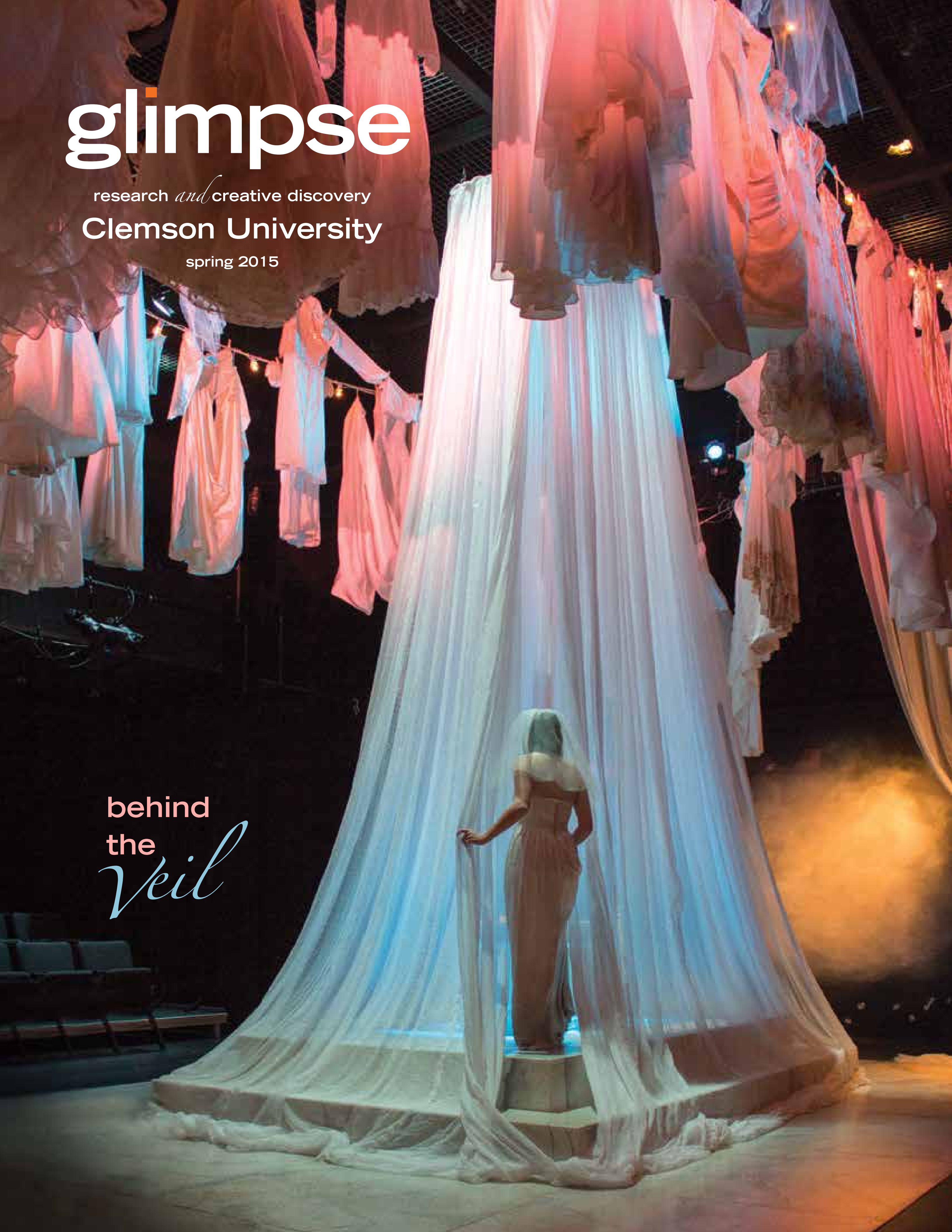
glimpse

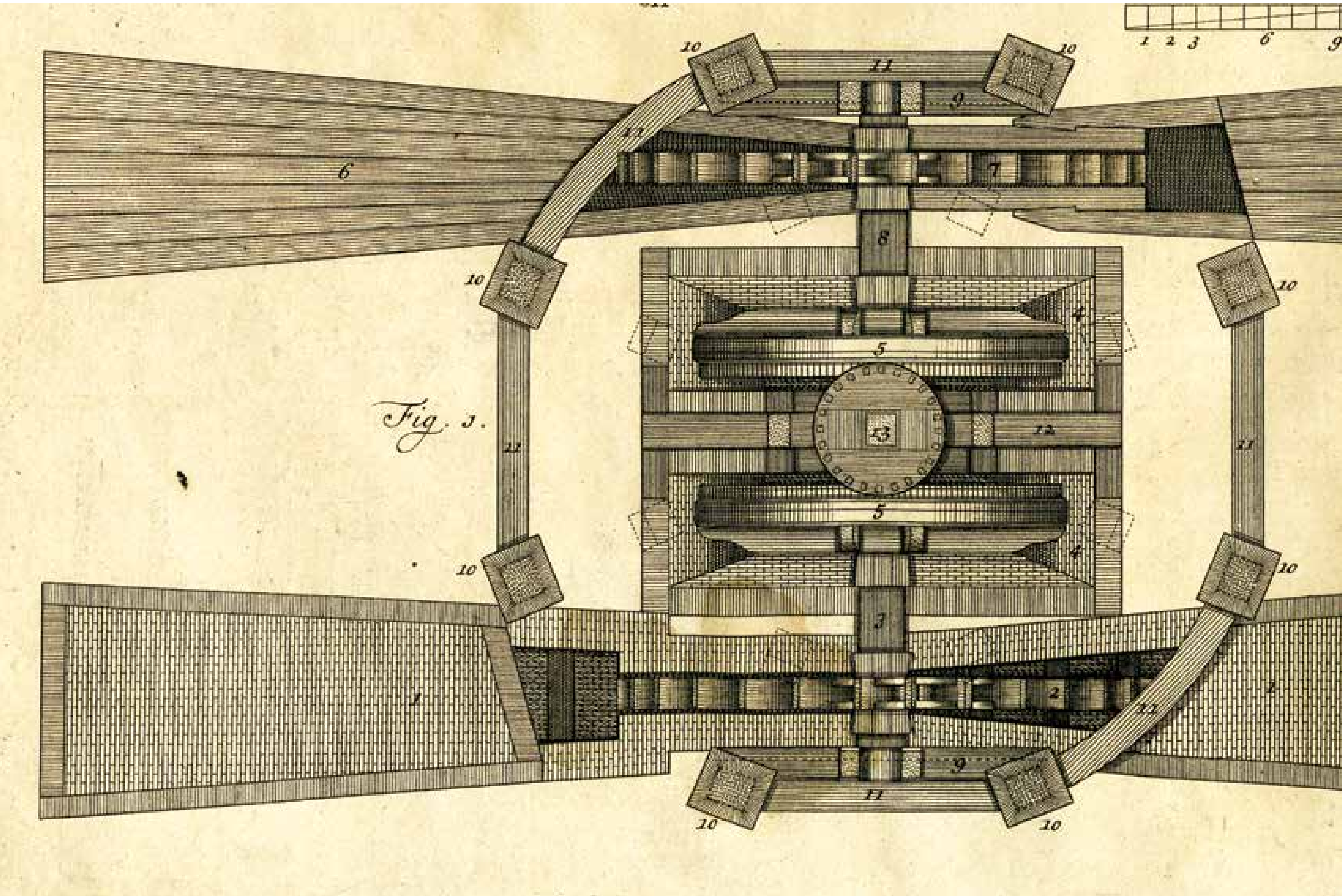
research *and* creative discovery

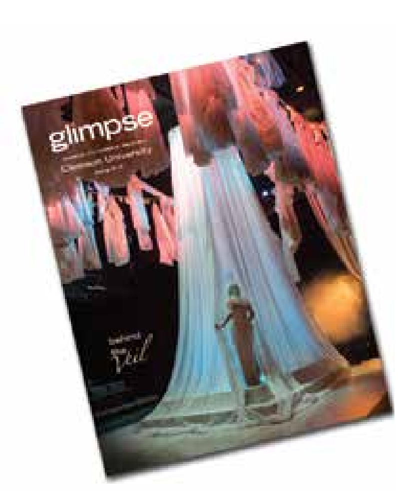
Clemson University

spring 2015



behind the *Veil*





of all human qualities

Behind the scenes of the play *Big Love*, we found a world of hard-won, deeply human discovery an audience never sees. Page 14.

Cover photo by Neil Caudle

glimpse

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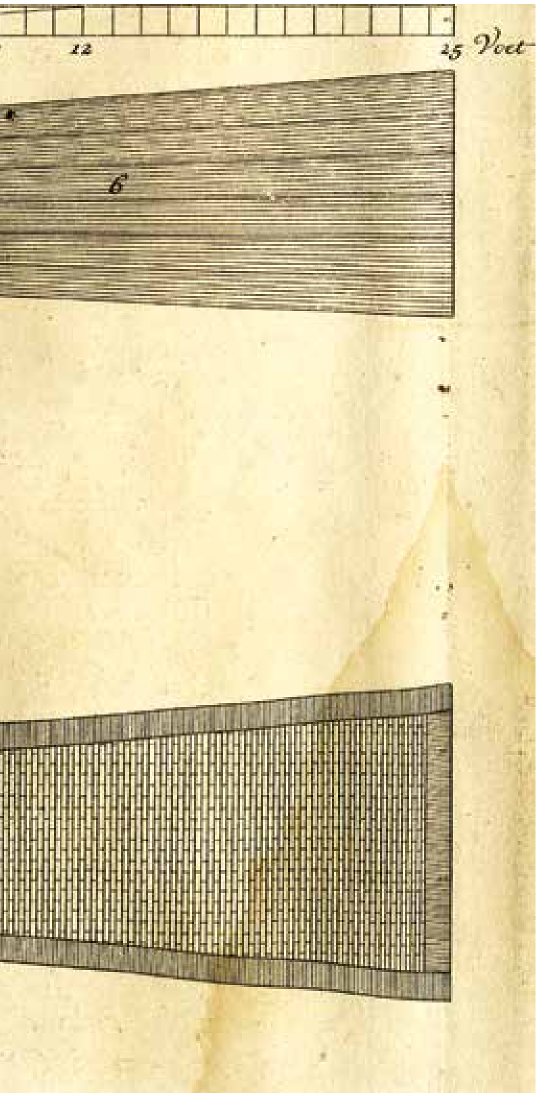


Courtesy of the Charleston County Public Library.

Wind power has deep roots in coastal South Carolina. Dutch engineers began using windmills to drain Lowcountry land for agriculture three centuries ago, and the technology spread into mills for lumber, paper, and rice. The image above, from Jan van Zyl's *Great Universal Mill Book* of 1734, shows the inner workings of a wind-powered paper mill. The two wide bow-tie shapes are troughs, and the wind-powered water wheels (top and bottom in the image) move paper pulp from trough to trough. Windmills like this were the pinnacle of technology in the early eighteenth century, embodying the best of engineering, mathematics, and practical craftsmanship. Today, the power of high-tech wind machines has returned to coastal South Carolina, in a facility for shaping the future of renewable energy. Page 32.

in this issue

What we learn from *Big Love*

A play, for those of us who have never attempted to stage one, may not sound like serious work. It is. As the poet Goethe put it, “Thinking is easy, acting is difficult, and to put one's thoughts into action is the most difficult thing in the world.”

