial development. Manufacturers have trouble sorting out their options, and investors don't know where to place their bets. As a result, the optics industry lags behind the electronics industry by a couple of decades, Johnson says.

"With the integrated-circuit industry you have silicon," he says. "Everything is built around silicon. The industry can introduce one new material at a time, and they can all adopt it, learn how to apply it to the silicon, and move forward. So it's very controlled in terms of the options you have for integration. But photonics is much more diverse—it's all over the place."

In conventional integrated circuits, information flows as electrical current—electrons—from source to detector through channels on a chip. Photons move faster than electrons but are harder to channel along a circuitous route from point *A* to point *B*. So integrating optics with electronics in a chip or tiny device is a challenge.

For LEDs, the wait goes on.

Consider, for example, the case of LEDs. For years, people have predicted that LEDs—light-emitting diodes—would replace incandescent light bulbs. LEDs save energy, and the lights themselves can be intelligent devices, communicating and following instructions. But LEDs have not replaced the incandescent light, and the reason, Johnson says, is cost. "How do you manufacture the LEDs," he asks, "and how do you integrate them at a cost that's competitive with an incandescent bulb?"

Johnson raises a similar question about one of the world's newest energy hogs: data centers, which handle everything from email to banking transactions. According to a report in the *New York Times* (July 31, 2011), data centers now account for between 1.7 and 2.2 percent of all electricity consumed in the U.S., and demand is growing. Worldwide, energy use in data centers rose 56 percent from 2005 to 2010.

Most of that power goes into routing information from one system to another, using wires and electrical devices, Johnson says. Light pipes and other optical equipment could route the information faster using far less energy, and Johnson's lab is developing devices that would help do that. But for data routing, as with LEDs and hundreds of other technologies, integrating optics and electronics is a big hurdle. Crossing it will require highly skilled leaders and workers—people savvy with math, physics, chemistry, engineering, and the nuts-and-bolts practicality of manufacturing.

"This is the biggest demand in industry today," Johnson says, "people who can cross those disciplinary boundaries and understand the technologies." Those people, he says, are the real product of his lab.

Fortunately, he says, students like to make things. "They see the value in it. They understand connecting the theory with the design and the fabrication—that's where you'll get the real return on investment for research."

Eric Johnson is a professor of electrical and computer engineering in the College of Engineering and Science. He is also the PalmettoNet Endowed Chair in Optoelectronics and head of the South Carolina SmartState Center of Economic Excellence in Optoelectronics. Private industry and the Department of Defense sponsor much of his research.

a gear head goes bio

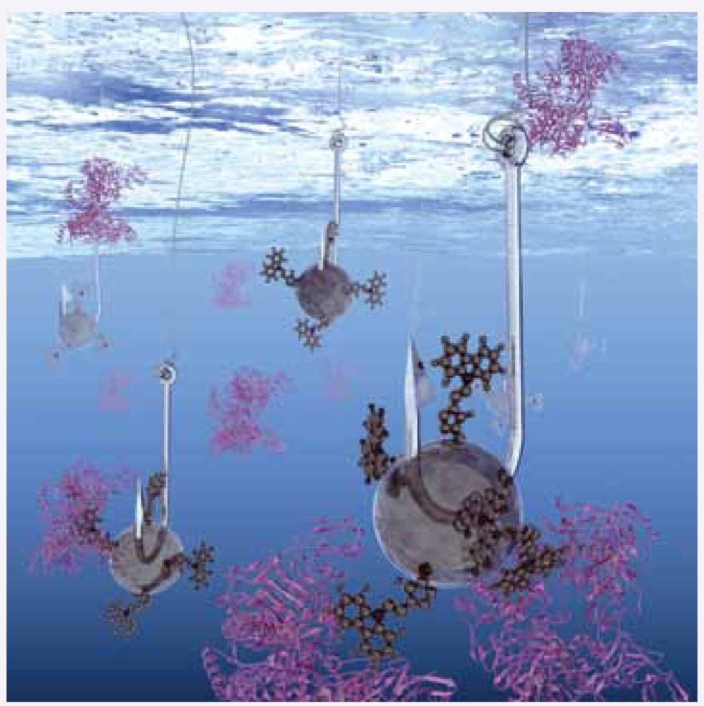
Arming particles for precision strikes against cancer.

His was not the usual path to a job fighting cancer.

Stephen Foulger was a California dude, a surfer and gear head who built motorcycles. He went to college at Santa Barbara to surf, studied English (it bored him), worked in a machine shop, and wandered into engineering (it didn't bore him). That led to MIT for grad school, polymer physics, and an R&D job with Pirelli, the Italian tire maker and European leader in fiber optics. He came to Clemson because his wife was disinclined to pack two babies off to Italy.

The story of Foulger's improbable ride from motorcycle mechanics to optics to cancer research is, in some ways, a fable for how science works these days. Say goodbye to pigeonholed specialists laboring in isolation. Solving big problems in science generally requires teams with many working parts. And, as any good surfer knows, you can't ride the same wave forever. Why would you want to?

The wave Foulger rides at the moment pushes his limits. For one thing, he has to learn the alien nomenclature of cancer genetics. And while he's a darn good mechanic when it comes to tuning up a polymer, his new line of work involves human biology. Don't tell the bio guys, but Foulger wraps his head around proteins by thinking of them as polymers, which oversimplifies but captures the gist: Polymers and proteins are both large molecules whose parts are connected by chemical bonds. As medical science drills down to the fundamental business of human cells, what it finds is a lot of basic physics, chemistry, and math. And that's the common ground on which Foulger meets people like Michael Sehorn, his collaborator from genetics and biochemistry at Clemson.



Nanofishing

Work in Stephen Foulger's lab, in collaboration with Michael Sehorn, was featured on the cover of the journal *Small* in July. The article describes a method for fishing a single type of enzyme out of a complex mixture by "baiting" a nanoparticle, the metaphor behind the cover illustration. An ability to isolate and manage proteins is a key step in using nanoparticles to diagnose and treat disease.

Stealthy particles

With help from Sehorn and others, Foulger figures out how to arm nanoparticles for seek-and-destroy missions deep inside the human body. He is concocting stealthy particles that can elude the body's efforts to expel them, so they can roam around long enough to connect with receptors or proteins common in cancer cells. With his knowledge of optics and chromophores (the parts of molecules responsible for color), Foulger can equip those particles to find their targets and switch on a tiny, biochemical light that means cancer.

"Take pancreatic cancer, for instance," Foulger says. "If you don't catch it right away, it has a huge death rate. So if you could do periodic imaging of the body, and you could see small speckles of light around the pancreas, you'd say, okay, this person has cancer. That's the approach we're taking."

Meanwhile, he's working on survivin.

It sounds like the title for a Grateful Dead song, but survivin is actually the name of a protein that helps keep cancer cells alive by defeating the normal process of apoptosis, which tells cells when to die. Stop survivin, and chemotherapy drugs will work better. And if you can deliver those drugs directly to the cancer by loading them onto particles, you'll have a lot less collateral damage, because the drugs won't slaughter the good cells along with the bad.

"Chemotherapy is a brutal, medieval way of killing something," Foulger says. "It basically just kills cells. And cancer cells have developed ways to prevent that. So if you get a chemotherapy drug that starts killing the cells, anti-apoptosis proteins like survivin can go in there and actually undo or slow the damage to the cell you've tried to kill with the drug. The idea is to make a particle that binds up survivin and then releases a chemotherapy drug. You'd get a synergy going on that would be really effective when it comes to killing cancer cells."

Foulger came to cancer research via work on colloids, substances microscopically dispersed in other substances (acrylic polymers in paint are one example). Because some kinds of colloids showed promise in imaging systems for cancer detection, the National Institutes of Health began asking Foulger to review medical research involving colloids. In the process, he realized that his work with chromophores could have an anti-cancer application—for both diagnosis and treatment.

"So I thought, okay, I'll give it a whirl," he says. And he did.

Stephen Foulger is the Gregg-Graniteville Endowed Chair and Professor of Materials Science and Engineering in the College of Engineering and Science. Funding for his work is primarily from the Defense Advanced Research Projects Agency (DARPA) and the National Science Foundation. Michael Sehorn is an assistant professor of genetics and biochemistry in the College of Agriculture, Forestry, and Life Sciences.

Genetics and the coat of many colors

Leigh Anne Clark helps dog breeders avoid some pitfalls of breeding for beauty.

by Peter Kent

Patrick Wright

Geneticist Leigh Anne Clark has identified the genetic basis for the appealing blue merle coat pattern on dogs such as Daisy, who embodies the breed standards of the rough collie. Clark's work in canine genetics also has clarified links between health and heredity in a number of dog breeds. Daisy is co-owned by Meredith Holliday and Nancy E. Reid, the daughter of former Clemson President R. C. Edwards.

The blue merle walks into the room, her long, luxurious coat following the geography of her body like contour lines on a hiking map. Everyone gazes at her, reaches to touch her, wants to be her friend. Her bright eyes, attentive ears, and slender snout are all part of the perfectly portioned package that confirms you are looking at a rough-coated collie. The splashes of grey on black present the distinctive and desirable blue merle coat pattern.

Leigh Anne Clark appreciates Daisy's looks, but Clark knows beauty is more than skin deep. It is coded in DNA, chromosomes, genes dominant and recessive, and expressed by the crosses that occur from sexual reproduction—the offspring of meiosis. Clark is a geneticist. If dogs are our BFFs, she is theirs, researching genetic waypoints that can improve canine health and also our own.

"I began learning about dog genetics when I got my first dog, Lucky—a male Shetland sheepdog—from a breeder, who became a friend and teacher," Clark says. "I thought about becoming a vet but realized that I didn't like treating animals as much as I liked figuring out what was wrong with them."

Clark builds relationships between scientists doing genetics research in labs and breeders doing fieldwork by breeding dogs.

"My laboratory studies canine inherited diseases to improve the health and quality of life for dogs and uses the dog as a model to understand the genetics underlying mammalian hereditary diseases," Clark says. "A major goal for us is to develop commercially available tests for early detection of disease, helping breeders eliminate affected and carrier dogs from breeding programs."

Clark specializes in canine coat pigmentation patterns, the colors and markings of dog coats. "I am interested in merle, which is a coat pattern, not a color," she says. "It is characterized by patches of full pigment on a dilute background."

As a teenager working for her friend the Shetland sheepdog breeder, Clark had learned about breeding for coat color—bi-color, tri-color, and merles. As a researcher she wondered if anyone had found the gene that causes merles.

"At least one researcher had looked, but nobody had found it," Clark says. Nobody, that is, until Clark and her colleagues did.

Merle as beauty mark

Imagine a solid color dog—usually black or brown—splashed with bleach. The result would be lighter color patches, often called blue by dog fanciers, on the base coat. Many popular breeds have merle patterning—Australian shepherds, coolies, Shetland sheepdogs, collies, Cardigan Welsh corgis (the ones with tails), Pyrenean shepherds, and Catahoula leopard dogs. Dachshund breeders call merle patterning "dappling." And the merle gene, Clark says, is involved in creating the harlequin pattern on Great Danes.

Many dog owners see merle as a beauty mark, distinctive and random, and they are willing to pay more for merle dogs. Uneducated or unscrupulous breeders mistakenly think that crossing merles with merles will increase the likelihood of a litter of merles. This approach may cause more pain than profit.

Responsible dog breeders certainly want to sell pups, but not at the price of a dog's health. They avoid merle-to-merle matings, which can produce double merles—those receiving the dominant variation from both parents. Double merles are mostly white and can have defects in hearing and vision.

Unfortunately some merles are hard to detect.

"A dog can be a 'cryptic' merle, which shows only small merle patches or no pattern at all and looks like a non-merle," Clark says. "If a cryptic merle is mated with an another merle, one in four of the puppies will be a double merle and at risk for deafness and blindness."

Double merles have been compared with humans who have Waardenburg Syndrome 2. Both groups have a genetic disorder that hampers the growth of pigment cells, which play a role in development of eye shape and color and the nerve endings in the inner ear. The results often are distinctive soft blue eyes and deafness. In humans, a stark white forelock also can be the calling card of the syndrome.

"There's no cure for Waardenburg syndrome, but the work will help researchers identify the genetics guiding it, which can alert genetic counselors and dog breeders to look for the problem during DNA screening," Clark says.

Merle figures into another topic of Clark's research, the harlequin pattern found on Great Danes. The pattern is the bold black-and-white look that is accepted as part of the breed standard, which includes black, brown, and brindle coloring as well.

The Great Dane Charitable Trust has funded her work to identify genetic mechanisms that produce the harlequin pattern. She has worked on the harlequin genetic factor since 2005.

"All harlequins are merles, but they are more than merle," says Clark. "There's a separate gene for harlequin. It is a dominant modifier of merle that removes the dilute pigment, leaving the background white."

In other words, the harlequin gene acts as a stronger bleaching agent, eliminating the merle's light bleach spots on the base coat, resulting in white base-coat spots.

A genetic test

Clark is the only researcher doing this work, which involves finding the gene or group of genes that result in the black-and-white pattern. It's important because, like producing merles in a litter, careful breeding is vital. If done without knowing the DNA portrait of the breeding dogs, the result can be lethal; puppies inheriting the harlequin gene from both parents die in the womb. Clark's research has given breeders a genetic test to identify dogs carrying the harlequin factor.

"It's a complicated pathway," Clark says, adding that the research may have a human link, too, because the responsible gene is part of a biological process involved in Parkinson's and Alzheimer's diseases.

Other dog breeds have found places in Clark's lab. She is working on a skin and muscle inflammatory disease—dermatomyositis—that affects collies and Shetland sheepdogs. It is also a painful and disfiguring autoimmune disorder in humans, mostly children.

Clark, who came to Clemson in 2009, has a longtime relationship with German shepherds going back to her days at Texas A&M, where she studied a pancreatic disorder prominent in the dog breed.

Markers for a deadly disorder

"We are looking for genetic markers for pancreatic acinar atrophy, which causes a lack of digestive enzymes made in the pancreas," Clark says. "The dog literally starves, even if it is eating well, because it cannot digest and absorb food."

Dogs with the pancreatic disorder are bags of bones, ravenously hungry and malnourished, startlingly thin, their coat dull, dry, and brittle. There is no cure, but the lack of digestive enzymes can be managed over the dog's life time by adding enzyme powder supplements directly to food or in pills and capsules.

The condition affects more than German shepherds. Chow chows and collies also are at high risk, but researchers say all dog breeds are vulnerable. The condition can occur at any time during a dog's life and may not be evident until much of the pancreas is damaged or destroyed. Every year about 8,000 dogs worldwide are diagnosed with the disorder.

The research indicates that the condition is inherited in German shepherds. Clark is examining the genetic variations between healthy German shepherds and those with the disorder. If she can identify the genes or group of genes harboring the mutation, researchers could develop a genetic test for it.

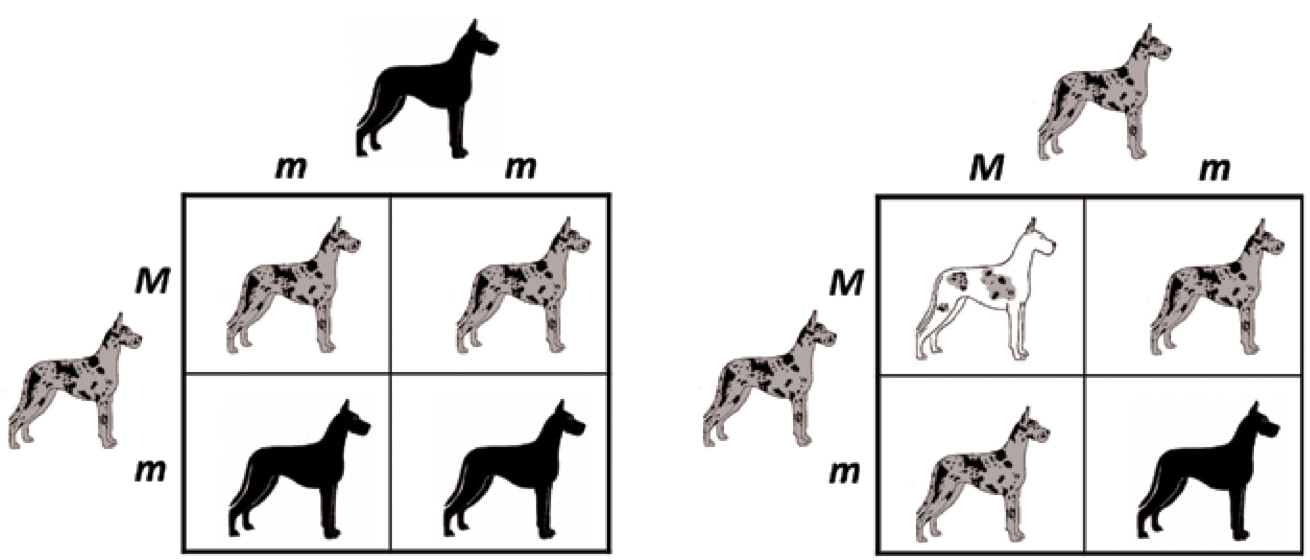
"Breeders would have a test to find out which dogs are at risk," Clark says. "The information could be used to make breeding decisions. Right now, controlled breeding is the only way to reduce the number of dogs with the condition."

Clark's pancreatic research has been funded by the American Kennel Club Canine Health Foundation. In support of the more than 140 breeds recognized by the AKC, the foundation has spent more than $22 million on studies in nearly all of the major diseases in dogs, including cancer, epilepsy, thyroid disease, hip dysplasia, allergies, heart disease, progressive retinal atrophy, and cataracts. It is the largest foundation in the world to fund exclusively canine health studies.

Man's best friend has millions of best friends in return; one happens to be a geneticist using her career to help dogs live healthier and longer lives.

"I am not a cat person," says Leigh Anne Clark.

Leigh Anne Clark is an assistant professor in the Department of Genetics and Biochemistry, College of Agriculture, Forestry, and Life Sciences.



Geneticists use Punnett squares (named for Reginald Punnett) to determine the probability of offspring having a particular genotype. In the Punnett squares above, a capital ***M*** denotes merle as the dominant allele, and a lowercase ***m*** denotes the recessive non-merle allele. Non-merle dogs are depicted in black, but they could have any coat color or pattern other than merle. The squares above show the expected outcomes from a merle-to-non-merle mating (left) and merle-to-merle mating (right). The latter may result in white progeny with sensory defects.

best friends forever

If dogs had a Facebook page, their relationship status with humans would be: "It's complicated."

Dogs descended from the gray wolf. A scant .04 percent difference in DNA coding separates the dog and wolf, the first animal to be domesticated by humans, more than 15,000 years ago. A high tolerance for genetic mutation has enabled dogs to evolve rapidly, becoming our companions and workmates.

At first, natural selection with a bit of human intervention guided the size, shape, coat, color, and other physical traits of the dog, resulting in canine guardians, hunters, shepherds, and cart-pullers. But what was once done for usefulness became a whim of fancy—breeding for a standard of beauty or physical excellence. Selective breeding has made the dog the most diverse land animal on the planet.

The wagging question is, why dogs? There are other domesticated animals that we have selectively bred and not achieved the same portrait gallery of natural variation.

It is the unique genetics of *Canis familiaris* that makes it happen.

Dogs have a genome of about 20,000 genes; humans have as many as 25,000 in their genetic inventory, estimate researchers. Unlike the case with humans, in which hundreds of genes work in small and many-stepped ways to bring about basics such as height or body size, it takes six or seven gene sites to determine 80 percent of the height and weight differences among dog breeds, according to researchers.

It takes only about 50 genes to account for the many colors, sizes, body types, snout and ear shapes, hair lengths, coat patterns, and leg heights in more than 350 dog breeds. Each breed is like a genetic island in the canine archipelago, isolated but part of a greater whole.

By developing registered purebreds, breeders created a DNA tool for geneticists. Being a member of a registered breed is more exclusive than being a member of the Daughters of the American Revolution. To become a registered purebred progeny, both parents have to be members of the registered breed and so do the grandparents. Each breed is a uniquely bred group, giving geneticists a tightly controlled and genetically identifiable population. Genetic researchers can sort through breed genomes, analyzing the regions, looking for variations that produce physical characteristics. Statistically, a breed's distinct genetic profile makes it easier to look for strings of genes that repeat or are different from other breeds or from whole species.

– Peter Kent

Craig Mahaffey

quantum heretic

Antony Valentini to quantum physics: Get real.
by Jemma Everyhope-Roser

In the warm winter sunshine, a distinguished man stands on the curb outside a local bank, wearing a casual jacket, his dark, curly hair stranded with silver. He watches with fascination as a taxi driver demonstrates how to fling a poisonous snake off into the grass using a stick. Antony Valentini shakes his head a little and wonders, aloud, if anyone would believe him back home. Poisonous snakes are foreign to him—as foreign as the big black king snake he found sunbathing in his back yard.

Valentini was raised in London, where his Italian parents still live. He has lived and worked in Italy, Austria, France, and Canada, among others. Accustomed to public transportation, he doesn't drive, and he's struck up a friendship with the taxi driver who drops him off every morning in town. After breakfast at the Pot Belly Deli, Valentini usually ambles across the street to Starbucks. "I'm addicted to their tea," he explains.

With a mug of Earl Grey in hand, Valentini sits down at a small table with his back to the windows. He removes a pencil and a notepad from his Italian leather briefcase. He carries this hardbound notebook everywhere, in case an idea strikes him. But this morning, he isn't jotting down new ideas. He has a stack of printouts from his book with him so that he can review it a page at a time.

"I like having a buzz around me," he says. That's why he works here at Starbucks, reviewing his final draft. About eight hundred pages long, the book is a summation of his work—a systematic rejection of the foundations of one of the longest and strongest-held theories in all of science.

At Cambridge, he started out studying standard quantum mechanics; it's what physicists are taught. But to him, it just didn't make any sense. He remembers thinking, "But how can we understand this?"

A strange conspiracy

In standard quantum mechanics, one particle's motion can be correlated to another's, even if they're distant and unrelated. So it seems like the particles are "communicating" at faster-than-light speeds.

Valentini shakes his head and says, "This looked like some kind of strange conspiracy. It's as if there's something going on, faster than light, beneath the surface, but you can't get your hands on it directly and use it to send signals. If there really are faster-than-light influences, why can't we use them? It's as if the laws of physics are conspiring to hide something."

Craig Mahaffey

"If atoms don't have definite physical states, then how can this cup exist?" he asks.

One of the reasons "quantum" sounds so mysterious to non-physicists is that, according to standard quantum mechanics, any given particle may or may not exist, or may be anywhere in a sliding scale of existence. But that makes no sense on the macroscopic level, in the world we observe every day.