When we ask our students to take on a drama as risky and robust as Charles L. Mee’s *Big Love,* we throw them into the deep end. We ask them to grasp, in one semester, explorations into the nature of justice, loyalty, and love that date back to Aeschylus, around 470 BC. We ask them to master the technical intricacies, not only of modern lighting, sound, and set construction but of acting, directing, and design. The effort of creating a character, and moving that character through space in a series of meaningful actions, and weaving those actions into a spellbinding whole, demands more than the creative impulse alone. Difficult skills must be studied and mastered, with all of the demanding complexities of a language or science or math.

As our writer and editor followed the student production of *Big Love,* sitting in to observe early meetings, midstream rehearsals, and the trial by fire of opening night, they noticed the same kinds of struggles and heard the same kinds of probing debates they’d heard among scientists or engineers. These drama students and their mentors were problem solvers, people pushing themselves and one another, often late into the night, toward answers, solutions, innovations—toward excellence. It’s a vivid reminder that a rigorous quest for discovery, whether in science or the arts, requires, at a minimum, character.

Perhaps that’s why businesses and institutions have begun using drama to help them excel. Corporations hire theater troupes to coach their executives in voice, movement, and improvisation, to break down the inhibitions that limit leadership and professional growth. Even in science education, teachers are using drama to open students’ minds to the possibilities of scientific research, engineering, and math.

At Clemson, we recognize in our student productions the essential motive of a land-grant university: to give our discoveries life beyond the academic realm. When students take the stage and perform for an audience, they deliver a product of real public value, and they teach us something about that “most difficult thing in the world”: putting thoughts into action. At Clemson, that is what we’re here to do.

R. Larry Dooley
Interim Vice President for Research

zoom in

Neil Caudle

A place for reflection, riverside

About an hour's drive north of Charleston, near Huger, South Carolina, stands a fine old brick chapel on a secluded, oak-shaded bluff overlooking the Cooper River. The place is known as Pompion Hill, but locals tend to pronounce it Pumpkin Hill, probably because the Huguenots who settled the area used an old French word for pumpkin, *pompion*. But there's nothing pumpkin-like about this faceted jewel of a chapel, which the National Register of Historic Places describes as a "miniature Georgian masterpiece."

(continued, next page)

Erected between 1763 and 1765 as an Anglican "chapel of ease" for St. Thomas Parish, the building remains substantially unaltered, except for reinforcement and repair. Most days, the site is closed to the public, but if you're one of Amalia Leifeste's students in historic preservation, you can follow her down a long, narrow lane through the forest and arrive here to study the place in detail, to soak it up as bricks absorb the autumn sun.

Under Leifeste's guidance, graduate students from Clemson and the College of Charleston have learned to measure and draw every feature of the building with exacting precision, from its carved red-cedar pulpit to its graceful fanlights and exterior brickwork laid in Flemish bond. Back in Charleston, they rendered floor plans and elevations using computer-aided design software. Sometimes, the most artful details did not easily yield to quantification.

"You can't really measure the dove," Leifeste says, pointing to a drawing of a hand-carved bird perched atop the pulpit's ogee roof. "So we take a straight-on photograph and then trace it to try to do a line drawing to approximate the depth and complexity of the carvings."

All of this meticulous attention to detail helps students internalize the architecture and its visual vocabulary. "They learn it in a different way than you would by just walking through quickly," Leifeste says.

But the primary reason for documenting a treasure like Pompion Hill is to provide a reliable record, a baseline. "We use documentation drawing to capture a snapshot of a building for that moment in time, in case something happens, or in case there are changes," Leifeste says. "The chapel's in really good shape, but if anyone needs to work on it later, it will be useful to have a baseline record of its configuration." The documentation will be available to other scholars through the Historic American Building Survey archives in the Library of Congress.

Along with documenting the building, students analyzed the grounds, learning about the chapel's relation to the land and the culture of the time in a workshop with adjunct faculty member Andrew Kohr. And, with Leifeste's colleague Frances Ford, they studied the materials science, working to conserve the nearby cemetery's gravestones.

After their study of Pompion Hill, the students presented their results to the stewardship board that cares for the chapel. "The board was excited to have these drawings and the work we're doing on the cemetery, the grave markers," Leifeste says. "It's really beneficial to them."

–Neil Caudle

Amalia Leifeste is an assistant professor and Frances H. Ford is a lecturer and conservation lab specialist in the Graduate Program in Historic Preservation at Clemson University and the College of Charleston. Carter L. Hudgins is director of the program.

The Pompion Hill Chapel, seen here from the e

Amalia Leifeste

Left: Students Haley Schriber, Sarah Sanders, and Meghan White measure a portion of the chapel's wall while John Evangelist records the numbers.

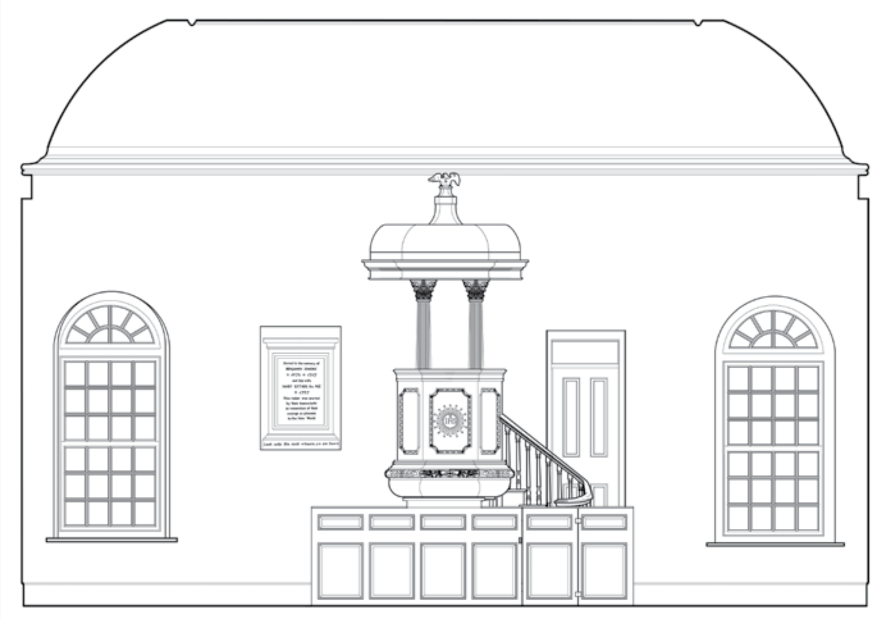
Right: A drawing of the chapel's west wall, including the pulpit with its sounding board and ogee roof. Students rendered every part of the building with this level of detail.

Far right: Naomi Doddington and Jean Stoll document details of a door in the west wall.

zoom in

east, is a small Georgian jewel.

Neil Caudle



Carter Hudgins

from dusty chaos, a planet forms

Sean Brittain and his colleagues find a new way to watch the birth of planets.

The twinkling stars in the night sky may look peaceful here on Earth, but it's chaos up there.

Some of those stars are surrounded by swirling clouds of gas, dust, and rocks that collapse into each other to form planets.

Given enough time and the right circumstances, the chaos will give way to order. A solar system like our own will begin to take shape, but exactly how that happens remains shrouded in mystery.

Maybe not for long.

Sean Brittain led an international team of scientists that discovered evidence strongly suggesting a planet is orbiting a star, known as HD100546, about 335 light years from Earth.

The team's work, combined with previous research, could mark the first time astronomers have been able to directly watch multiple planets forming in sequence. It's something astronomers have long believed happens but have never been able to see. Other solar systems that astronomers have observed are either fully developed or too far away to see in the kind of detail that HD100546 offers.

"This system is very close to Earth, relative to other disk systems," Brittain says. "We're able to study it at a level of detail that you can't do with more distant stars. This is the first system where we've been able to do this.

"Once we really understand what's going on, the tools that we are developing can then be applied to a larger number of systems that are more distant and harder to see."

Signs of a gas giant

The star is about 2.5 times larger and 30 times brighter than the sun. It's in the constellation Musca, or the Fly, and can be seen only from the Southern Hemisphere.

The "candidate planet" that Brittain has been watching might be at least three times the size of Jupiter and might be an uninhabitable gas giant. It would take more than four lifetimes to get there, even traveling at the speed of light.

Brittain made three trips to Chile as far back as 2006 to gather data for his research. He used telescopes at the Gemini Observatory and the European Southern Observatory.

The team reported its findings in *The Astrophysical Journal.* News outlets around the globe covered the discovery in at least four different languages.

Previous research by a different team that included some of the collaborators on the Brittain team found a collapsing blob of gas and dust that could condense into a planet in about one million years. That means astronomers believe they have found not one but two potential planets orbiting the star.

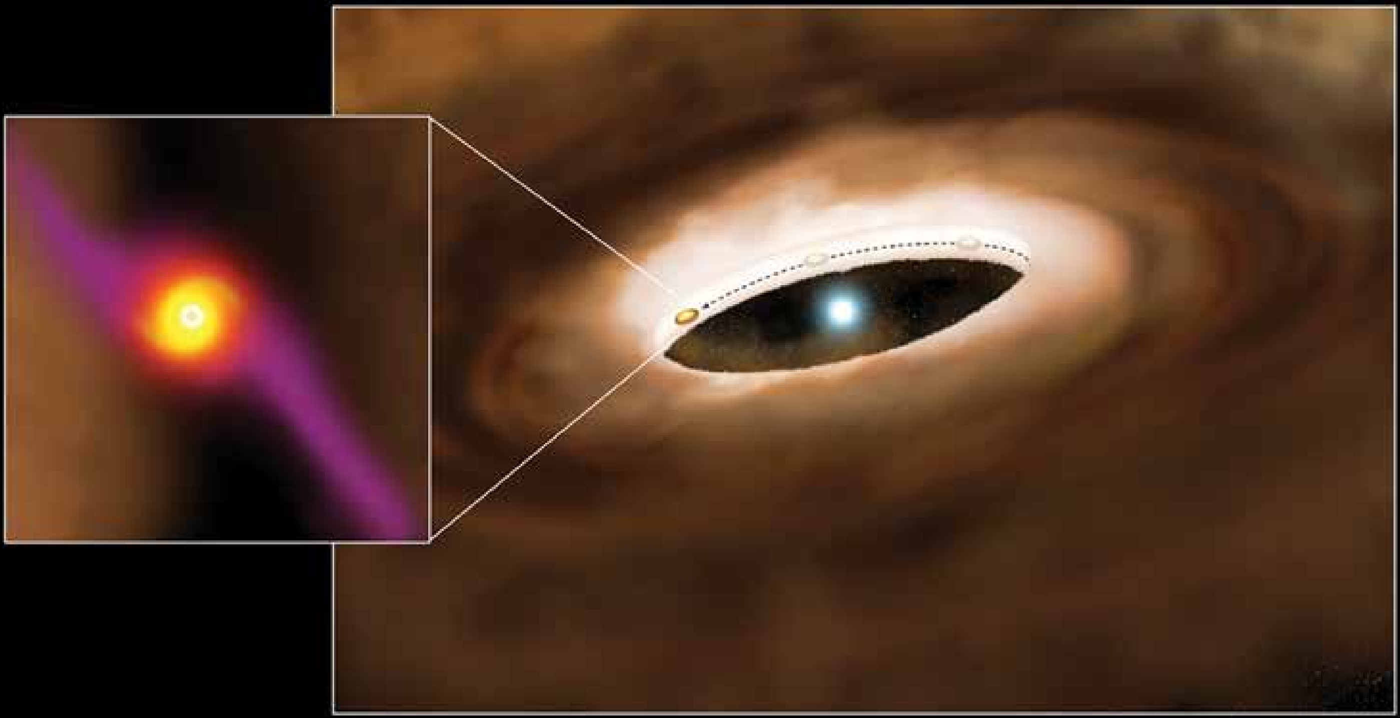
Mark Leising, the chair of Clemson's astronomy and astrophysics department, says that Brittain's collaborations with leading institutions around the world have raised the department's international profile and contributed to discoveries "at the forefront of astronomy."