"If you're holding a cup," Valentini says, hefting up his white ceramic mug of tea, "it's not going to vanish. It's there. If atoms don't have definite physical states, then how can this cup exist?"

In standard quantum mechanics, Antony explains, "On the microscopic realm, there's no definite reality, and in the macroscopic realm, there is." He taps the brown-varnished table, demonstrating its physical reality. "So standard quantum mechanics is ultimately ambiguous, because there's no precise boundary between these two realms."

This is a part of what's known as the measurement problem because it usually comes up during experiments, when physicists are attempting to measure particles. The question always becomes, "Did that particle exist in this way before we observed and measured it?" The term is actually a misnomer, Valentini explains, for what should really be called the reality problem.

Standard quantum mechanics is what Valentini calls "a dirty theory" because you can use it and get accurate results, but you can't understand it. "Why should the world be like that?" he remembers thinking. "There had to be an explanation."

When Valentini encountered the de Broglie-Bohm pilot-wave theory, he says, "It gave a beautiful explanation for this conspiracy."

The basis of pilot-wave theory is particles are guided (or piloted) by a wave. You can imagine this by picturing driftwood riding a wave. If you have a bottle on the same wave, the debris would wash toward the shore together, almost as if it were one.

Of course, this metaphor only goes so far. According to pilot-wave theory, this debris would actually be a single higher-dimensional object. When you get what looks like multiple particles riding the wave as one object, there are faster-than-light effects. But you don't have to explain them away with that state of "indefinite reality" like in quantum mechanics. There's a definite reality here. Essentially, in pilot-wave theory, the measurement problem isn't even a problem at all.

"It gave a precise hypothetical account of the world," Valentini says.

A law that isn't

Pilot-wave theory has three axioms. The first is de Broglie's law of motion, which specifies exactly how particles are guided by the wave. The second is Schrödinger's wave equation, telling us how the wave itself changes over time. The third is that particles have to start off with a certain probability distribution.

"In any given experiment, each particle is accompanied by a wave. The particle starts off somewhere inside the wave. If I repeat the experiment, the particles sometimes start here, or there, or there, or there," he says, indicating points in the air with his pen. "If I repeat the experiment many times, they start out with a distribution that is proportional to the square of the height of the wave."

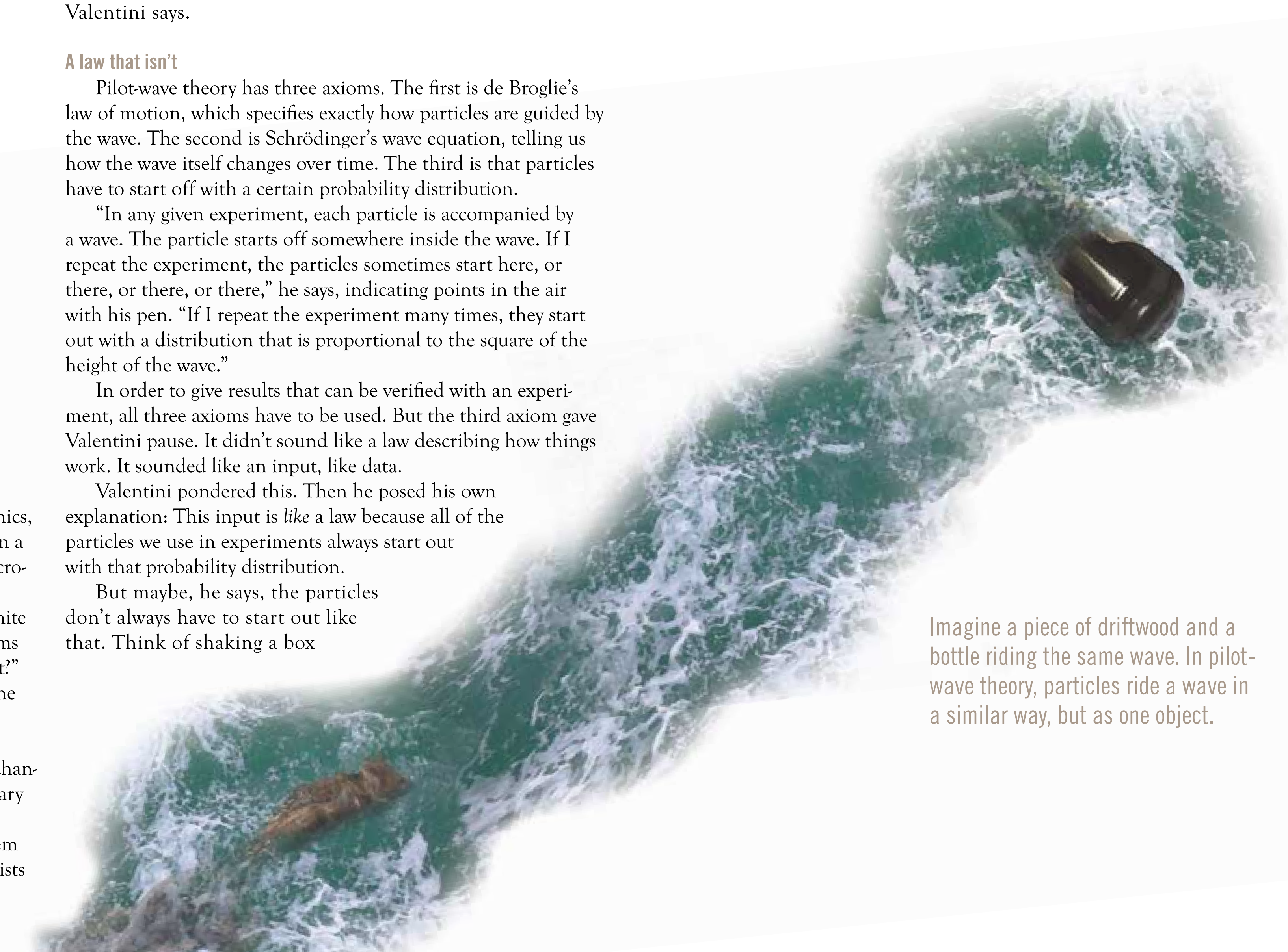
In order to give results that can be verified with an experiment, all three axioms have to be used. But the third axiom gave Valentini pause. It didn't sound like a law describing how things work. It sounded like an input, like data.

Valentini pondered this. Then he posed his own explanation: This input is *like* a law because all of the particles we use in experiments always start out with that probability distribution.

But maybe, he says, the particles don't always have to start out like that. Think of shaking a box of pennies. If you shake it enough, you'll get an even heads-to-tails distribution. That's sort of what's happened to the universe. It's been around for a while. It's been shaken up. The particles have reached an even distribution, or close enough.

Roman Oleinik

Shake a box of pennies long enough, heads and tails will come up even. The universe has been shaking for a long time.



Imagine a piece of driftwood and a bottle riding the same wave. In pilot-wave theory, particles ride a wave in a similar way, but as one object.

But what if those starting conditions changed? What if the distribution wasn't always like that? If you go back far enough, right back to the beginning of the universe, then you might get really different conditions. You could be talking about a physics that describes the early convulsions of the universe, the big bang itself.

This would also answer a question that other physicists ask Valentini a lot, which is: "If standard quantum mechanics and pilot-wave theory provide the same experimental results, then why study pilot wave at all?"

Because these two theories may not describe the same physics. Because, if the conditions were different in the beginning of the universe, maybe only pilot-wave theory can describe the big bang.

"Now," Valentini says, "how can we test that?"

The universe as a lab

The experimental lab is all around us—it's the universe itself. The universe started out as homogenous, a smooth and even distribution. But now, clumps of galaxies are divided by vast swathes of nothingness. How did that happen?

Cosmology actually does have a good understanding of that. In the very beginning, the universe was smooth—but it wasn't perfectly, uniformly smooth. There were tiny lumps. Each region of space that was slightly lumpier, slightly thicker, exerted more gravitational pull. It attracted other matter to itself, and the more matter it attracted, the more it could attract. And eventually you got galaxies, nebulas, solar systems, suns, and planets.

What's not understood about this process is this: Why didn't the matter start out as perfectly, evenly distributed? What seeded the formation of galaxies, of structure in the universe?

"In the nineteen-eighties, there was a theory developed called inflationary cosmology," Valentini explains. "It is by now the leading candidate for what happened in the beginning of the universe. The reason why it's called 'inflation' is because, in this theory, the universe went through a period of exponential expansion very early on."

People began to calculate, using quantum mechanics, what would happen on an exponentially expanding space—and they found fluctuations that could explain the non-uniformity of the universe. "Basically," Valentini says, "these fluctuations in turn trace back to the third axiom."

It seems impossible to gather data about what happened fourteen billion years ago, in the universe's first fraction of a second, but Valentini says, confidently, "There is a way."

Data from space

It's called the cosmic microwave background. A relic of the big bang, this is background radiation that provides a snapshot of the past. It shows what cosmology knows must have been true: small ripples, the slight non-uniformities that led to what we see in the skies today.

As we point more satellites at deep space, we get more information on what cosmic radiation actually looks like. Valentini believes he may be able to use this information to show something: that the third axiom is wrong, that particles don't always have to have this starting point distribution. If that's the case, then we should see anomalies in this cosmic background radiation.

And anomalies have been reported.

But these anomalies are controversial and they may not even be statistically significant. The data we have are from the old WMAP satellite, which is not as precise as it could be. Valentini needs the new data coming from the Planck satellite. With its next-generation instruments, the Planck will provide data that are more precise than ever before.

But before the Planck satellite's data can be released, the data must be "cleaned." Starting with the satellite's readings, scientists will use complex calculations to subtract our galaxy's background noise, instrumental noise, and instrumental errors. Only then will they release the cleaned data—and this should happen within the year.

"There are some hints in the data on large scales," Valentini says. "I hope this will be clarified by the new data from the Planck satellite. But in the meantime there is some work that needs to be done to make my predictions more precise."

Valentini wants to use the Palmetto Cluster—the university's supercomputer—to run complex computer simulations of the early universe. If he can accurately predict anomalies shown in the Planck satellite's data, he'll have solid evidence supporting pilot-wave theory. If pilot wave could describe what standard quantum mechanics cannot, that would have huge ramifications in the physics world.

Antony Valentini sips his tea from a mug that is as undeniably real as the busy coffee shop around him. If he's right, then we may have a whole new way to understand how the universe works.

Antony Valentini is a professor of theoretical quantum physics in the Department of Physics and Astronomy at the College of Engineering and Science. His work is funded jointly by Clemson University and the John Templeton Foundation.

an underdog theory

At Solvay, de Broglie lost, but did physics win?

You've probably heard of string theory, standard quantum mechanics, and general relativity. But pilot wave? No, never heard of that.

The reason why goes back to the theory's history. Antony Valentini wrote about this (and other things) in the book he coauthored, *Quantum Theory at the Crossroads: Reconsidering the 1927 Solvay Conference*.

This story begins in the early twentieth century, a time of revolutionary advancements in physics, at the Solvay Conferences in Brussels, Belgium. Some of the best and brightest minds attended these conferences: Einstein, Marie Curie, Heisenberg, Schrödinger, and Planck, to name a few.

Louis de Broglie was also there. He was from Paris, then something of a backwater in theoretical physics. His theory, presented at the 1927 conference, was well regarded by figures like Einstein and Schrödinger (who adapted it but threw out the particle aspect in his famous equation). But de Broglie's theory wasn't widely read. That's because it was in French. Louis de Broglie was an isolated francophone in a world of high-powered Germanic physicists.