"Astronomers are now very good at finding already-formed planets around many nearby stars, but it has been difficult to watch the planets in the process of forming," Leising says. "Using very clever techniques and the most advanced

Craig Mahaffey

Sean Brittain's path to astronomy led through chemistry, and he has used a chemist's tool, high-resolution spectroscopy, to study stars and planets.

P. Marenfeld & NOAO/AURA/NSF



This artist's conception shows the young massive star HD100546 with a planet forming in its surrounding disk. As gas and dust flow from the disk to the planet, the material surrounds the planet as a circumplanetary disk (inset). These rotating disks are believed to be the birthplaces of planetary moons. Sean Brittain and his collaborators have reported evidence for an orbiting source of carbon monoxide emission whose size is consistent with theoretical predictions for a circumplanetary disk. Observations over ten years traced the orbit of the forming planet from behind the near side of the circumstellar disk in 2003 to the far side of the disk in 2013. The observations provide a new way to study how planets form.

telescopes on Earth, they have accomplished that."

Fusing chemistry and physics

For Brittain, the path to the stars was through chemistry.

He received his bachelor of science in chemical physics from LeTourneau University in Texas and then headed to Notre Dame to study the foundations of quantum mechanics. But he found that the advisor he wanted was retiring and not accepting new graduate students. Brittain soon found another professor who was doing research into the organic chemistry of comets. He received his Ph.D. in 2004 and became a NASA-funded Michelson postdoctoral fellow at the National Optical Astronomy Observatory. Brittain came to Clemson University two years later.

Brittain's chemistry background helped get him an early start on using high-resolution spectroscopy to study the formation of stars and planets. It was a relatively new technique early in his career, he says, and has played a major role in his research on HD100546.

The technique enabled the team to measure small changes in the position of the carbon monoxide emission. A source of excess carbon monoxide emission was detected that appears to vary in position and velocity. The variations are consistent with orbital motion around the star.

The favored hypothesis is that emission comes from a circumplanetary disk of gas orbiting a giant planet, Brittain says. "Another possibility is that we're seeing the wake from tidal interactions between the object and the circumstellar disk of gas and dust orbiting the star," he says.

–Paul Alongi

Sean Brittain is an assistant professor of physics and astronomy in the College of Engineering and Science. Brittain served as lead author on the article in The Astrophysical Journal. *Coauthors were John S. Carr of the Naval Research Laboratory in Washington, D.C.; Joan R. Najita of the National Optical Astronomy Observatory in Tucson, Arizona; and Sascha P. Quanz and Michael R. Meyer, both of ETH Zurich, Institute for Astronomy. Paul Alongi is a technical and features writer in the College of Engineering and Science.*

why the pitcher does research

An athlete prepares for a future in baseball's number-crunching culture.

When Matthew Crownover takes the mound for one of his starts, he doesn't think about analysis. Any other day, he can tweak his pitching mechanics or analyze the tendencies of opposing hitters. But when it's his turn to pitch, he sets analysis aside. He takes the ball and throws it to his catcher. Anything else would just get in the way.

But Crownover knows very well that off the field the business of baseball today is all about numbers and analysis. Ever since Billy Beane brought a statistics guru to the low-budget Oakland Athletics and propelled the team into the playoffs (inspiring Michael Lewis's book *Moneyball*), major-league clubs have been waging a stats-and-analysis arms race, hiring their own statisticians to crunch the numbers and advise them on every aspect of the game.

So Crownover, who is planning for a future in baseball after his time on the field, saw an angle for his career.

An eye on the dream job

"I know baseball's not going to last forever," he says about playing the game. "So whenever it's over I want to have a job to do. And one of my dream jobs—aside from being a coach one day—would be to work in a front office somewhere, and be like a general manager. These days, you have a lot of analytical guys who run the front offices, but there are also other, old-school guys who are baseball guys. I would be more like the old-school guys because I've played the game and been around it for a while, but I thought it might help to have a little background in some of these statistical things, to have a little bit of résumé."

In the fall of 2013, Crownover was taking a class in sports communication and began talking with Jimmy Sanderson, who directs the B.A. program in that area. "He knew who I was, and he comes to the games," Crownover says. "So I asked him if he was interested in helping me with an independent study."

Yes, Sanderson was interested, and he liked the topic Crownover pitched him. "I had some ideas about how each club constructed its team," Crownover says, "and whether it was more effective to build through free agency or build through homegrown players. Which positions were more effective, homegrown versus acquired?"

Sanderson and Crownover used statistical modeling to investigate MLB roster construction for all playoff teams from 2009 to 2013. "We wanted to know if there are certain positions that produced more significant results based on whether the player is homegrown or acquired," Sanderson says. The researchers created variables for player position, league affiliation, how the player was acquired, and wins above replacement (WAR) value, a statistic that summarizes a player's total value to the team.

The tests revealed that left fielders, relief pitchers, and catchers who were homegrown had higher WAR values than those who were acquired. The researchers also found that it was even more advantageous for American League teams to develop their second and third basemen from within their organizations.

Where homegrown players pay off

"The results show generally that teams need to protect their homegrown players at these positions and focus acquisition efforts on players at other positions," Crownover says.

He and Sanderson presented their results at the 2014 conference of the Society for American Baseball Research (SABR) in Houston, Texas, winning the USA Today Sports Weekly Award for the best poster presentation at the conference.

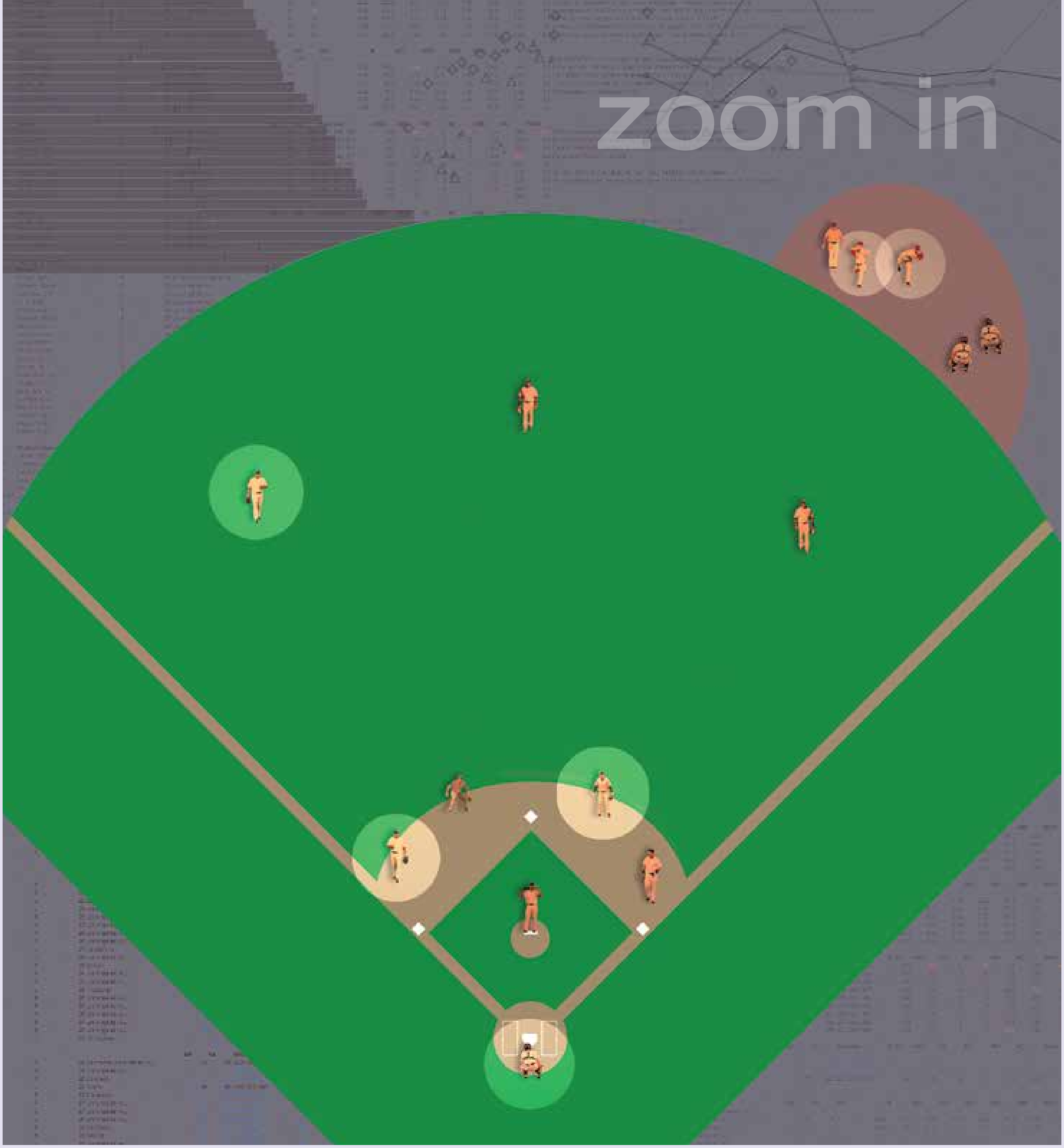
Over the fall and winter, the researchers expanded their research to a thirty-year period, 1982–2013, and are running a statistical analysis of the data.

"This research is an example of the ways that sports are being quantified," Sanderson says. "Baseball was the early adopter, but now most professional sports leagues are using advanced metrics to try and optimize player development and roster construction."

For Crownover, the project has helped him strengthen a weakness. "I'd never been big into the stats thing. But if I really want to get into this business one day, with all of these kids who are coming out of Harvard with Ph.D.s and are running

Dawson Powers

Matthew Crownover in action for the Tigers.



Neil Caudle

Winning with statistics

Today, stats drive decisions in Major League Baseball. Should a team grow its own players through its farm system? Or should it trade for new talent and sign free agents? Sanderson and Crownover found that teams fared best when they cultivated homegrown left fielders, relief pitchers, and catchers. In the American League, teams also found an advantage using homegrown second and third basemen.

baseball, I kind of want to know what's going on. I want to be the guy who knows the baseball side, and has played at a high level—in Division One and maybe even some professional ball. But I also want to be the guy who, while he was in college, tried to do something on the analytics side. So he's got a baseline understanding of what we're doing here; he's going to understand both sides. And that's what a communications major can do, right? Talk to both sides?"

—Neil Caudle and Brian Mullen

Matthew Crownover, a junior from Ringgold, Georgia, is majoring in communications studies; he is also a left-handed pitcher for the Clemson Tigers. Jimmy Sanderson is an assistant professor and director of the Sports Communication B.A. Program in the Department of Communication Studies, College of Architecture, Arts, and Humanities.

Drilnoth, Creative Commons

matchmaking
for healthier melons

Watermelon growers around the world are learning from Clemson a new technique for plant grafting that could help produce more food with fewer chemicals. Grafting, which involves splicing the rootstock of one plant to the fruit-producing top—called the scion—of another, isn't new. What *is* new is the ability to prevent rootstocks from sprouting their own shoots and leaves, the "regrowth" that takes over the plant and starves the scion. Until now, farm workers have had to scout grafted plants and pinch off the rootstock's unruly offspring by hand.