In the end, Bohr and Heisenberg won the day. At the Fifth Solvay Conference in 1927, physicists met and debated quantum theory. It wasn't exactly a popularity contest. But what ended up happening was a "victory" for standard quantum mechanics, also known as Copenhagen quantum mechanics. After that, all other approaches were just seen as, well, wrong.

For all that, de Broglie went on to win the Nobel Prize in physics in 1929.

Sparking new thought

Now, fast forward. It was after World War II and de Broglie's work had fallen into obscurity. A young assistant professor named David Bohm started employment at Princeton University's Institute of Advanced Study. Coincidentally, that was also where Albert Einstein worked. So, when Bohm published a book in 1951 defending standard quantum mechanics, Einstein criticized it. Apparently that sparked a new line of thought in Bohm, because he ended up developing de Broglie's partial proof and demonstrating that pilot-wave theory was completely equivalent to standard quantum mechanics.

But the story doesn't end here.

Around this time, McCarthyism was burning across the country. And David Bohm, when working on his Ph.D. thesis at Berkeley under Oppenheimer, had dabbled in communism. He was recommended for and then denied access to the Manhattan Project. He was brought up to hearings again and again. When he received an invitation to work at the University of São Paulo in Brazil, he took it and got out of the country. His work was further discredited when he later turned to mysticism.

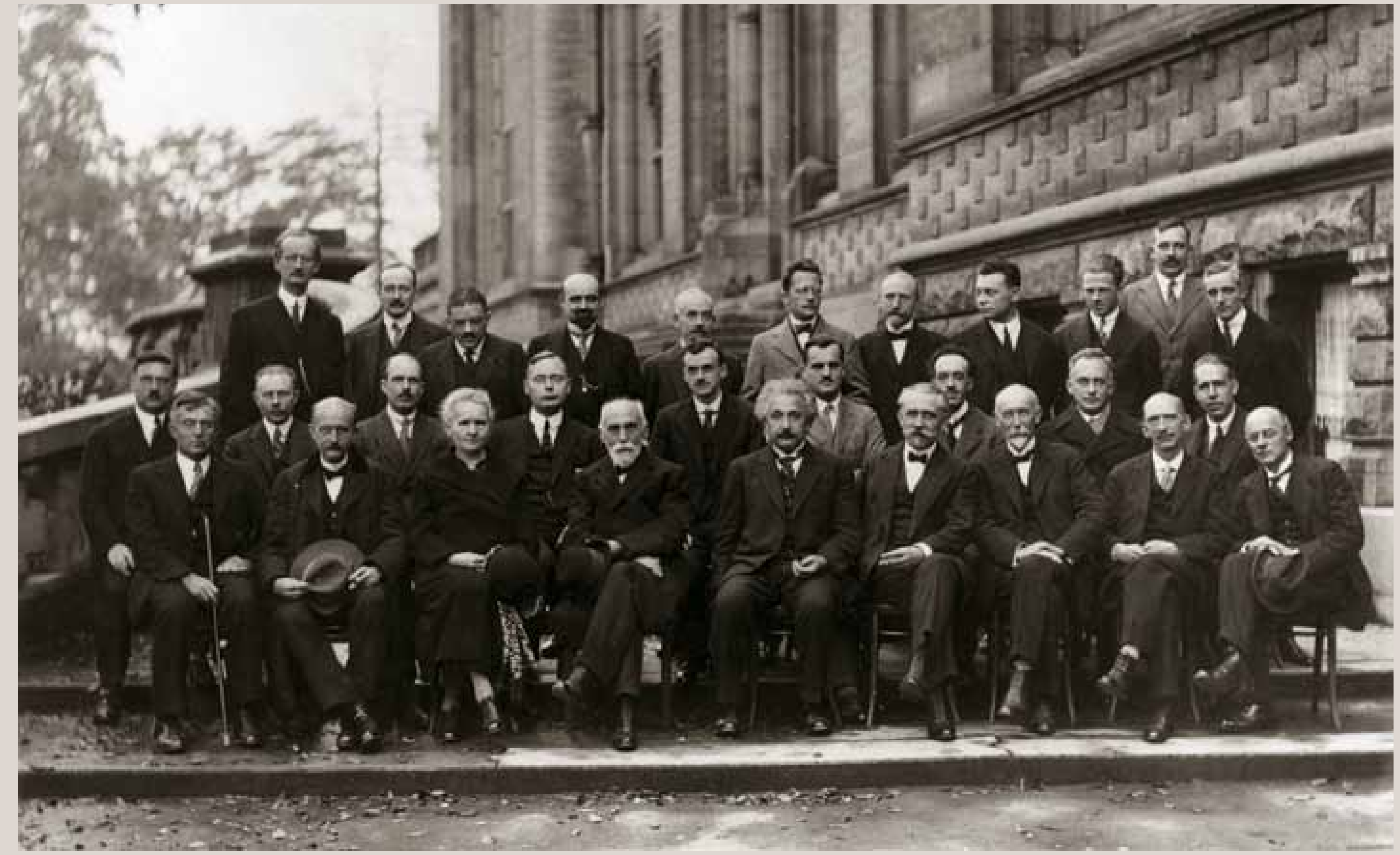
For years, most physicists didn't know about the theory or thought, vaguely, that it had been proven wrong. The few scientific papers that were written about pilot-wave theory dismissed de Broglie's approach as just plain wrong and Bohm as a kooky communist.

But in the '80s, many physicists began to question standard quantum mechanics. The theory had problems, unanswerable questions, and just didn't make sense. In those days, Valentini says, people were defending quantum mechanics by saying things like: "It's meaningless to ask such questions," and "I don't believe any other theory can be true." But in the last fifteen years, majority opinion began to change as pilot-wave theory became accepted as a legitimate theory. The criticism changed to: "Well, if it *is* equivalent experimentally, what's the point in studying it then?"

John Bell, after spending a year's leave from CERN at Stanford, wrote a paper that arguably came out in favor of the de Broglie-Bohm pilot-wave theory. This paper was what prompted Antony Valentini to look for real answers to the big questions in physics.

– Jemma Everyhope-Roser

Benjamin Couprie



Above: In 1927, the giants of physics gathered at the Solvay Conference in Brussels, where Niels Bohr (second row, first on right) and Werner Heisenberg (back row, third from right) won a victory for standard quantum mechanics, rendering the theory of de Broglie (second row, third from right) "wrong."

Leopoldina National Academy

Right: Louis de Broglie, an isolated francophone in a world of high-powered Germanic physicists, won the Nobel Prize, but his theory was not widely read.

Battisto conceived this virtual prototype, Patient Room 2020, in collaboration with Clemson alumnus David Ruthven and the nonprofit firm NXT.

rooms for getting better

Architect Dina Battisto and her team reshape health care's spaces. by Lauren J. Bryant

Say it's the year 2020. You wake to find yourself in a hospital bed and take a look around. Here's what you see:

- a room with sleek curves and seamless microbe-resistant surfaces,
- a digital flat-screen monitoring your vital signs,
- sliding entry doors made from smart-glass technology with digital alerts for patient allergies or special conditions,
- a foot-of-the-bed media center for information exchange between caregivers and visitors,
- trash containers with sensors that alert maintenance robots for pickup, and
- a cantilevered nook projecting from the wall that contains a pull-down bed, workstation, and drink chiller for family members.

Craig Mahaffey

Welcome to Patient Room 2020, a virtual prototype envisioned and created by Clemson University's Dina Battisto, associate professor in the School of Architecture, along with Clemson alumnus David Ruthven and the healthcare innovation nonprofit firm NXT. Their prototype received the 2010 Professional Conceptual Design Excellence Award in a competition cosponsored by the interior design industry magazine *Contract* and the Center for Health Design. And though the prototype looks a little like the sick bay of the Starship Enterprise, there is nothing science fiction about the principles grounding its design features.

"We had five goals that guided the prototype's creation," says Battisto, whose voice rises with enthusiasm when she discusses the project. "They were humanization, sustainability, efficiency, empowerment, and adaptability. Efficiency and adaptability are primarily aimed at helping healthcare professionals do their work better, so the process of healthcare delivery is no longer about the wait and the waste."

While all of these goals were important in the 2020 vision, it's the goal of humanization that drove Battisto the most. "The Patient Room 2020 mock-up is very high tech, but it's not about that," she says. "It's about restoring hope and comfort and control to patients and their families."

'It comes from deep inside'

Battisto knows what it's like to sit hopeless beside the hospital bed of a gravely ill loved one. She's been there, twice.

When the MVP-athlete Battisto graduated from her Alabama high school, she had more than ten basketball scholarship offers for college. Her father's health was not good, though, and Battisto worried. She was the oldest child of her Italian-immigrant father and American mother, and a first-generation college student. She felt responsible, she says, to "make sure that I had a profession that would allow me to care for my parents if I needed to."

So Battisto gave up on all those scholarships and turned herself to the study of architecture at the University of Tennessee. In her junior year, her father had a massive stroke. Her parents were divorced by then, and Battisto decided to leave school to take care of him.

Battisto's mother intervened to enable her daughter to stay enrolled. But at every summer break, Battisto returned home to help care for her father, who eventually moved to a nursing home. "In summers, I waitressed in the early morning, took care of him at the nursing home during the day, and waitressed again at night," she says.

By 1991, with a B.A. in architecture, Battisto knew she wanted to specialize in healthcare architecture: "That's what brought me to Clemson the first time—my experience with my father and Clemson's unique focus on healthcare design," she says.

In 1996, Battisto's father died. ("That was tough," she says simply.) In 2007, her mother developed stomach cancer and died not long after. Once again confronted with the healthcare system and its environments, Battisto says her mother's illness and death "re-upped" her motivation.

"The one thing we all have in common is that, when we are sick, we are dependent on our environment," she says. "It's our human 'common denominator,' but we don't realize it until we experience it firsthand.

"I think motivation comes from deep inside," she continues. "That's what happened to me. My passion is a result of my experience with my parents, that's why I committed my professional life to healthcare design."

An art and a science

Many of us consider architecture an art—we might think of the nested shells of the Sydney Opera House or the floating planes of Frank Lloyd Wright's Fallingwater. Battisto, who holds four degrees in architecture including a Ph.D. and two master's degrees, one of them from Clemson, takes a different point of view.

She begins with research, which is not typically part of the plan. To Battisto, though, architecture is just as much science as art, and she doesn't mean simply the technical calculations it takes to make a building stand up.

Battisto is a firm believer in the tools of the scientific method—observations, hypotheses, predictions, experiments, and analyses. She believes these tools are essential to creating efficient, healthy, and beautiful buildings. This is especially true in the field of healthcare architecture, which deals primarily with designing hospitals, clinics, nursing homes, and other such facilities. Because of strict codes and federal regulations, sophisticated medical technology needs, and the urgency of life-and-death situations, healthcare design is complex and constrained. It is also expensive, making a huge economic impact on the United States.

"Healthcare clients are getting smarter and starting to demand evidence to demonstrate why a certain design is proposed," Battisto says. "They want to know how the design has an impact on outcomes. Does it make patients more satisfied? Does it reduce stress and strain on nurses? Does it reduce bottom-line costs? What's the value design offers?"

These are questions research can answer, according to Battisto, who has been building a research program within the School of Architecture at Clemson over the last decade or so. One of the strengths of the program is the unusual Architecture 821, a research and design methods seminar now required for students in Clemson's master's of architecture program (*see sidebar, page 55*).

Battisto admits that, when she first returned to Clemson as a professor, she felt a little like an outsider. "Architecture embraces the designer, not the researcher," she says. "I'm surprised at how long it takes for some people in the field to recognize the value of research."

She does see architecture's culture shifting, but to Battisto, a self-described perfectionist who likes to "get things done correctly and quickly," the slow pace of change has been frustrating.

"To me, the value of research is obvious," she says. "A project can be creative and pretty, but does it work? You have to ask that question. Architecture becomes transformational when it brings together design and research."

Designing what comes next

In her work, Battisto conducts research and feeds the results into new conceptual designs and architectural prototypes that can be evaluated under simulated conditions. It's this approach that led to Patient Room 2020.

In 2005, collaborating with David Allison, professor of architecture at Clemson, as well as with Clemson students, Battisto designed an inpatient room prototype with support and sponsorship provided by the Spartanburg Regional Healthcare System. Various suppliers and contractors volunteered time and supplies to help build a mock-up of the prototype in NXT's research lab

Craig Mahaffey

Battisto (center) reviews design concepts with her graduate students, Deborah Franqui and Mason Couvillion.

near Greer, South Carolina. There, under simulated conditions, Battisto and her research team studied things like the head wall (where outlets for electricity and medical gases are located), the lighting, and the location and functionality of the bathroom. (The lab near Greer is one of two architecture research labs she uses; the other is on the Clemson campus in the School of Nursing.)

Battisto and her team used the prototype test results to inform the next iteration. The patient room was actually built in the Village Hospital at Pelham, South Carolina. Battisto and her students conducted a post-occupancy evaluation, using surveys, observation, and interviews. “The majority of the staff listed the patient rooms as the best feature of the hospital,” Battisto says.

Encouraged by the success of the patient room at Pelham, Battisto went “blue sky.” What, she wondered, would the patient room of the future look like? “I thought, ‘Let’s take it further, let’s figure out how to translate a design into a futuristic room.”

For two years, she did just that. Collaborating with David Ruthven, a Clemson alumnus, as well as NXT, Battiso created a patient room design prototype as part of the Department of Defense’s Hospital of the Future initiative. That design became the award-winning Patient Room 2020 prototype.

Making a difference

Along the way to her career in architecture, Battisto spent several years working as a senior management consultant for a healthcare planning company in Ann Arbor, Michigan. Although Battisto enjoyed helping healthcare clients as a consultant, she found the work limiting. “I didn’t see a lot of opportunity for really being creative,” she says, “and I really wanted to help make a bigger impact.”

After twelve years at Clemson, she’s certainly accomplished that goal. Selected as one of Twenty Who Are Making a Difference in 2008 by *Healthcare Design* magazine, Battisto is widely recognized in the field for her evidence-based design expertise. That expertise has drawn the attention of the U.S. Military Health System.

Battisto explains that, in the wake of the 2007 scandal over derelict conditions and neglect at the Walter Reed Army Medical Center, the Military Health System received sizable federal funding to renovate existing facilities and build new ones.

“People were horrified by the sight of this very old, outdated facility where wounded soldiers were being cared for,” Battisto says. “That exposure spurred quite an investment.”

But investment in what, where, and how? The MHS mandate was to “create world-class facilities,” Battisto says, “but they didn’t know what they needed to do.” So they turned to Battisto, along with her longtime co-investigator David Allison, to figure it out. “Our charge was to develop the guiding principles and values that define what the MHS should do,” she says.

Over time, working with Allison, collaborators at Georgia Tech, NXT, and the Noblis consulting firm in Virginia, Battisto and her team developed nine principles that defined a world-class facility, such as safe, patient-centered care, operationally efficient settings, and a positive work environment. Those nine principles became the basis for evaluating how well a military health facility is performing.

Next, her team developed a facility-evaluation toolkit. The toolkit includes an eight-step implementation methodology plus a set of tools including surveys, interview techniques, and other instruments designed to collect data systematically from facilities about what’s working and what’s not.

For example, what is the most effective, patient-centered layout for helping people find their way in a clinic or hospital? What is an acceptable distance for a staff member to travel between the medication room and a patient unit, or an acceptable distance for a patient to travel from the facility’s entrance to the ambulatory surgery department? What’s the optimal size and layout for a patient room?

“We don’t know these things,” Battisto says. “We don’t have a knowledge base to go on, like medicine does. If we don’t have a knowledge base, if we don’t make changes based on lessons learned, then we continuously repeat the same mistakes.”

A $49 billion organization that provides health services to 9.6 million patients in close to 50 hospitals, the Military Health System is motivated to know what does and doesn’t work, Battisto notes. “Obviously, it’s in their best interest to learn from their existing facilities, so when they build new or renovate, it can be better. The data that our toolkit collects can be used to build a database for benchmarking, to provide guidance on how to make changes and improvements.”

Battisto and her research team initially tested their facility evaluation toolkit at Bassett Army Community Hospital in Fairbanks, Alaska. Impressed with the potential of the toolkit, the MHS made a commitment to continue building the program. Battisto and her colleagues are currently conducting a second pilot test in the Fort Belvoir Community Hospital just outside of Washington, D.C. The goal is to refine the instruments and processes offered in the toolkit, and eventually, for the MHS to use the findings from the evaluations to reform space-planning criteria, guidelines, and room templates.

“The toolkit is the beginning. The evaluations it produces should feed forward into facility planning,” Battisto says. By constructing a facility evaluation program, she says, “the MHS will learn how to build a facility that is ultimately world class.”

For too long, Battisto says, healthcare architecture has been treating the symptoms, not the cause, of problems in healthcare facilities. She hopes the MHS toolkit and the knowledge base it is beginning to yield will someday influence all hospital design.

“In the end, it all comes down to research and the knowledge that comes from it,” she says. “Research makes for better designs, and better designs make for better environments. That’s why I do it—I really want to make a difference.”

Dina Battisto is associate professor in the School of Architecture and leads the Built Environment and Health Concentration in the interdisciplinary Planning, Design, and Built Environment Ph.D. Program in the College of Architecture, Arts, and Humanities.

Derrick Simpson

Students in Dina Battisto’s research course present their results for critique by faculty members and peers.

For students, research enables design

Consider this from a Clemson syllabus: “We will examine the different ways of gathering data using research methods; relevant tactics will be introduced as well as basic data processing and analytical techniques.” What discipline does it come from? Biology? Biochemistry? Computer science, perhaps?

Try architecture. The sentences are from the syllabus for Dina Battisto’s Architecture 821: Research Design and Methods Seminar, a required graduate-level course for all students in the master’s of architecture program at Clemson. Architecture has been taught at Clemson for nearly a century, but it wasn’t until 2007 that the program included a focus on applied research.

Why research? Isn’t architectural education all about theory and design? Battisto, now an associate professor in Clemson’s highly regarded Architecture + Health program, says that’s been the case for too long.

“As a discipline, we are not trained to do research,” says Battisto, who holds four degrees, including a Ph.D., in architecture herself. “Professional degree programs leading to a bachelor’s or master’s in architecture don’t offer training in how to develop research questions, formulate a research plan, collect and analyze data, and write results. That is not what we’ve been about.”

In 1999, Clemson’s School of Architecture decided to change that by committing to build a research program within its Architecture + Health program. David Allison, professor of architecture and director of graduate studies for the program, recruited Battisto to lead the process. “A big part of my role at Clemson is to cultivate a research culture that integrates, not separates, research and design,” Battisto says.

Her primary cultivation tool is the Architecture 821 seminar. “We start with ‘what’s a hypothesis?’” Battisto says. The course has three basic sections: the foundations and basics of research; research methods; and research applications. The course culminates in an annual event where student teams display posters that depict their research topic and report their results. In fall 2012, the class, which will enroll close to eighty students, will carry out a post-occupancy evaluation of the brand-new Lee Hall as an applied research project. (“Here Comes the Sun,” Spring 2012 *Glimpse,* page 42.)

Battisto notes that emphasizing research is a hard stretch for many of her students. “In the beginning, a lot of students are resistant, because architecture is always about design, design, design. But there are a lot of things that go into a great design, that’s what we have to teach them,” she says.

Some of those things, according to Battisto, are fundamental research skills—gathering evidence, formulating arguments, predicting results, all with an eye toward presenting an evidence-based design plan. Battisto wishes she’d had these skills herself as a young master’s student at Clemson in 1992.

As her thesis project for her master’s of architecture degree, Battisto designed a forward-thinking nursing home, based on a resident-centered household model. “People don’t live in forty-bed units, they live in households,” she says. Battisto worked with a client to get the nursing home built, but along the way, she says, “I fought with the client over my ideas about the most appropriate model for communal living. Back then, though, I had no way to demonstrate or convince them that I was right. I realized I needed research skills.”

That realization has been a boon for countless Clemson architecture students who have learned how to give their art some scientific grounding.

“Most people come into studying architecture thinking they are going to go build skyscrapers and be famous designers, but that becomes a reality for only a very few,” Battisto says. Armed with research skills to inform and back up their designs, Clemson’s architecture graduates can “design the cool building, but they can also provide the evidence for why it works.”

– Lauren Bryant

forest by nature

stories by Jemma Everyhope-Roser

In much of the Southeast, the landscape's native vocation is forest. But when European settlers arrived here, they did not find a forest primeval, wild and pristine. For centuries, native people had managed the forest, extracting its resources for shelter, fiber, fuel, and food. Deer and other game thrived in understories cleared with fire. Hunters traveled shady, park-like woodlands on broad, open paths. And in clearings, native farmers sowed their crops in the fertilizing ash of trees.

When Europeans claimed the land, forests swiftly changed. Planters cleared the coastal swamps, ditching and draining them for rice. As settlers pushed inland, great tracts of timber fell to pasture and crops such as cotton, tobacco, and corn. By the end of the nineteenth century, even steep, rocky slopes of the mountains were stripped to their bones.

The soils of South Carolina did not fare well, laid open to weather as hungry crops mined their nutrients. By the early twentieth century, once-fertile topsoil was depleted or eroded, and the land, like most of the people who tried to farm it, was impoverished. From its inception as a land-grant college, Clemson's mission included a mandate to rebuild the vitality of the land and the economy that depended on it. Science-based farming and forestry were the tools of choice. With time, newly planted forests healed the gullied wastelands, attracting wildlife and supplying timber to the mills.

Today, the job is not finished, and the science of forests is urgent as ever. Development, pests and diseases, and a warmer climate threaten forest ecosystems and complicate the job of using resources without exhausting them again. In these pages, you will find a few examples of research that is helping to write the next chapters on how to manage a forest.

Courtesy of S. K. Cox

1930s

The Great Depression devastates South Carolina, much of which is now unfit for agriculture. Approximately two-thirds of the most badly eroded and gullied land in the U.S. is in the Southeast. This photo shows gullied land near Clemson.

Courtesy of S. K. Cox

mid-1930s

Thomas Aull, Clemson graduate and professor, decides to help impoverished locals by increasing knowledge of land stewardship. With the help of several government agencies and the university, he founds the Clemson Experimental Forest.

Paul Wray, Iowa State University

chestnut dreams

In 1905, American chestnut trees in the Bronx Zoo began to die. The zookeepers, with the help of a mycologist, discovered that chestnut blight was to blame. Chestnut blight is a fungus, *Cryphonectria parasitica,* thought to have originated in Asia. It had already cast its spores to the wind.