Richard Hassell and his colleagues have found a way to save farmers the trouble. By applying a carefully calibrated formulation of a chemical used by tobacco growers to control plant suckers, the team stopped rootstock regrowth in melons and their kin, squashes and cucumbers.

"We found that we can apply it to growing tissue in the rootstock, and it will stop regrowth one hundred percent of the time," Hassell says.

Graft without corruption

The method, which previously had not been tested with watermelons, led to a patent last year and attracted lots of attention from melon growers. Hassell has met with producers in Asia, South America, Israel, and Australia. And he's been helping South Carolina farmers and gardeners willing to put their fingers on the line. At a workshop in Columbia last winter, trainees used razor blades to cut seedling stems then mix and match disease-resistant root bottoms with robust vegetable-growing tops.

"Grafting is more art than science," Hassell told the group. "You have to do it carefully and consistently if you want to get results."

Grafting has a special following among organic growers, because disease-tolerant rootstocks can replace the use of chemicals for treating disease-ridden soil. What's more, research suggests that grafted plants respond better to environmental stresses and produce longer during the growing season than non-grafted plants.

Conventional growers in the United States, who typically raise melon crops from seed without grafting, have controlled soil-borne diseases with chemicals. But some of the chemical products they have relied on have been taken off the market. Growers have also rotated their crops and cultivated new fields to avoid infected soil, but land is scarce and costly, especially around cities.

In Korea and Japan, where land is even scarcer and chemical options even fewer, growers have depended on grafting to plant the same crops continually on the same acreage. One hundred percent of the watermelon plants grown in Korea are grafted. Asia does have plenty of people, though, and a lot of them are busy plucking regrowth from watermelon plants.

"We don't have the labor here," Hassell says of the United States. "And we aren't willing to pay what it would take to do it."

But with the new method for controlling regrowth, coupled with automated grafting equipment, grafted plants may soon be bearing fruit in melon fields here and around the world.

"Everybody wants to know how we do it," Hassell says.

–Peter Kent

Richard L. Hassell is a vegetable specialist at the Clemson Research and Education Center in Charleston. Hassell, along with Clemson Extension vegetable specialist Gilbert Miller and University of Florida vegetable researcher Josh Freeman, demonstrated grafting methods in January at the South Carolina Watermelon Association's annual meeting, in Columbia, South Carolina.

Peter Kent

A grafted watermelon seedling.

the good sense of Glucosense

A team creates low-cost testing for diabetics in need.

Twelve dollars. That's the entire monthly household income for more than 25 percent of the families living in Tanzania. And the traditional cost of diabetes testing supplies per month? $120. According to the World Health Organization, 347 million people worldwide suffer from diabetes, and more than 80 percent of them are living in low- and middle-income countries.

To control their blood sugar levels, diabetics typically use test strips to check their glucose levels multiple times a day. Unfortunately, each test strip can be used only once. Low-income patients can't afford strips at market prices, and they rely heavily on donated supplies. But donated strips are rarely compatible with the donated machines. And since test strips are temperature sensitive, they are often not usable after being shipped.

Developing a solution

A team of researchers at Clemson set out to solve the problem. They wanted to make testing devices both cheaper and more easily accessible by finding a way to print test strips for pennies.

First, the team developed working test strips that could be manufactured on an ordinary inkjet printer. Because standard filter paper could easily tear and contaminate the meter, the researchers used contact paper to reinforce and protect the filter paper.

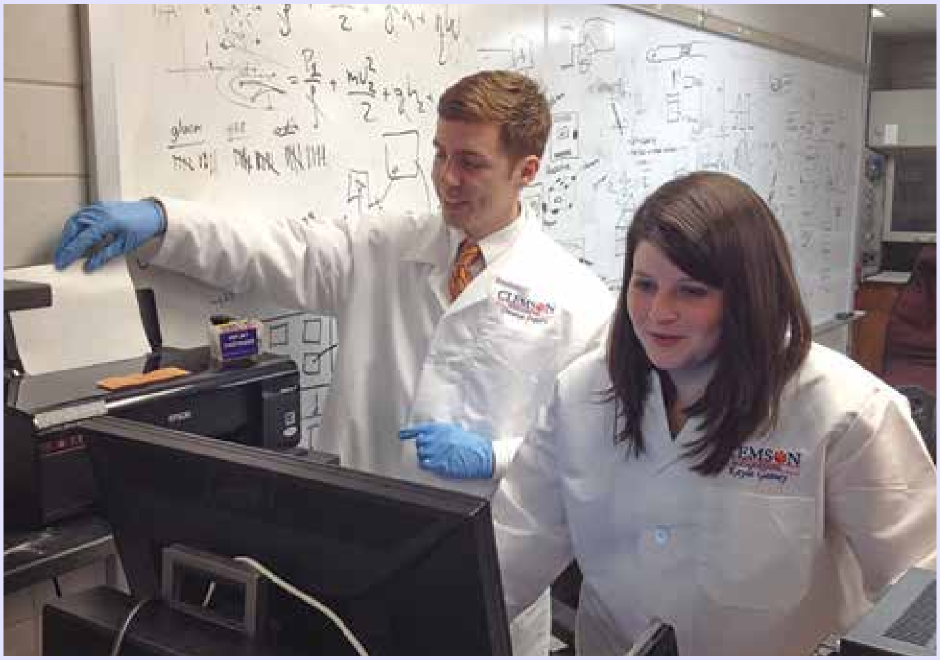
Each paper receives three solutions, printed on the strip in layers: enzyme one, enzyme two, and the dye. A separate ink cartridge is used for each solution, and the team can easily specify the amount of enzyme deposited on the paper. Every strip contains both a control side, which does not receive the enzyme one solution, as well as an experimental side, which receives all three solutions. The glucose in blood reacts with the glucose oxidase in solution one, causing the enzymes to turn the paper blue. The more glucose present, the darker the paper will be after the reaction.

The researchers found a relationship between the glucose concentration in blood and the amount of light absorbed by the strip. More glucose leads to a darker solution, absorbing more light. Using a simple meter, the team shines LED lights above the strip, while photodetectors below measure how much light passes through. The machine can then calculate the glucose level in the blood.

A start-up company, Accessible Diagnostics, LLC, was formed to bring Glucosense to the market. The members, Delphine Dean, Kayla Gainey, John Warner, and Brian McSharry, are working on production-level prototypes through collaboration with Sealevel Systems. They will use the machines to pursue FDA approval. Their goal is to get Glucosense to patients abroad as well as low-income diabetics in the U.S.

–Rachel Wasylyk

Paul Alongi



Tyler Ovington and Kayla Gainey print test strips in the laboratory.

Real-world application

The testing system, called Glucosense, includes a printer, a set of cartridges, blank test-strip paper, and ingredients in powder form for greater shelf life. The distributer then simply adds water, and approximately four thousand strips can be printed per cartridge at a hospital, clinic, or pharmacy.

Kayla Gainey, one of the lead students on the Glucosense project, has been a diabetic since the age of two, and she can't imagine having to regulate her blood sugar levels without a monitor. "I don't believe that just because someone is born in a place where there are no basic treatment options means they have to go without," Gainey says. "We're working in Tanzania right now, but think about how many other countries need this, as well."

Glucosense recently won first place in the South Carolina Bio Pitch Contest, the Lemelson-MIT "Cure It!" Student Prize for undergraduates, as well as the bronze student-authored abstract award from the Diabetes Technology Society. This research was made possible by Clemson Creative Inquiry, Madaktari Africa, EWH, and the National Science Foundation NSF RII-EPS 0903795. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the NSF.

Delphine Dean is a professor of bioengineering in the College of Engineering and Science. Rachel Wasylyk, a 2012 graduate and former editor of Decipher, *a student-led research magazine at Clemson, is now a marketing manager and freelance writer based in Charlotte, North Carolina.*

From the first scan of script to the jitters of opening night, a play sweeps the faithful away on a journey of fearsome discovery.

Survivors: Lydia (Julia Dingle) couldn't bring herself to murder Nikos (Jonathan Bull). Their balancing act at last comes to rest in a tender embrace.

Neil Caudle

# of all human qualities

by Jemma Everyhope-Roser

November 14, 6:30 p.m., 49 hours until opening night.

Enter the black box theater from backstage and push aside a heavy fall of black velvet. The stage glows white. On it: faux-marble tiles framed by pale columns, a froth of cloth, a podium with its petite white tub, and, hanging high above, forty-seven wedding dresses. The stage divides the black-upholstered seating into what's called a "tennis court" configuration.

You and I have walked in on what Lauren French calls "stage work." French, the production's director and a student at Clemson finishing her senior year, sits to one side in the front row. Her expression is attentive, her straight blond hair tucked behind one ear, as she calls instructions to the actors on stage.

The actors have just finished practicing the wedding scene so that the lipsticks can be smoothly handed off between the actors. Now French calls up Alessandro McLaughlin, who's playing both Leo and Piero. She's working with him on mannerisms, to make his two roles visually distinct.

French asks McLaughlin to run through a scene, instructing him to make his gestures bigger. "Come on, Leo's hands don't live in his pockets!" she calls, and he adjusts.

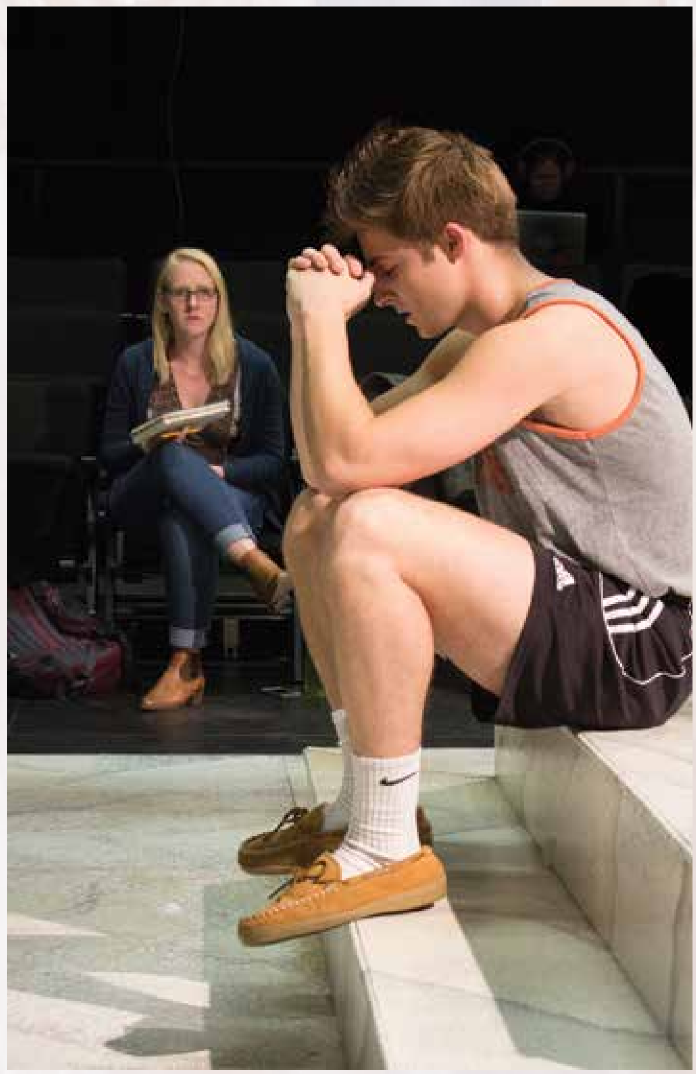
"I need to see some reaction there, Leo," French says. "You're about to *get* some!"

When McLaughlin successfully runs through the scene, complete with large gestures and lascivious looks, French congratulates him and says, "Can we see that again?"