At that time, the American chestnut dominated the forests directly west of the Appalachians. Geoff Wang, a forest ecologist, estimates that the American chestnut accounted for one in four mature trees in the southern Appalachians. The chestnuts fruited prolifically, and in addition to their commercial value, must have fed many wildlife species. Unfortunately, we don't know exactly what role the American chestnut played in this ecosystem. That's because he American chestnut was gone by the 1950s. Today, Wang says, it is "functionally extinct." The root survives the blight and sprouts a sapling. But as soon as the new sprouts are large enough, the fungus kills them.

Now there is hope for the American chestnut. The American Chestnut Foundation has produced a hybrid that is 96 percent American chestnut and 4 percent Chinese chestnut, which is resistant to the blight. The tree looks like an American chestnut, but Wang and his former graduate student, Ben Knapp, now at the University of Missouri, want to learn whether it will act like one, too, physiologically and ecologically. Wang's study is a part of the effort, led by USDA Forest Service, to find the best way to reintroduce chestnut trees so that they thrive and propagate themselves.

"It's a dream that, one day, the Appalachian landscape may look more like it did in the past than it does today," Wang says.

Geoff Wang is professor of silviculture and ecology in the Department of Forestry and Natural Resources, College of Agriculture, Forestry, and Life Sciences.

the forest's winged enigma

Before the microchip, it was almost impossible to study bats. Scientists chased bats with nets or studied them in caves, where some but not all of them hibernate. It's no wonder then that bats are still very much an enigma.

"They're tiny. They fly at night. And that made it difficult to track them," says Susan Loeb, a U.S. Forest Service research ecologist and an adjunct professor at Clemson.

In the 1990s, the Forest Service began investigating claims that deforestation was cutting into the endangered Indiana bat's maternity habitat. The problem was, no one knew *exactly* where the Indiana bats went to raise their young. For the first time, radio transmitters were small enough for tracking bats.

Loeb, who'd previously studied how the endangered red-cockaded woodpecker and flying squirrel use longleaf pine habitats, joined the project. She fell in love with bats.

"They're fascinating animals," she says. "Bats are really important for ecosystems, for agriculture and for forestry." Bats, she says, control insects, pollinate crops, and spread seeds.

Loeb tracked the Indiana bats using radio-telemetry, following them to their maternity roosts. "We found them roosting in deeply forested habitats, in the southern Appalachians, although they roost in woodlots in the Midwest, and even in the Indianapolis airport," she says.

Ralph Eldridge

The little brown bat weighs about as much as two teaspons of sugar but can catch 1,000 mosquitoes in an hour.

She also discovered, in the Great Smoky Mountains, the first southern maternity roosts. Oddly, the bats migrated to more northerly sites to breed. Young mammals need to be kept warm; everyone knows that. So why were the female bats going to the sunny sides of trees in cooler areas? Do bat pups also have difficulty keeping cool?

Some maternity roosts are in areas where climate models predict increasingly hot summers. Loeb wants to learn whether the bats will migrate farther north or just move to shadier trees. Figuring this out will help forest managers protect potential roosting sites.

Meanwhile, Loeb also studies a more immediate threat to bats of all cave-hibernating species: white-nose syndrome. The syndrome, caused by a cave fungus, *Geomyces destructans,* shows up as white fuzz around the bat's muzzle and distinctive mildewy spots on the bat's wings. Infected bats wake from hibernation, flying during bitter winter days in search of food they'll never find. They die emaciated. In northern states where the syndrome first struck, 72 percent of Indiana bats and 95 percent of little brown bats died. Unlike most small mammals, bats can live to be more than thirty years old and have only one pup a year, so their populations take a long time to recover.

A threat close to home

White-nose syndrome has been sighted at the same latitude as one of Susan Loeb's favorite bat colonies, a group of little brown bats that roost in a fish hatchery's shed. Loeb hopes that even if these bats wake from hibernation, the southern winter will be so mild and short that they won't deplete their fat stores and starve.

To help bats survive, Loeb studies their habitat. She knows that they prefer to hunt in open spaces such as meadows. Prescribed fires can burn out clutter and restore the forests bats love. Loeb is part of an interdisciplinary project in the Nantahala Forest looking at how clear cutting small patches affects bats, other animals, and people who use the forest. She hopes to learn whether bats will use these clear-cut areas to hunt insects, and what size and arrangement of spaces work best.

As disease, pesticides, habitat loss, wind turbines, and other threats keep the pressure on, Loeb will be looking for ways to keep the bats alive. "We're only starting to learn about them and getting the tools we need to manage their habitats," she says.

built to take the heat

Usually, setting something on fire creates more problems than it solves. The longleaf pine is a notable exception.

Before European colonization, longleaf pine savanna stretched across the Southeastern coastal plains from Virginia to Mississippi. Tall pines and broad meadows composed a unique park-like vista that housed the highest biodiversity seen outside the tropics.

There were 92 million acres. Today, only 5 percent of the savanna survives. Fortunately, that's enough to give researchers like Geoff Wang an understanding of how this ecosystem works. The keystone species is the longleaf pine, which provided both sustenance and shelter to many species, including the red-cockaded woodpecker, that are now endangered because of the longleaf pine's decline.

The longleaf pine is uniquely adapted to regenerate after fires. As Wang says simply, "No other tree can do that."

Native tribes burned the pine savanna every two to five years. Fire would wash through the forest, clearing the midstory and searing through normal saplings. The resulting open spaces and fertile ash gave rise to the region's diversity.

Wang has already studied the tree's special adaptations and the best methods to restore this ecosystem. Now he's studying how Southeastern forests might adapt to climate change and increased drought. Using an extensive data set taken from the USDA's Forest Service Forest Inventory Analysis (FIA) program, he's trying to determine which species are drought resistant, which will grow more abundant, which will decrease, and what kind of stand density and conditions will help a tree flourish.

Longleaf pines grow in the driest and sandiest sites, tolerate nutrient-poor soils, and are very drought-resistant. So the longleaf pine, a survivor from the past, may come to stand for the future.

Below: Longleaf pine cones. When young, the longleaf pine protects its terminal bud from fire with a spray of water-dense needles. When its root is long enough, the tree armors itself in thick fire-resistant bark and shoots upward, elevating vulnerable branches above the flames.

Erich G. Vallery, USDA Forest Service

USDA Forest Service

Controlled burning, used by native tribes centuries ago, helps forest managers maintain a healthy ecosystem and reduce the risk of larger fires.

the question of value

How can you measure a tree's economic worth? It's a question people ask Thomas Straka, an expert in forest economics. Trees, he says, are one of the few goods that accrue value as they age. But it takes complex calculations—using wood-yield and valuation functions—to determine when it's best to harvest. And the equation has to take into account more than money.

Conservation typically means using forests wisely, and a forest manager's job is to make sure the lands serve public interests, Straka says. That means, before a manager can make decisions, he or she has to know the value of the trees in terms saleable wood, wildlife habitat, aesthetics, recreation, socioeconomics, and more. One of Straka's recent projects uses socioeconomic data with GIS to predict wood arson, a major cause of wildfires.

Socioeconomic factors also apply in the new field of sustainable forestry. Straka works with everyone, from paper mills to private citizens, to help them attach a monetary value to sustainability. Conservation easements that compensate property owners for losses in the transition from loblolly forests to longleaf forests are one example of this approach, he says.

How do we value a tree when its use isn't lumber or pulp?

Straka also works on systems that will help city officials and private owners assess the value of urban trees, taking into account air-quality improvement, carbon sequestration, and storm-water reduction. If a tree shades a building, it can reduce electricity costs. Straka also accounts for the value of the tree itself, its girth, type, region, and even aesthetic value.

But a huge amount of a tree's value comes from people's perceptions, he says. A tree-shaded shopping district may attract customers and generate revenue. People especially like oak trees, Straka says, because we view them as a long-term investment. "If you have a beautiful live oak in your front yard that's two hundred years old," Straka says, "how do you put a value on it?"

Thomas Straka is a professor in the Division of Forestry and Natural Resources.

battling invasives

Dozens of invasive species vie with natives for sunlight and nutrients. There are three simple methods to control an invasive plant species: cut it out, burn it, or poison it. Geoff Wang and graduate student Lauren Pile are exploring combinations of all three on Paris Island, trying to keep the Chinese tallow tree from taking over.

In an ideal world, you'd use a manual method, weeding out the invasive species. But with huge populations to control, the manual method is impossible. Fire is the cheapest. But it doesn't kill invasive species—it only limits how tall they grow between burnings. Herbicides, the most expensive option, do eradicate unwanted plants. But most herbicides don't discriminate; they can kill desirable plants too.

Wang and graduate student Karen Vaughn are working in Congaree National Park with Chinese privet, an invasive shrub that strangles young trees. The researchers have chosen an herbicide that is absorbed through leaves, and they're applying it in the dormant season, when most native species are leafless and the semi-evergreen Chinese privet is not.

"When an invasive species becomes abandoned in a native ecosystem, we want to know how it impacts the regeneration of native species," Wang says. "We want to be able to bring the original ecosystem back."

James H. Miller & Ted Bodner, Southern Weed Science Society

Chinese privet, a semi-evergreen shrub, is an aggressive invader in Southeastern forests.

Pine killer

Tiny as a grain of rice, the southern pine beetle has caused several hundred million dollars in timber losses in the U.S. The beetle bores into trees and chews serpentine galleries into the innermost bark, stopping nutrient flow. It also spreads a fungus deadly to pines. Especially vulnerable are loblolly pine trees, planted for their quick growth. Unlike longleaf pines, loblollies don't cope well with drought, which lowers their resistance to beetle attacks. Geoff Wang's research is aimed at helping forest managers restore beetle-damaged forests.

USDA Forest Service, Southern Research Station

salt and the cypress

Cypress trees, with their roots in dark mud and their leaves in the sunlight, have quietly outlived empires. With their neighboring maples, ashes, and gums, they form the basis of a complex ecosystem that once stretched along many Southeastern waterways.

William Conner has been studying these ecosystems, called freshwater forested wetlands, for about forty years. He measures tree growth and leaf production, comparing his findings against twenty-five years of data, but he can tell by observation alone: The trees are under stress.

Look at the ground. If you see dapples of sunlight, above is an unhealthy cypress. Sunlight reaching the ground means a thinning canopy and reduced leaf formation. When there aren't enough leaves breaking down, you get fewer nutrients in the soil and more carbon in the atmosphere.

Conner, along with a team that stretches from Virginia to Louisiana, has been researching environmental causes for the stress. The trees have two main problems: dams and climate change. Nearly all Southeastern rivers have been harnessed by dams and hemmed in by dikes. The dikes prevent sediment from entering the streams, and the little sediment that does enter gets trapped behind the dams instead of fertilizing the wetlands downstream.

Conner is studying sedimentation in the Congaree National Park, home to one of the last and largest intact forests of its kind it the United States: an old-growth, bottomland, hardwood, floodplain forest. Conner and his colleagues compare soil layers to a tree's age to get a historical perspective on how sedimentation affected growth. He updates this picture by tracking current tree growth and sediment deposits. Using the data, he can get an idea of what these trees need to flourish.

He's also looking at coastal freshwater forested wetlands influenced by tides. Over the course of Conner's career, he's seen the health of these forests decline, mostly because of rising water levels and increasing salinity. Sometimes salinity rises after dredging, which allows salt to intrude upstream, and locks can draw seawater into a river.

Other factors are related to climate change. Droughts concentrate the water's salt. Hurricanes do immense damage to forested wetlands—not because of the winds but because of the slugs of salt water they push inland. Topographies simplified for farming and commerce now provide fast-track channels for a hurricane's inland attack; roads, dikes, and other man-made structures detain the water on land.

But one of the biggest culprits is the rising sea level. In South Carolina, it's approximately two millimeters per year. That's nothing compared to the ten millimeters in Louisiana. There you have what Conner calls ghost forests—white dead trunks jut up like bones from dark waters that were once the forest's lifeblood but are now its poison.

Growing toward safety

This slow and encroaching death seems almost impossible to stop. The cypresses, being more salt-tolerant than their neighboring maples and gums, are usually the last to go. Sometimes, Conner says, you'll see regions of dead forest with only a few hardy cypress survivors. Conner and his fellow researchers want to plant seedlings of these salt-tolerant trees to help regenerate the forest. His work in the Southeast will help him understand what the trees need to flourish.

Conner says the seas have risen before. He explains that there's a cycle of sea level changes that happens slowly over the course of approximately one hundred thousand years. In the past, as the seas rose millimeter by millimeter, the trees migrated away from the threat, casting their seeds and growing their way to safety over the course of centuries.

But the cypresses can't save themselves anymore because we're in the way. Over 50 percent of the region's population lives within a mile of a coast or a waterway. Conner works with landowners and developers to preserve as much as possible, but it can be difficult to balance the landowners' goals with the complexities of ecosystems. As Conner says, "It's all connected."

William Conner is professor of forestry and natural resources in the College of Agriculture, Forestry, and Life Sciences. For more about Clemson's efforts to protect cypress forests, see "Of Seeds and the River," Spring 2012 issue of Glimpse.

Jemma Everyhope-Roser

Bottomland forest in the Congaree National Park: Where sunlight reaches the ground you'll find unhealthy forest.

ullstein bild / The Granger Collection, New York

The synagogue on Fasanen Street in West Berlin was one of many that served Germany's largest Jewish community before the Holocaust. The Nazis destroyed the building's interior, but its shell survived until demolition in 1958, when this photo was taken.

sacred places, shattered spaces

Michael Meng traces the material legacy of the Holocaust.
by Jeff Worley

Fist-sized chunks of limestone and cracked brick.

Crumbled masonry and leveled columns. Shattered buttresses and pots, toys, and tools. Unfathomable mountains of the stuff in city after city. Shredded books and ash. An occasional charred bicycle.

In many European and Polish cities after World War II, rubble defined the postwar landscape, says Michael Meng in his recently published book, *Shattered Spaces: Encountering Jewish Ruins in Postwar Germany and Poland* (Harvard University Press, 2011).

And in focusing on these blasted artifacts of war, Meng admits that he writes from a slightly unusual niche as a historian. "Historians devote their careers to studying what happens through time," says Meng, an assistant professor of history at Clemson University. "I'm interested in exploring the relationship between space and time, how time permeates the spaces around us."

Shattered Spaces examines the material traces of Jewish life in five cities—Berlin, Warsaw, Potsdam, Essen, and Wroclaw—from 1945 to the present. Meng says he focused on Germany and Poland because they have received international scrutiny like no other European countries for how well or how poorly they have dealt with the legacies of the Holocaust.

His goal in this book was to answer two questions: What happened to Jewish sites after the Holocaust? And how have Germans, Poles, and Jews dealt with these sites since 1945?

"These five cities," Meng says, "were reduced to debris from aerial bombs, street fighting, and also deliberate acts of violence, especially against Jewish property. The Nazis demolished Jewish sites across Europe, targeting in particular sacred spaces such as synagogues and Jewish cemeteries." Because they symbolized an enormous genocide, Jewish ruins and spaces in postwar Europe were distinct from other postwar ruins, he adds.

Confronting the rubble

After the war, German and Polish Jewish leaders in what had been reduced to tiny communities began to deal with the issue of what should be done with all these ruins, clearly realizing the enormity of the problem. "Berlin, the epicenter of Hitler's empire, which caused much of the damage, had seventy-five million cubic meters of rubble after fifty-two thousand tons of aerial bombs and street-by-street fighting in the last throes of the war," Meng states.

Despite the scale of the work ahead, Jewish leaders knew what ideally should happen: Jewish sites should be preserved. In 1951, a group of American and German rabbis demanded the preservation of synagogues and Jewish cemeteries in the Federal Republic of Germany (FRG). In the Communist East, Jewish leaders made similar appeals to officials in the German Democratic Republic (GDR) and the Polish People's Republic.

But Jewish organizations could do only so much, Meng explains. Local Jewish leaders had little control over what happened to Jewish sites. In West Germany, East Germany, and Poland, municipal officials owned and controlled most communal property. Despite the similarity of this political reality, Western and Eastern leaders handled the issue of Jewish property very differently.

"Though it's true Jewish leaders in West Germany thought the ideal solution was to preserve religious ruins, the word 'ideal' is key here," Meng explains. "The amount of property and scale of the problem was so large that widespread preservation simply wasn't a real option." And though most Jewish communal property was returned to newly created Jewish successor organizations in West Germany, they often ended up selling it to local governments in order to distribute the profits as quickly as possible to Holocaust survivors.

A distinctly different political solution unfolded in East Germany and Poland, where both Communist parties rejected restitution altogether and seized all Jewish property. This happened for three reasons, Meng says.

"Seizure of Jewish property fell right in line with the Communist parties' general nationalization of property rights under Communism. These systems also viewed restitution—and this was especially true in East Germany—as a Western, American solution and therefore untenable as the Cold War began. Thirdly, property seizure stemmed from anti-Semitism that not only hadn't dissipated after the Holocaust but shaped the Communist regimes."

Meng says that when he started the project, he thought that the main framing of the book would be about a "divided memory," about differences in postwar handling of Jewish sites rather than similarities. This turned out not to be the case.

"For example, in both East and West, local officials were almost always the ones with the power to decide what to do with Jewish sites, and decisions by local officials often proved disastrous," Meng says. In the 1950s and 1960s, urban planners, historical preservationists, and local political leaders demolished numerous damaged Jewish sites or allowed them to fall into ruin. In some cases, such as in Warsaw, almost every last fragment of the Jewish past—its streets, shops, and prayer houses—vanished from the urban landscape.

"As Poles and Germans rebuilt their bombed-out cities, towns, and villages, they expelled the traces of the Jewish past," Meng says. "The few Jewish sites that escaped the wrecking ball gradually decayed by neglect or were turned into movie theaters, storage houses, swimming pools, libraries, and exhibition halls."

Michael Meng

Across Germany, small memorials mark places where Jews once lived. The squares are called "stumbling blocks" because people stumble on them in everyday life.

Michael Meng

In Wroclaw, Poland, a Jewish community has been restoring the White Stork, the only synagogue in the city to survive the war. Plans call for a Jewish culture center and museum in the building.

Local officials in Poland, East Germany, and West Germany made deliberate choices about what to rebuild and preserve from the rubble of the war. In his book, Meng points out that when selecting what was culturally valuable, the officials were also making choices about what was not.

"In the 1950s and 1960s, they rarely perceived Jewish sites to be part of the national or local heritage worthy of being maintained. Jewish sites also reflected a deeply discomforting past that few Germans and Poles wanted to deal with in the early postwar decades."

A Renaissance for Jewish ruins

Not all Jewish sites in the cities Meng researched were destroyed during the war or by the postwar wrecking ball. Cemeteries were the main Jewish spaces that survived urban reconstruction, and two main synagogues in Essen and Wroclaw also survived.

"By the late 1970s, a dramatic change started to unfold across this diverse region," Meng says. "In one of the more remarkable shifts in postwar European history, Germans and Poles went from seeing Jewish sites as worthless rubble to perceiving them as evocative ruins that had to be preserved." This transformation came about in large part, he says, as younger generations of Poles and Germans grew up in societies with much less hostility toward Jews.

In East Germany and Poland, Jewish sites became national and international issues, as the two Communist parties experienced growing pressure at home and from abroad, primarily from the United States and Israel, to rethink their earlier anti-Jewish policies.

"Preserving Jewish sites became important as both East Germany and Poland started to shift their foreign policy, gradually, to build better relations with the West toward the end of the Cold War," Meng says, adding that since the collapse of Communism in 1989, interest in Jewish sites has increased at a dizzying rate. Tens of thousands of tourists from the United States, Israel, Canada, and the United Kingdom have traveled to Poland and, increasingly, Germany, in search of the Jewish past.

"People have become drawn to Jewish spaces for a variety of reasons—heritage, growing discussions about the Holocaust, nostalgia for a lost past, and quests for new meaning and identity," Meng points out. "Jewish sites have become historical monuments, valuable ruins of the past."

Some archival globe-trotting

Meng says that when he first began thinking of doing research for this book, he knew it would be a time-intensive project.

"I spent three years researching the book and three years writing it, and during that time not a day went by when I didn't think about Jewish spaces in Germany and Poland—it was constantly on my mind."

His research was also travel intensive because the documents and histories he needed to read were so spread out. Meng worked in over thirty archives in Germany, Poland, the United States, and Israel.

"One of the things I most enjoy about being a historian is working in archives, those depositories of letters, diaries, memoirs, reports, and memos," Meng wrote in an email from Germany, where he's doing archival work for another book. "Historians have only what has been conserved in the archives, and multiple threats exist to conservation—politics, time, war, and water. So historians reconstruct what they can from fragments."

A number of fellowships, from the Holocaust Educational Foundation, the American Council of Learned Societies, the Graham Foundation, and the Charles H. Revson Foundation, among others, supported his work and travel.

"While my book deals with many differences, it is ultimately about a shared history of Germans and Poles encountering Jewish ruins in quite strikingly similar ways across both sides of the Iron Curtain. The absence of a clear divide along national and political lines surprised me the most. This book complicates the traditional wisdom that Western democracies got things generally right, while the Communist East failed to do so," Meng says.

Another major point, he says, is how the meanings of space shift over time.

"Contemporary historians typically think of time in linear or circular terms. But in following the thinking of scholars such as Reinhart Koselleck, an intellectual historian, and Stephen Jay Gould, I'm attracted to the notion of geological, layered time as a different way of considering the depth and complexity of the past. Just as geologists study the history of the earth preserved through the strata of its sedimentary rocks, scholars can examine the past through its layers in all their variety of shape, size, density, length, texture, and color.

"This book is one measure of such historical depth, an exploration of the movement from destruction to gradual preservation."

Michael Meng is an assistant professor of history in the College of Architecture, Arts, and Humanities.

Patrick Wright

drive time

Jillian Weise gets some of her best ideas when she's driving her car. No wonder her poetry and fiction cover so much ground.

by Jemma Everyhope-Roser

Until she took a college course about the Holocaust, Jillian Weise thought she wanted to be a broadcast journalist. Disabled people, she learned, had been the first to be exterminated by the Nazis using the cyanide-based pesticide Zyklon B.

"This came as a shock to me," she says, "and it also felt a little like hidden history." She started thinking: Where is disability history? Where does it reside? Why isn't it taught? What does disability history even mean? Who would write it? These were the questions that would eventually lead her to write her first novel, *The Colony.*

"Then I went to New York for six months," she says, "and realized that in order to be a broadcast journalist you have to always tell a story on someone else's schedule. You have to be where the story is. And I would rather the story come to me."

When she came back to college at Florida State University, she took courses in fiction and poetry. She loved it. She knew what she wanted to do: write. She was ready to go anywhere. At the University of North Carolina Greensboro, she found a small family of writers. She says, "I really love the idea of being in conversation with other writers, other artists, finding ways to propel a conversation forward, so that it's not the same old thing, so that it's something no one's ever considered before."