At age fourteen, French focused her considerable energy on acting. She attended an arts high school where, as a junior, a guest artist introduced her to Charles Mee. But, only when that guest artist returned to teach Chekov and Stanislavski, did she think: "Oh, I could do theater. I could do this the rest of my life and be happy. And not just acting. I could try directing and work backstage..."

Her senior year in high school, she chose to direct a scene

Neil Caudle



Director Lauren French coaches Michael Bonini, playing Constantine, through an especially difficult monologue. "I think we both were really proud of it in the end," Bonini says.

from a Charles Mee play—and followed that up by directing another scene from the same play last year.

"So," she says, "he's been a part of my life for a while."

Tony Penna, associate professor and director of the theater program, says that every once in a while a student comes along who wants to pursue a career in directing. These students, once they've done the relevant coursework and proven themselves reliable, creative, and ready, get the opportunity to direct. It's a lot of responsibility, but since French met the qualifications, she got offered the job.

That was December, 2013.

French immediately considered directing *Big Love*. The play appealed for many reasons. Great cast size. The female-to-male ratio, though not dead even, came close. And, most importantly, French says, "I really liked the story."

French goes on to say that she believes the story challenges the audience to think about what "gender wars" mean today. But most of all, she values how Charles Mee doesn't provide answers in his script, whether it's about the paradigm he's set up in his play or his stage directions. This openness and flexibility of the script allows French to discover, again and again, new ways of reading and staging the play.

Yet there's more to starting out as a director than selecting a play. French decided to forgo using a dramaturge—a researcher who studies references in the script—and embarked on that job herself. If she didn't understand it, she figured it out, line by line. French started by reading the play that Mee based his remake on, *The Suppliants* (which is also called *The Danaids)*, a play by Aeschylus probably first performed around 470 BC. In the original, the women, rather than being central characters, appear only as the chorus. As for the grooms? They aren't even in it. The group murder at the end? Now, that's the same.

"Same basic structure, same basic idea, but updated and much more interesting," French says. "It's incredibly Greek. It's epic. It's larger than what we would do in contemporary play."

But confronted with a confusing barrage of lines at the play's finish, French turned to her advisor, Penna, to learn more. Penna has kept in touch with Les Waters, the director of the original production of *Big Love* at Actors Theater of Louisville in Louisville, Kentucky, and he asked Waters about those lines. Turns out, they reference *The Pillow Book,* an eleventh-century Japanese classic. Go figure.

While this information will never make an appearance in any performance, knowing the lines' origin helps the actors understand what they mean and how they should be said.

At this point, Penna had already contacted Charles Mee about performance rights. Usually, playwrights publish their scripts and the theater becomes responsible not only for purchasing scripts but also for buying the right to perform the play. But unlike most playwrights, Charles Mee makes his scripts available online.

"If you're doing his plays," Penna explains, "and you can't afford to produce a fully realized production, he does not expect you to pay for performance rights. You can do the show for free. But if you're an established organization that has a budget, paying for performance rights is appreciated *and* expected."

Photos by Tony Penna

October 9: Madelene Tetsch and fellow cast members read through the script.

Getting a feel for the play's dynamic movements often meant turning things upside down.

October 20: Shannon Robert presents her set design.

Clemson paid for the performance rights, because, as Penna stresses, that's part of how the playwright makes his money and "it's the right thing to do."

Penna also set French up with the playwright, Mee, who told her that if she had any "burning questions," he might answer them…or he might not. He told her that each actor and director must figure out the show on her own.

"That gave us the okay to really take it on and make our own story with his words," French says. She found this liberating.

French also took her research one step further while studying abroad at Accademia dell'Arte in Arezzo in Tuscany, Italy. "That gave me a great jumping off point when starting in on *Big Love*," French says, "because I knew going in that I was directing *Big Love*, so I got to research while I was there."

French took the time to visit the Italian coast so that she could get firsthand experience of the play's setting. She explored Cinque Terre on Italy's mountainous western coast, near to the play's actual location, taking photos to carefully analyze the city's elements.

"I got to get a feeling of the culture, the art, the people, the food," French says. "All these wonderful things have enriched the process."

When French returned, she began casting the play and met with the designers. Immediately she realized that the crisp, film-like image she'd had in mind wouldn't work. In a lot of realistic plays, French explains, things are set for you. But in *Big Love*, Mee writes the setting should be:

> If Emanuel Ungaro had a villa on the west coast
> of Italy, this would be it:
>
> we are outdoors,
> on the terrace or in the garden,
> facing the ocean:
>
> wrought iron
> white muslin
> flowers
> a tree
> an arbor
> an outdoor dinner table with chairs for six
> a white marble balustrade
> elegant
> simple
> basic
> eternal.
>
> But the setting for the piece should not be real, or
> naturalistic.

With all of that information and these options before them, French worked with Shannon Robert, a faculty member and set designer, to figure out what they both wanted and how it might fit with French's vision (see "Art for the Fearless," page 24).

And to communicate that vision, French had to learn a new vocabulary to speak with designers. Penna states that it's to her credit that she never shied away from her position, comfortably talking to her faculty designers as equals and steering them toward her vision (see "A Transformation of Light," page 26).

"In this department we focus on professional development and preparing students for the professional world," Penna says, "and she has the kind of confidence that will serve her very well after she graduates."

Being able to gauge Clemson's resources, not only for set design but also in terms of personnel, helped French lead the production effectively, especially when it came to casting the show. French says, "We're very fortunate here because we get to see each other's work all the time. So I had an idea when choosing for the show: Will we be able to have the people to play certain roles? Will I be able to cast this show? Yes."

Auditions began. Actors showed up with roles in mind. French made final decisions.

November 15, 6:30 p.m., 25 hours until opening night.

When you take a seat on one of the black chairs, you've got the chance to watch the actors work through a "fight call." Michael Bonini, the actor playing Constantine, throws himself into a headstand while the other two leading men, Jonathan Bull, playing Nikos, and Jeremy Schwartz, playing Oed, support his feet. Bonini almost tumbles right onto his head, and the three try again.

"Guys, slow down!" Liz Haynes calls. "You all right?"

Haynes, as the stage manager, organizes productions, rehearsals, production meetings, and performances. Because of her, all the actors are at the right place at the right time. She calls light cues and sound cues, too. Or, as Penna says more simply: "She makes it all happen."

Right now, Haynes is frosting the top half of a wedding cake that will be cut during the wedding scene. The lower half of the cake, also still under construction, consists of Styrofoam, plastic flowers, artificial pearls, and caulk.

But they're not going to a wedding; they're going to the after party. In this case, a brutal massacre. Haynes shouts out to the girls, "If you don't have knives, grab 'em," and the actors begin to assemble.

Kacey Bair, playing Olympia, flips open her knife and fumbles. The actors play through the scene again. This time Bair goes through the motions of slitting Schwartz's throat. The two women who've successfully murdered their male counterparts stand over their kills, at a loss, while the only surviving couple cuddles amidst the pools of red light.

With fight calls and scene work done beforehand, French releases the cast for a dinner break.

Next up? The dress rehearsal.

Afterwards, Penna comments that the actors let pauses go on too long, causing the show to run over. The actors gather around French to talk excitedly about how it all went. The faculty, who've taken extensive notes on every problem that must be solved before opening night, drop into the conversation to hand over their pages.

Robert, her notes in hand, tugs at the bunched tulle at the

Neil Caudle

October 15: Kacey Blair, Lauren French, Madelene Tetsch, and Julia Dingle work through the emotional buildup that erupts into tantrum.

back of an actress's wedding dress. She wonders, aloud, "What about the problem with this dress? How do we fix it?"

The actors are all silent for a moment. This has been an ongoing issue, clearly.

"Burn it," someone mutters.

French heads over to the green room with the actors to discuss each issue individually so that that the group can brainstorm solutions.

The green room, with its sturdy couches, bric-a-brac, and kitchenette, looks like a combination between a dorm common area and an office break room. The director, actors, and actresses seat themselves in a circle, some flopping onto the couch, others pulling up chairs.

"How do you feel about the run-through?" French asks.

After listening and responding to her actors' feedback, French goes through the notes that the faculty members and stage manager have given her. French tells Bair that she's been playing with the other actresses' hair too much during performances. This distracts the audience.

"I just like that hair play," Bair admits.

"It's my job to pull you back," French says and goes on to speak with Bonini about the scene where Thyona bites

Neil Caudle

Left: Liz Haynes, stage manager, decorates a new wedding cake for each dress rehearsal and performance. She also keeps things moving, making sure people and props are in the right place at the right time.

Right: A view from above the lighting grid, looking down on the stage as a crew member arranges props. When people are working overhead, those on the set wear hard hats, just in case.

Neil Caudle

Neil Caudle

November 14: In the green room after a full-dress run-through, French leads the cast in a discussion of what worked and what didn't.

Constantine on the hand. French tells Bonini to wait a little to react after the bite, to give the audience time to see the bite and make sense of Constantine's reaction.

"I don't know about ya'll's pain," Bonini comments, "but my pain is immediate."

"Just wait a beat," French instructs, and Bonini nods thoughtfully. To an outsider, it seems counterintuitive that an artificial pause will end up looking more natural than an immediate reaction. But it does. French turns to Madelene Tetsch who plays Thyona, and says that she needs to play up the taunting butt dance a little more. The other actors tease Tetsch.

"I'm fine with my butt," Tetsch comments impatiently, "but if I pull up the dress, the knife shows."

French considers this. The knife, strapped to the actress's thigh, is supposed to be concealed before the post-wedding murder scene. French says, "Don't do it then."

"It's in the script," Tetsch says.

"If it doesn't work," French says, "don't do it."

As the team finishes discussing issues and solutions, French brings the meeting to a close. When she asks the actors if they have any questions before opening, there's an anxious eek from the actors and a little playful yelping. French relates how Italians say "in bocca al lupo" or "in the mouth of the wolf" to mean "good luck!" The correct response to this is "crepi" or "kill it." The group promises to wish each other luck before each show the Italian way, and then French disbands the meeting.

At opening night tomorrow, French's job will end.

After French had her cast assembled, she set the actors to reading Charles Mee's script. It can be easy to make a reading flat and boring, so French says that one of the largest leaps she saw was from "page to stage."

"When I first read the script I didn't realize how funny it was," says Julia Dingle, who plays Lydia.

After that initial read-through, French led the actors through what's called "table work," which usually consists of sitting down and talking a scene through. "With every scene we dug through all the background," Dingle says, "and all the meaning and all the subtext that you may or may not get as an audience member but you need to know as an actor."

But, instead of remaining seated at a table, French took a more innovative approach.