She also found attention, direction, mentorship, and honesty.

"It's difficult to find teachers who can be brutally honest with you about your work," Weise explains. "Your family will never be that for you. Your friends will never be that for you. They'll never be that honest, because there's too much at stake."

The Amputee's Guide to Sex

In graduate school, she realized, "The people who write disabled characters for the most part are not themselves disabled. So we see disability in film and literature and culture, but these representations are inauthentic."

When *The Amputee's Guide to Sex* was published, she was twenty-five and working on her Ph.D. She was also as a part-time editorial assistant at *The Paris Review* and had written several one-act plays that went on to be produced.

"I had no intent to write about being disabled," she says. "I had no intent to write from an autobiographical viewpoint. But once I realized that there really wasn't a model of how to do it, it was liberating. I could start anywhere then. It didn't have a canon. It was brand new."

Although critics received *The Amputee's Guide to Sex* very well, Weise found having her poetry published difficult on a personal level. "When I would read from the book, people would want to know if it's true, or which parts are true, what really happened."

Fiction, on the other hand, operates under different parameters. The expectations that the content will relate to personal experience are gone. It's safe. So that's when she decided to really take some of the research she'd done, dive into fiction, and pursue something else—a Fulbright.

The Fulbright

The application process was rigorous. Weise planned her writing and her travels, then was selected for an interview. She also needed a mentor located in the country she was visiting.

Weise's mentor was a woman named Delfina Muschietti, a poet, critic, professor, and director of translation at the University of Buenos Aires. Weise had previously worked with her on a translation of Bob Dylan's *Tarantula.*

"Because she really loves Bob Dylan," Weise says, "and she wanted to bring it into Spanish in an updated, contemporary vernacular. Anyway, she was lovely. And it was great fun to work with her on Bob Dylan's first novel, deliberate with her over a word he used in English and what it would mean in Spanish."

Dylan's novel *Tarantula* has speed, spontaneity, and snippets of poetry that informed her work, Weise says. She also admired how his "sentences were alive with spirit and syntax," and she wanted that to be present in her own writing.

Jillian Weise received her Fulbright and went off to Argentina to follow in Darwin's footsteps.

Before the *HMS Beagle* sailed to the Galapagos, Darwin's ship first landed in Argentina at Tierra del Fuego. Darwin observed local cultures, examined the geology, and collected specimens to send off to Cambridge. At the time he was writing *The Red Notebook*, which contained his theoretical writings.

Weise read *The Red Notebook* and lived for seven months at the end of the world in the southernmost city, Ushuaia. Darwin's image was everywhere, from buildings to bars and beers. The work Weise did in Argentina inspired her interest in genetics and engineered the premise behind her novel.

From *The Colony*, page 124

Old Faithful said, he was worried, I was young, but that wasn't it, that wasn't where he stopped. If he had stopped on "you're young" then it would have been fine. Old Faithful said, "There's your condition to consider. What if I cheated on you with a two-legged woman?" That was his fear. "How often do you think about cheating on people before you're with them?" I asked. "Not often," he said. "Only with you."

This did break my heart.

"I'm also disappointed by fiction in which characters' feelings never get hurt. Probably it's just bad fiction. But even in good fiction, it doesn't seem like anyone really gets hurt—to their core. I don't see the point of writing pleasantries and stories in which people are surface-level hurt but never really deeply traumatized or affected."

— Jillian Weise

From *The Amputee's Guide to Sex, page 18*

Despite

At six in the morning
the woodpecker took
to the tree, the man from
last night slack-jawed
& asleep. The leg would
not slide on & would not
slide on. He said he rather
liked it, could
kiss despite it. I know
that word. It means
the desire to hurt someone.

"Obviously, I have a fake leg. Speakers in the poems in *The Amputee's Guide to Sex* often have fake legs, but I am real reticent to say this is factually correct account or chronicle of my life. Because that's not true. And that's probably one reason why I wrote a novel."

— Jillian Weise

The Colony

This novel had been a long time in the making. What finally gave her both the impetus and the time to complete it was a breakup.

"The world does not want you to write a novel," she says, laughing. "The world would rather you buy something or drink something or go out with your friends. But, after that breakup I really didn't want to see anyone or do anything, so I really had time to dig in. It was very helpful, actually."

She says she also stopped reading during that time. She says, "It can feel almost suffocating, having all these things you ought to be reading, but to say, 'I'm not going to read anyone's recommendations or any books right now' allows another kind of freedom."

This also helped her turn off the insidious, editorial side of her brain. Apparently it worked, because, she says, "Before, when I had written prose, it always seemed laborious and too difficult. But then, when I had that emotional gravity, it seemed easy and carefree. That's what I want to achieve anytime I go back to prose."

At the same time she was writing *The Colony,* she was also very aware of two movies that had won Oscars: *Million Dollar Baby* and *The Sea Inside*. The former was American and the latter was an international film, but both have a similar message. Weise says, "The answer at the end of both is, if you're disabled, euthanasia is the only option for you. They're both endorsing this narrative, that is, if you're different, you should die. And that's a really quite terrifying prospect."

The Colony was published when she was twenty-eight.

"Cathedral by Raymond Carver"

Her next project took a new turn. Initially, she was afraid no one would take her eight-page poem, "Cathedral by Raymond Carver," because she's stealing Carver's story and characters. The original "Cathedral" is a short story about a blind man who comes to visit a married couple. The husband is jealous of the blind man, because of a decade-long audiotape correspondence between the blind man and his wife.

Weise loves the short story but hates how it's taught. The blind man is usually seen as this noble character and his friendship with the wife is interpreted as being platonic, she says.

So Weise formed a hypothesis: "It's because we can't imagine a disabled person being anything other than noble or platonic. This is what led to me to write the poem."

Carver, known for his minimalism, didn't provide the contents of the audiotapes. This is what gave Jillian Weise the in that she needed to get started.

"It's a great prop," she says, "just to imagine what these two people are sending each other through the mail for a decade."

The poem will appear in *The Literary Review*, published by Fairleigh Dickinson University.

The Book of Goodbyes

Her other current project, *The Book of Goodbyes,* is nearly finished. Weise's manuscript was solicited by BOA Editions and judged along twenty-five other semi-finalists before it was awarded the Isabella Gardner Prize.

Isabella Gardner (1840–1942) was a great patron of the arts. In addition to leaving her money to many charities, she left an endowment for her museum with strict orders that her permanent collection should never be altered and all the main exhibits should remain as she left them.

The Book of Goodbyes contains poems Weise wrote when she was writing *The Colony*.

"I like having multiple projects happening at once," she explains, "so you can never get discouraged about one project because you always have something else to go to."

The collection is structured like a play with four sections: Act I, Intermission, Act II, and the Curtain Call. As for content, it traces the arc of a relationship with a character named Big Logos.

"He functions as a sort of Johnny Depp, John Keats character," Weise says. "But also, metaphorically, he's the word—he's the word of classically male canon, the medical establishment, and so on. He has many connotative values."

The obvious connotative value is religious. Her family was, she says, "extremely Christian," but her relationship with her faith is more comfortable now. She self-describes as an Augustinian Christian: "Let's challenge everything. Let's question. Let's have lots of doubts. I guess, the term for what I am is an apologist. I bring that to my work too, a belief in a God, a belief that science and religion are not irreconcilable, that they can be in conversation."

But for all those big concepts, Weise says, "At its heart I hope *The Book of Goodbyes* is a great love story told in poems with the structure of a play."

> **"I think the concerns I bring to poetry are the same as for fiction, which is feeling and emotion and wanting to transform a feeling through language. This is really difficult. I mean, think about the last time a book made you cry. It's so difficult. Yet, that's the point."**
> **— Jillian Weise**

The Book of Goodbyes, her third book, will be coming out in 2013. Jillian Weise will be thirty-one.

What's next?

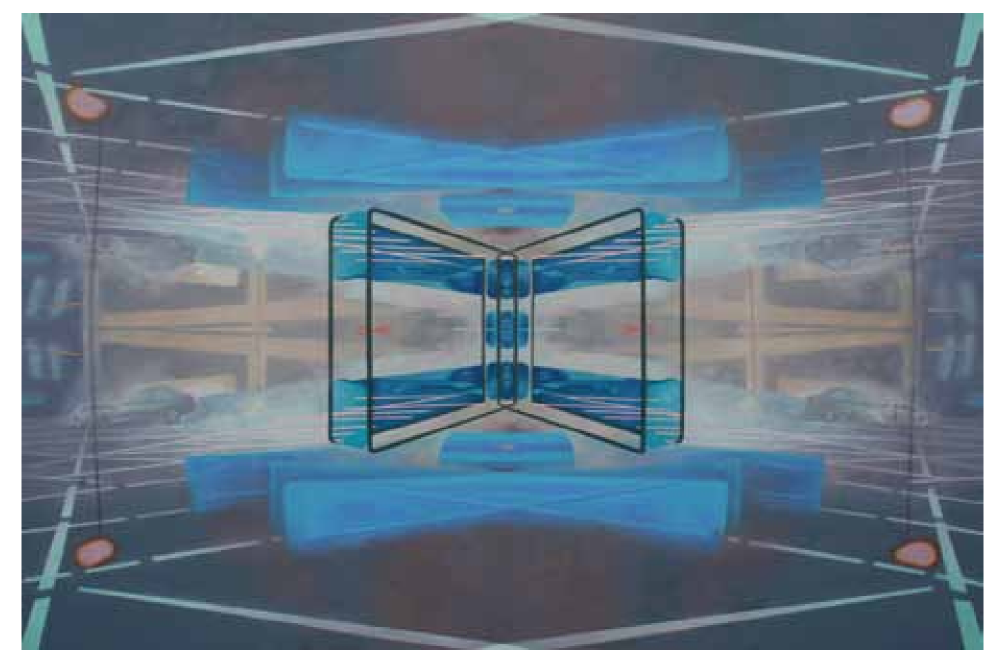
Weise has a new novel, she says, "But I don't know anything about it yet. Except that I'm some pages into it and it has momentum. But I'm really superstitious. So I won't tell you anything about it, because as soon as I tell you something, it will annihilate itself." She laughs. "Or that's my fear, at least."

Jillian Weise is an assistant professor of creative writing in the Department of English in the College of Architecture, Arts, and Humanities. Her poetry collection, The Amputee's Guide to Sex, *was published by Soft Skull Press in 2007. The* Colony *was published by Soft Skull Press in 2010. Her newest collection,* The Book of Goodbyes, *won the Isabella Gardner Poetry Award and will be available from BOA Editions in fall of 2013.*

zoom out

Ribbon of light

John Ballato's lab in COMSET created this ribbon of polypropylene film with light-emitting nanoparticles carefully dispersed within to maintain clarity and supply a brilliant green. For more about COMSET, see page 32.



Bloom

Todd McDonald, associate professor of art, is a painter who finds extraordinary visual ideas in ordinary settings. The painting above, *Bloom* (oil on panel, 48 by 72 inches), is based on an image of a shopping-cart corral at a Bloom grocery store. "Through the elevation of everyday visual scenarios I draw comparisons to the history of visual spectacle to provoke discourse about how humanity finds meaning in everyday life," McDonald says. The work of one of his students, Carly Drew, is featured on page 28.

CLEMSON
UNIVERSITY

Office of the Vice President for Research
and Clemson Public Affairs
Trustee House, Fort Hill Street
Clemson, SC 29634-5611