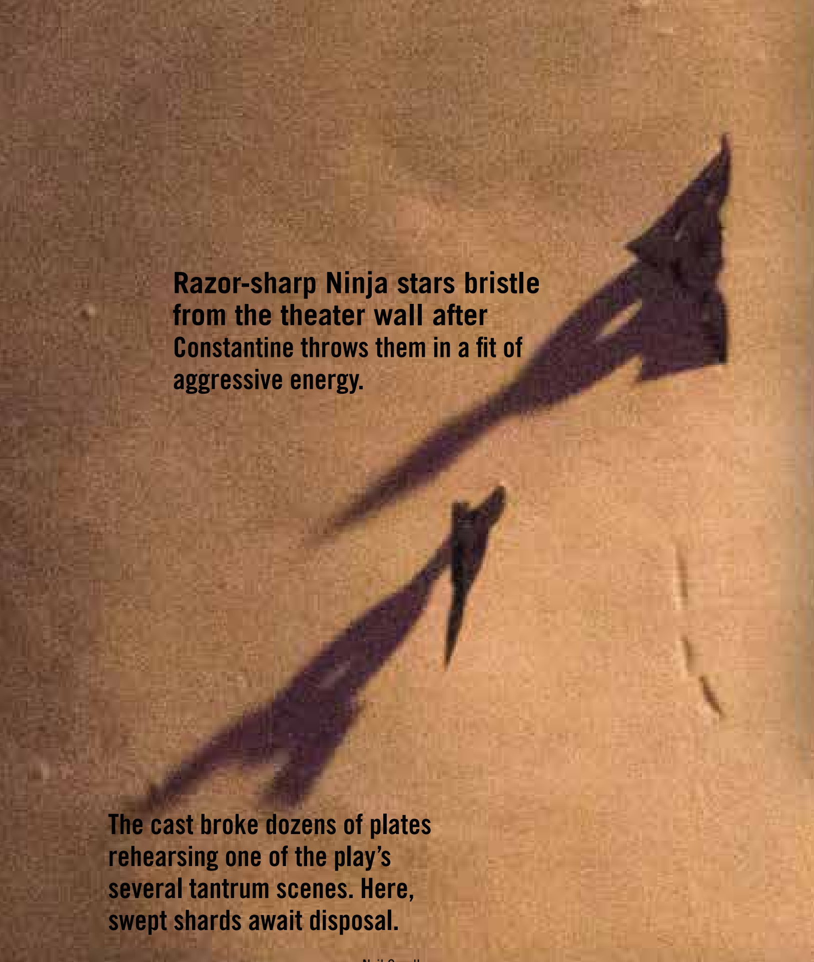
"I had them get up and talk about it," French says, "because if you have them sitting down for too long it could be detrimental, especially in a piece like this that calls for a lot of physicality."

Bonini says it was the most physical production he's ever done, and that his background in gymnastics helped him tackle the role. He adds, "But it was such an awesome experience to be able to tell the story through more action than text."

After the table work, French and the actors block out the play scene by scene. Blocking, an exhaustive and involved process, establishes what each actor does when.

Blocking decisions might be tiny but can have huge ramifications. For every scene, the director and the actors must decide where they stand, why they're standing there, if they move to cross the stage, what might motivate this cross, and much more. It can include the choreography of fights and slaps. It can involve handing off items so that each motion seems natural, unforced, and in character. In one scene, a character may need to step backward and sit down on a chair. Missing the chair would be funny in all the wrong ways—and would miss the point of the play.

What's more, French had to work out the sight lines. She'd watch each scene from different rows and seats to ensure that everyone in the audience would get an unobstructed view.



Razor-sharp Ninja stars bristle from the theater wall after Constantine throws them in a fit of aggressive energy.

Above: Michael Bonini and Madelene Tetsch rehearse a tricky bite scene, coached by Bill Muñoz (right), the production's fight choreographer.

The cast broke dozens of plates rehearsing one of the play's several tantrum scenes. Here, swept shards await disposal.

Neil Caudle

Tony Penna

Tony Penna

rough stuff

Big Love's vigorous action tested the actors' physical and emotional stamina. Tony Penna calls the tantrum scenes "expressionistic moments" that represent the characters' inner states through overlapping monologues and extreme physicality.

"One thing that terrified me completely was directing the tantrums," says Lauren French. "I had no idea how it would turn out."

Tony Penna

Tony Penna

Thyona kicks into a handstand on the rim of the set's metal tub.

Neil Caudle

In a movement that required careful choreography and long practice, Constantine manhandles Thyona, yanking her across the stage.

To complement the play's physical intensity, the production's sound designer, Jim Breitmeier, updated some of the newer pieces of music called for in the script, especially for the tantrum scenes.

"He's bringing in his own preferences and influences," Tony Penna says, "and he's trying to match the sound with the tempo and energy of those tantrums."

Facing page: Tetsch rehearses the stab that will murder Constantine.

French says, "You have to watch everything that's going on. You have to be aware of the whole picture. And I think it's like your focus expands to the whole stage."

French had the first rehearsal with all of the actors together. But along the lines of the play, she split the actors based on gender. The males rehearsed together and the females rehearsed together. The first exception? Drew Whitely, who played the gay character Guiliano, appears on stage only with the women. The second exception? The actors playing the surviving couple, Dingle and Bull, continued to work together.

"It was very interesting when we all came back together," Dingle says, "because we had all been developing our characters. It was fun to watch all these characters fill out and take shape."

At this point, the blocking had been worked out right up until the point of the large fight scenes. The director and the actors had to develop a choreography to get their point across, and they needed help to do that—from an expert.

Bill Muñoz, a professional fight choreographer, was brought in to instruct the actors. He did most of his teaching at the beginning of the third week in, Bonini says, but also dropped by a couple of nights before opening to clean up the scenes. Under his tutelage, the actors learned how to throw ninja stars, how to safely fall and throw yourself to the ground, how to kick, and how kill each other. Everyone had a distinct and specific method of murder.

"It was not only good for the show," Bonini says, "it was a good learning experience for the actors and people involved, just to see what goes into making these things look real but still safe."

Regarding blocking specific scenes, French says, "If I had a set moment I really wanted to see happen, I would tell them how I wanted to see that happen. Like the Lydia and Niko scene. I wanted the kiss to happen near the swing. And I wanted him to be pushing her."

But for other scenes, French only set the boundaries. She wanted actors to know the scene's stakes but she "let them run with it," telling them to get out there and give it a try. The actors would tackle the scene again and again from different angles until French found a version she liked. Then she'd have the actors rehearse that version, making minor adjustments.

"I would offer suggestions," French says, "but I really wanted to make them make their own choices."

French admits that it can be hard, as someone with acting experience and training, to sit back and let the actor work through a moment. "I know what I would do in that moment. I want to tell them to do it. But they're coming from a completely different place and I have to find ways to make choices that are okay for them."

Yet her training in acting has also helped her give the actors productive notes and guides. Without that training, French says, "I would be lost." Both Bonini and Dingle agree French's approach gives actors a say in what they want from their characters. Dingle says that French created work from what felt natural to the actors. Bonini says that he worked with her to hone his monologue into something he could really be proud of.

"It was the first time I had worked with a student director," Bonini says, "so I was super excited for that new experience. It was especially cool and interesting because it was very collaborative process. We really came to middle ground well."

"She is very actor-oriented," Julia Dingle explains, "in that she lets you do what you're going to do and then she takes what she likes from that and works with it."

And through the actors, French had the opportunity to see characters from new angles. In particular, the actors' portrayal of two characters, Thyona and Constantine, deepened her insight. Thyona and Constantine, arguably the most aggressive characters in Mee's play, initially seemed extremely angry. But French came to understand that these characters had been conditioned by society to take their ideological positions and weren't necessarily happy with the worlds they inhabited.

Constantine's monologue, in particular, has some harsh language and sentiments:

> so it may be that when a man turns this violence on a
> woman
> in her bedroom
> or in the midst of war
> slamming her down, hitting her,
> he should be esteemed for this
> for informing her
> about what it is that civilization really contains

As French says, "He's using this speech to justify beating women, and it's not okay. But you see that, oh wait, he's also human. You have to look at it through his point of view as well. Which was hard for me, and really scary, because I didn't want to see that side."

For all the harsh qualities and physical drama, French found herself surprised by the other elements that Bonini fed into the character. "He's brought a lot life to it and a lot of the softer qualities that you need," French says. "Otherwise, people wouldn't listen to what he's saying."

Michael Bonini, the sophomore playing Constantine, says that he's played characters like this before. His familiarity with this type of character did help him, but Mee's surrealistic exaggeration brought this character to a whole new level for him. He says that it could get outright frightening, because of the "intensity of the character."

"The first thing I do is I walk on stage and choke Thyona's character. So I mean that can get kind of intimidating," Bonini says. "Then after that I throw her on the ground. That took a lot of trust, rehearsal, and choreography to really get perfected and put together well."

French made a conscious decision not to dictate but to collaborate. Getting actors on their feet, seeing what worked, and pressing the actors to develop their own solutions became key to her directing style. "The fact that I have to talk to each actor differently has been a huge surprise to me," French says. "The fact that I'm not automatically given the respect and trust that I would get, but that I have to earn it. Which was so frustrating at times! But once I earn that trust, it's really rewarding."

November 16, 7:30 p.m. Opening night.

The audience sits quietly in the dark while the soft sound of surf plays throughout the small space. An actress enters the theater from backstage, right next to the main doors. She ventures across the stage, and behind the soft gauze around the podium, undresses in the dim blue light. Setting her wedding dress aside, she climbs into the tub. The sound of real water mingles with that of waves while we wait for the play to begin.

As an audience, we are divided along gendered lines below wedding dresses, the men sitting on one side of the stage, dyed blue with light, and women beneath the pink on the other side. We echo the thematic contents of the play, collaborators in this elaborate act of creation.

French's work is done. The designers have stepped back. The actors must go on, working together each night to rivet the audience, to elicit thought and sympathy. Tonight, they fumble their lines before their full house. Only a little.

I can tell they're nervous, because I've seen them work out these scenes together, but I'm not sure if anyone else can. As they warm to us, surprised and delighted when their jokes cause a burst of laughter, we warm to them.

The truth is, we're all here for the same reason.

Because, in the end,
of all human qualities, the greatest is sympathy—

how'd it go?

"We sold out five of seven nights, so I was really proud with how they did," French says of the cast. "It was a lot of fun to watch their progress."

As the actors performed live, they became more comfortable with the play. The ensemble solidified and the actors engaged with the audiences. French says that every night was completely different: "Wednesday night, people were laughing at everything they said. Then the next they performed it people were completely silent."

Over the course of the run, the actors had to adapt not only to one another's evolving performances but also to the audience's mood.

Neil Caudle

Bella (Adrian Eppley) injects a comic counterpoint.

Neil Caudle

Olympia, Constantine, and Lydia test the territories of gender.

art for the fearless

On this crisp Sunday morning, Shannon Robert and I sit on the removable step of the marbled dais while undergraduate Cassey Lanier fetches the paint. Today Robert will teach Lanier how to repaint a damaged wall.

The repairs I'm about to witness today will have to be done every morning before each show over the next week, and this is only the tail end of the set designer's work.

When Robert met first with French, she'd read the play but she went into the meeting knowing little more than what the seating arrangement would be. "I always get ideas when I read a script," Robert says. Although she had researched the Italian setting, "Charles Mee's approach is not realistic. I would call it magical realism meets poetry meets... I don't even know. It defies definition. To approach the play realistically isn't serving it the way it wants to be served."

At the meeting, the team talks about what the play means to each of them. What-ifs are bandied around the room. "Because this is a collaborative art," Robert says, "maybe your ideas change a little. It may not be exactly what you thought you were going to do in the first place."

Tony Penna

Thyona rips down the "bridal veil" central to Robert's design.

In the meeting, French spoke about her experiences in Italy. The photos of clotheslines got Robert thinking about this world's form and function. Given that French wanted to use three brides and three grooms to represent the fifty (of each) mentioned in the play, Robert thought: These girls talk about hanging themselves. So, fifty hanging dresses—they aren't the brides, not literally. What if this could be the canvas for the lights to play on?

Calls went out for bridal gowns. Emails, Facebook requests, and then Robert turned to borrowing from other theaters. For each dress, the crew arranged pickups and tagged the gown so it could be returned to the correct owner.

Once Lanier has found the paint—a beige, a black, and a white—Robert gets down on her knees next to Lanier to take a look at some of the floor-level damage to the wall. Due to the rough, "painterly" style and dim lighting during the show, the spackle won't need to be sanded out. Lanier can paint it now.

Robert shows Lanier how to blend, how to dry brush it to get distinctive brush strokes, and how to fix mistakes. Then she hands the brush over to Lanier and sits back to supervise while Lanier gets some hands-on experience.

The floor she's stepping on, which looks like a high-quality marble laminate, she made. Starting off, Robert "based out" the floor in white. With varieties of Italian marble in mind, she painted, taking into account rock's geological formation. The gray tone in these tiles is natural, but Robert added pink "for a little lift." That, and the blue tones, allude to the gendered theme of the play.

"Painting it is a very, very wet process," Robert explains. "It's sprays and slinging and lots of wet, and once it's done, we seal it."

You'd think that her job would be finished with sealing, but in reality, this floor requires continual upkeep. Typically, Robert explains, "we don't do black, rubber-bottomed shoes if we do a light colored floor." But in this case, the actors dressed as grooms had to wear dark dress shoes. So, after every performance, scuffs mark the floor. Cleaning them removes the seal, so the floors must be resealed afterwards.

Part altar, part boxing ring

Robert waves at the columns around us and says, "I knew I wanted to frame the set. I wanted it to have a ritual feel. Like an altar. The cake, the celebration. A boxing ring, enclosed."

The four columns framing the set were cut down from three beams used in a previous production. The fourth column was constructed from end pieces.

"These," Robert says, pointing up at the columns, "are top heavy, but they're tied in with aircraft cable that's connected all the way through. They're basically hanging. They can move and flex a little, but they're not going anywhere because they're supported at the bottom too."

The square bases, neither Corinthian nor Doric, also originate from another show.

Remaking pieces from old sets is not only practical and frugal, but also a conscious pedagogical decision on Robert's part. She says, “We’re teaching students how to reuse, recycle, and upcycle. I am making a concerted effort not to put more material in the landfills.”

The swags of cloth draped around the columns give the stage a wedding-like feel and, as Robert explains, “The fabric is left over from our gala last year. The entire lobby of the Brooks Center was draped in fabric. It was really lovely, so I pulled some of that out.”

But more here around us has been upcycled. Robert taps a surface beneath the bathtub that looks like clouded glass, and says, “This lexan has been used in many shows. In fact, I think I’m going to use it for my next show. The tub was a trough.”

Robert has a “footed tub that’s quite lovely” but chose the trough because, on top of the podium, it mimics the shape of a stacked wedding cake. The cake, which is perched upon the trough near the play’s end, becomes a final piece of the puzzle that gets slotted in.

Learning their way out of a mess

The cheap scenic gauze draped around the podium at the beginning is meant to represent “a protective bridal veil” that the girls tear down. Velcro tabs hold this netting to a hanging white frame. That frame is metal, Robert says, looking upward. “They welded it and painted it white. The structure is designed to bear the load of all action in the play.” The frame lowers, so that it can be dressed, from the grid above, which according to Robert, “could hold a couple of busses.”

The technical director, Matthew Leckenbusch, has done the math. He’s figured out the load. For everything. He’s calculated the weight the swing can hold, taking into account how the 450-pound rope is expanded by the swing seat’s two-by-ten. He figured how much weight the lexan could hold.

“Every time we do anything,” Robert says, “it’s a collaborative effort.”

As we sit, Robert gives occasional instructions to the student, Lanier, to help her with technique. “Just change your pressure until you get the desired effect. Don’t worry about those spatters down there. We’re going to go back and deal with those shortly because you may get a few more as you’re going. I want you to get a ladder so that you’re comfortable, not reaching.”

As Lanier leaves to get the ladder, I ask Robert if it’s possible do this work if you’re afraid of heights. Robert gives me a long look. “Anyone who’s interested in scene painting, they have to be able to go up. That, really, in some cases can be as important as being able to paint.”

More than being willing to brave any height for painting, a set designer must be fearless. Robert explains that she likes her students to make mistakes, because then students learn how to figure their way out of the mess they’ve gotten themselves into.

But making mistakes is hard. It takes guts to look at something, know exactly how badly you might fail, and do it anyway. Some mistakes can hurt worse than a fall off a ladder.

“If they can’t problem solve, they won’t work in this field. Or, in any field,” Robert says and turns to instruct Lanier. “Feather it out. Change your pressure, so that you’re kissing the surface with the paint.”

Neil Caudle

Shannon Robert (right) advises Lauren French after a rehearsal.

“I’m afraid I’m going to mess it up,” Lanier says.

“I know. You got this,” Robert says. “It’s going to do exactly what you tell it to.”

That willingness to jump right in serves Robert well. She has worked on high-profile large productions in cities and says that, because people don’t know the type of work that goes into this, there can be a condescending attitude toward what she does. She says on a recent project she encountered an artist with the attitude of: “You do this theater stuff. I do real painting.” It doesn’t seem to matter to them that Robert has been educated in art and architecture, and that she’s got experience with fine art as well.

When Lanier asks Robert if the wall looks finished, Robert takes a good long look at it. She explains that Lanier has missed some spackle. Even though it’s white on white, not visible to the audience, it needs that layer of paint. If the actor hits it with a ninja star, “it could crumble out if it doesn’t have a coat of something on top of it.”

Lanier nods, a little glumly, and goes back to work.

“It’s definitely not for everyone,” Robert says. “I tell students: If this is something you can’t not do, great. If there is something else you would be happy doing, this can be… a soul killer, a soul crusher of a job. You hear no so many more times than you hear yes. You are assumed incompetent until you prove otherwise.”

As I’m making ready to leave, Robert gets on the floor next to Lanier. They’re putting down the black all-floor, a low-sheen paint. The floor around the stage needs a layer tonight, because the actors have smashed plates on it, and it’s looking a little chipped. Robert tackles the problem, in her element, right in the action, with a paintbrush in her hand.

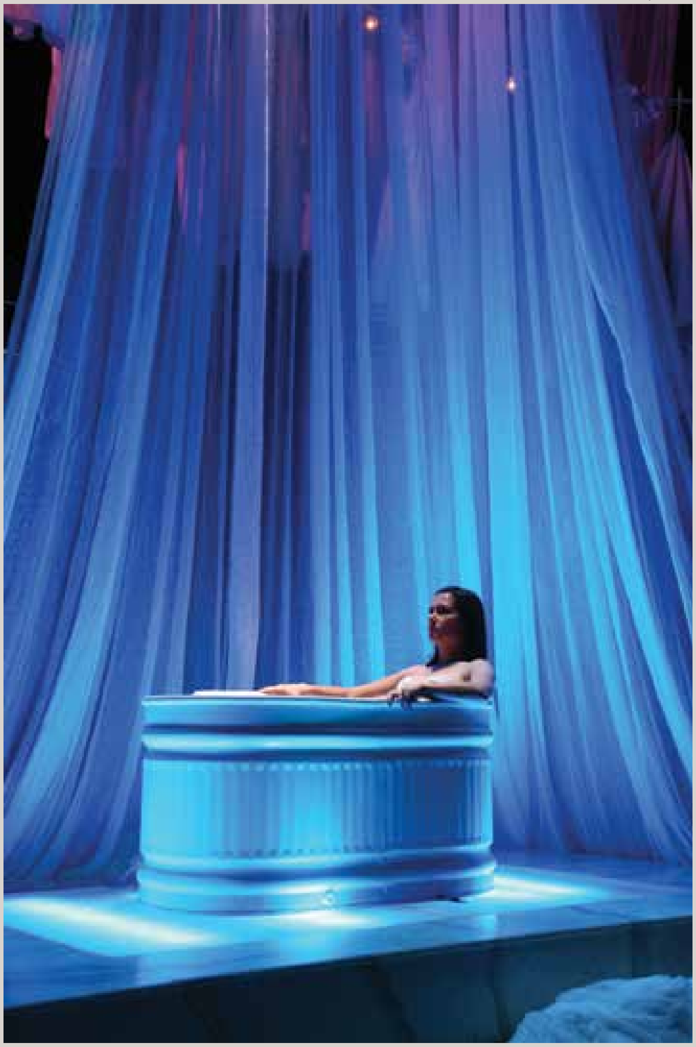
Shannon Robert is an associate professor of theatre in the Department of Performing Arts, College of Architecture, Art, and Humanities.

a transformation of light

The wedding dresses proved a challenge to Penna as a lighting designer. "I had to figure out a way to get light underneath all of these dresses to light the stage and yet make the lighting look the way it needs to, and have these moments of realism versus theatricalism." At the beginning of the performance, the pink and blue lights shimmer across the dresses' white fabric and suggest the play's central theme: gender.

Neil Caudle

Tony Penna



Above: A searing hot pink inflames the women's tantrum.
Right: Lydia (Julia Dingle) in a moment of cool blue reflection.
Below: Tony Penna at the controls during a dress rehearsal.

Neil Caudle

Neil Caudle

Tony Penna bides in a liminal space, between light and darkness. He's Lauren French's lighting designer, and, as the director of the theater program, also serves as the *de facto* producer. So, all at once, he embodies the paradox any theater production: collaboration with hierarchy.

Penna offers to take us up to the catwalk and the grid. He's headed up there anyway to make some notes, to focus some lights before this rehearsal. He leads us through a back access door, past paint cans and tool racks, to a metal spiral staircase.

The catwalk rings the theater in a second story. He brings us around to the light booth, a small loft area that inconspicuously hangs over the audience seating below. Right now, Liz Haynes and Wylder Cooper, two undergraduates on the stage crew, sit there. The tilted panel before them is covered in groups of sliders, which are controlled electronically by the computer at Haynes' shoulder. To Penna, after all these years, that monitor's an easy read.

"It's like being in the matrix," Penna explains. "I look at that monitor and see the stage."

Haynes, the student stage manager, calls out, "Standby light cue one hundred!"

"Lights," Cooper replies. A sophomore interested in going into theater, he's Penna's go-to guy for tech. He rigged up the wireless up-lighting beneath the stage's central podium.

"Light cue one hundred go," Haynes says.

The set below us transforms, saturated with reds and blues.

Penna intends to light the realistic scenes starting with lights that mimic midday but over the play's course dim down to sunset. The impressionistic scenes, which reflect the characters' internal realities rather than any physical ones, will follow other rules.

"It's not a traditional narrative play," Penna explains. "It has moments of realism and moments of expressionism where you experience the play through the eyes and ears of the characters. You see and hear what they see and hear."

So when it comes to the women's tantrum scene, Penna spoke with French about lighting the stage with deeply saturated colors, to represent the world as the women see it. But he wasn't as certain about the lighting of the men's tantrum scene.

"I started thinking about opposites, men versus women, and opposites in lighting, and what is the opposite of light?" Penna asks. "I don't want to do darkness because that would be visually very boring. So we came up with the idea of during the men's tantrum of lighting the stage with black lights."

When we climb up and reach the grid, it bounces underfoot, a network of cables and pipes. Around our heads are air ducts, a corrugated ceiling, and soundproofing painted black. Penna shouts and the stage crew downstairs hurries to put on hard hats. He explains that the Occupation Safety and Health Administration (OSHA) categorizes theater as construction, so when anyone's up here everyone below has to gear up.

Penna clips a wrench to his belt—it's been jerry-rigged to a telephone cord per OSHA regulations—and turns on each light. He tightens bolts.

"This particular set," Penna explains, "there are few set pieces that come on stage to change the stage picture, but for the most part it's a static set that you see on the stage through the whole show. It's the lighting—this is why I'm so drawn to lighting—the lighting is what transforms the space from the real world into the inner world of the characters."

And that's the whole point, isn't it?

Tony Penna is an associate professor of theatre in the Department of Performing Arts, College of Architecture, Art, and Humanities.

Neil Caudle

the play

Big Love, by Charles Mee, is a modern remaking of *The Danaids* (also called *The Suppliants)* by Aeschylus. In Mee's play, fifty brides, fleeing an arranged marriage to their cousins, seek refuge in a luxurious villa on the Italian coast. When the grooms catch the brides and wed the women against their wills, the brides murder their grooms. Only one couple falls in love and survives.

"About the same odds as today," quips the summary on Charles Mee's website.

For the full text of the script, go to: www.charlesmee.org/big-love.shtml.

Tony Penna

living and breathing

"When I got into the program I had no idea what to expect," Michael Bonini says. "I had never taken acting classes or been in college-level performances. But it's shaped me quickly."

A sophomore, Bonini has already had the chance to take acting classes, directing classes, and performing arts classes. He's learned everything from the business side of performing arts to what casting agencies search for. He credits his leap in knowledge to the professors' ability to communicate the technical aspects of art to students.

"It's different than any other major because it's the only major that you go into and you're just submerged into it completely," Bonini says. "You can ask any student and they will say that they spend about ninety percent of their time at college at the Brooks Center."

Bonini, giving an example of his usual schedule, says that he'll often come in around eight a.m. to practice monologues and for rehearsals. Then he returns again from noon until five for classes. Then, after a dinner break, he's back again to rehearse from six to ten or so at night.

For *Big Love,* Dingle says, rehearsals began at the end of September and generally lasted four hours a night, five to six days a week. "We probably rehearsed well over ninety hours, I would think."

Taking time to find their characters

Apparently ninety hours of rehearsal for a ninety-minute production is normal. The general rule of thumb for any production is one hour of rehearsal for each minute on stage. Or, as French says, "The amount of work that goes into an hour-and-a-half production is insane."

As though ninety hours weren't enough, many actors would meet outside the time they were strictly required to be in the Brooks Center, working together to memorize lines or to figure out what they wanted from a monologue or scene. Sometimes, they'd talk to their acting professor, Kerrie Seymour, which French always encouraged.

"We really dig into why these characters think the way they think, what their past was like, what is their favorite food," Dingle explains. The girls would often get together in order to figure out their pasts, creating elements to the characters that were never written out in the script and would never be seen in the play, but that would give background and motive to each action the characters took in the script.

"Many of us do work outside of rehearsals because we want to bring our best when we walk into that rehearsal room," Dingle says. "It isn't just you trying to discover things. It's everybody else and if you can bounce off of each other the result is going to be much greater."

"Now that I am doing it I couldn't see myself doing anything else," Bonini says.

Photos courtesy of The Clemson Players.

next?

As you read this, many of the same actors will be working on their next big production, *Eurydice*, a play by Sarah Ruhl. These photos are from early rehearsals during the winter.

Lauren French (top of the photo above, with Claire Richardson, in blue, and Rebekah Swygert) will be guiding movement for the play as well as acting as the Loud Stone. Julia Dingle and Alessandro McLaughlin are working as assistant directors in the production. Michael Bonini will be playing Orpheus.

Adrian Eppley (below right) was cast as Eurydice. Jeremy Schwartz has the role of the father, and Jonathan Bull (below left) is the lord of the underworld and the nasty, interesting man. Kacey Bair is understudying as the Loud Stone and the Big Stone. This semester, Madelene Tetsch is studying abroad, and Drew Whitley pursues other interests.

Can art *heal?*

by Jemma Everyhope-Roser

Prospect

In prospect images, there's real or symbolic access to a view. Usually vegetation grows low, and trees, if present, tend to be horizontally branched. The sky is an aching blue. Any water lies still as a mirror. "If you're a hunter-gatherer," Ellen Vincent (below) explains, "being able to see what's around you can help you live longer."

Craig Mahaffey

Health and nature has been an ongoing theme in Ellen Vincent's life. An environmental landscape specialist, Vincent has heard in focus groups, again and again, that people retreat to trees when stressed. So Jay Appleton's prospect-refuge theory resonated for Vincent.

The theory, which Appleton developed by examining landscape paintings and finding common elements, posits that viewers respond to landscapes as hunter-gatherers would. Appleton stated, in his book, that some of the most pleasing landscapes mix "prospect" and "refuge." And Vincent was not aware of any research done on mixed prospect-refuge images.

In Clemson's doctoral program, planning and design in the built environment, Vincent found funding for hospital research in the interdisciplinary architecture + health division through Dina Battisto. Vincent, excited to develop a rigorous methodology, set out to construct a study. A photographer herself, Vincent decided to work with images because "they'd make for clean research."

Vincent gathered hazard, prospect, and refuge images—but she also collected mixed prospect-refuge images. Even though an image may be mixed, Vincent explains, "It doesn't necessarily have to be fifty-fifty in terms of spatial quality, but in terms of impact, we're *striving for* equal impact. So it will be perceived slightly differently by different people."

She achieved that equal impact through focus groups and sorting tasks.

After assembling over three hundred images from various sources, Vincent then narrowed that down to seventy-two images that exemplified the prospect-refuge theory. Vincent gathered focus groups on campus, mostly of professionals, to categorize the images. Once Vincent developed a survey criteria, she recruited college students to sort and rank the remaining twenty images.

A mix that relieves pain

At the college campus facility, Vincent tested images' effect on students, simulating stress by placing the students' hands in ice water for up to two minutes. "What we found from our study at the university, our pilot trial, that it was the mixed prospect-refuge image that had the most significant impact on sensory pain perceptions," Vincent says.

So Vincent selected the images of highest impact for use at the hospital.

There, Vincent studied inpatients and outpatients. Outpatients had a small eight-by-ten-inch image on a gooseneck clip that they viewed before and after surgeries. For the inpatients, Vincent posted a three-by-two-feet image on the wall for two days. The staff surveyed the patients three times a day for perceived pain, profile of mood states, and heart rate and blood pressure.

"People who had images displayed less pain and better moods than people who did not have images," Vincent says.

When asked about the real-world ramification of her research, Vincent explains hospitals use many criteria when selecting art. Sometimes, for example, choosing a local artist's work may foster community but may not be the best choice for the patients.

Hospitals can be stressful—for patients, visitors, and staff. Vincent hopes that hospital administrators use this information to make educated decisions regarding décor. Or, as Vincent puts it: "If you choose works that make people generally feel better, then that's a good thing."

The images used in clinical research were not provided for copyright reasons, but each photograph appearing was used in the focus groups and experimental sorting. Ellen Vincent took and provided all photos.

Ellen Vincent is an environmental landscape specialist and an extension associate in the School of Agriculture, Forest, and Environmental Sciences, College of Agriculture, Forestry, and Life Sciences. Her sources of funding include Department of Defense, which is courtesy of Dina Battisto, and the South Carolina Forestry Commission. Jemma Everyhope-Roser is the editorial assistant at Glimpse.

Refuge

"Refuge is the opposite of prospect," Vincent says, "in that it represents real or symbolic situation for hiding or sheltering." "Hides" protect the viewer from animals or people. "Shelters" tend to be structures that protect from inclement weather. Refuge images are also associated with dim light, climbable trees, fences, and buildings with windows.

Five-megawatt turbines rise 500 feet above the waves in the Belgian part of the North Sea. Europe has a head start over the United States in wind energy, but Clemson's new testing facility could help close the gap. Photo by Hans Hillewaert, Creative Commons.

Defining the Wind

How do you tune a huge turbine to the forces of nature and help deploy the next generation of green-energy machines?

by Neil Caudle

Charleston. It's a city where history loops forward. Where an iron-hulled Civil War submarine, the H. L. *Hunley*, an engineering marvel of her time, slowly surrenders to science the secrets of her last fateful hours at sea.

Charleston is also a city built in part by the wind. In the early 1700s, Dutch engineers came to the Lowcountry to erect windmills, engineering marvels of their time. From Cape Romain to Edisto Island, coastal breezes spun the lacy blades above the landscape, milling the pine and cypress lumber from which Charleston would rise.

Today, you can walk a few steps from the Warren Lasch Conservation Center, where the *Hunley* steeps in a chemical broth that will leach away her salts and preserve her hull, and enter a space-age, hangar-size building fitted out with enough high-tech hardware to incubate a new generation of engineering marvels: futuristic wind machines. These turbines will not mill pine or cypress. They will not grind corn. But they could spin Charleston full circle and make it, once again, a city attuned to the wind.

If things here in North Charleston go according to plan, no other city in the United States will have a better chance to help put the wind back to work—and not just as a marginal player in a carbon-laden energy market. Wind power, our engineers tell us, has serious, big-time potential. One large turbine, well sited and engineered, could supply the entire Charleston peninsula with power. Imagine what dozens or hundreds could do.

Making it work

Some people are not yet convinced that wind is an answer. We have, for the moment, a relatively cheap abundance of fossil fuels and a great deal of costly infrastructure devoted to using them. And some of us don't like the looks of wind farms, or the politics of the renewable-energy lobby, or the risk to bats and birds that a spinning hub of blades poses. But carbon emissions and a warming climate present their own aesthetic downside, their own risks to bats and birds. So when practical-minded engineers like Ryan Schkoda tune out the pundits and just look at the numbers, and the rapidly evolving technology, and the freely available force of the wind, more and more of them are saying, as the Dutch engineers did three centuries ago, "This will work."

Schkoda is definitely one of those make-it-work sorts of guys. Having earned a Ph.D. in mechanical engineering from Clemson in 2012, followed by two years of postdoctoral research here, he is now a research scientist and one of several Clemson faculty members based at the wind-turbine testing facility. And he is the right guy to explain, patiently and clearly, how a great many complex technologies can mesh to yield not only the power of electricity but the power of knowledge.

It's a job that might almost seem too big for a man so young. Schkoda is the guy at Clemson most responsible for persuading computers to simulate and predict, right down to the last bolt and bearing, the way turbines behave in the wind. That means every imaginable kind of wind, from the gentlest zephyr to a catastrophic hurricane. Schkoda is also the guy most responsible for making sure that, before General Electric or some other corporation goes to the considerable expense of installing one of its enormous new turbines for a test drive in one of the facility's cavernous bays, the computers and software will be able to put that turbine through its paces in a realistic, reliably informative way. Because if Clemson can't pull this off, then millions of dollars' worth of facilities and a whole lot of pent-up potential may well go to waste.

But no pressure, Dr. Schkoda.

Bigger turbines for bigger gains

Let's take a step back for a moment, from Schkoda's computer screens full of cockpit-like readouts and graphic animations, and consider the *why*. Why have the U.S. Department

Ryan Schkoda

of Energy and various big corporations invested millions in this place, a reclaimed former navy yard in North Charleston, South Carolina? Why do we need a NASA-scale behemoth of a building, packed with so much high-powered electrical muscle that it needs its own substation?

The answer, at its simplest, is that we don't really know yet the limits of wind power. We don't really know, exactly, how the next generation of turbines will work. Yes, wind farms are sprouting on ridges and prairies across the United States, supplying, at last count, about 4.3 percent of the nation's electricity production. But most of these wind farms are land based and use relatively small turbines, usually in the range of 1 to 3 megawatts each. The two bays of Clemson's facility at Charleston are designed for testing turbines of up to 7.5 and 15 megawatts. Turbines in that range would be a huge leap forward, both in generating capacity and environmental friendliness. Studies by Swiss and Dutch researchers have found that the larger the turbine, the greener the energy it produces.

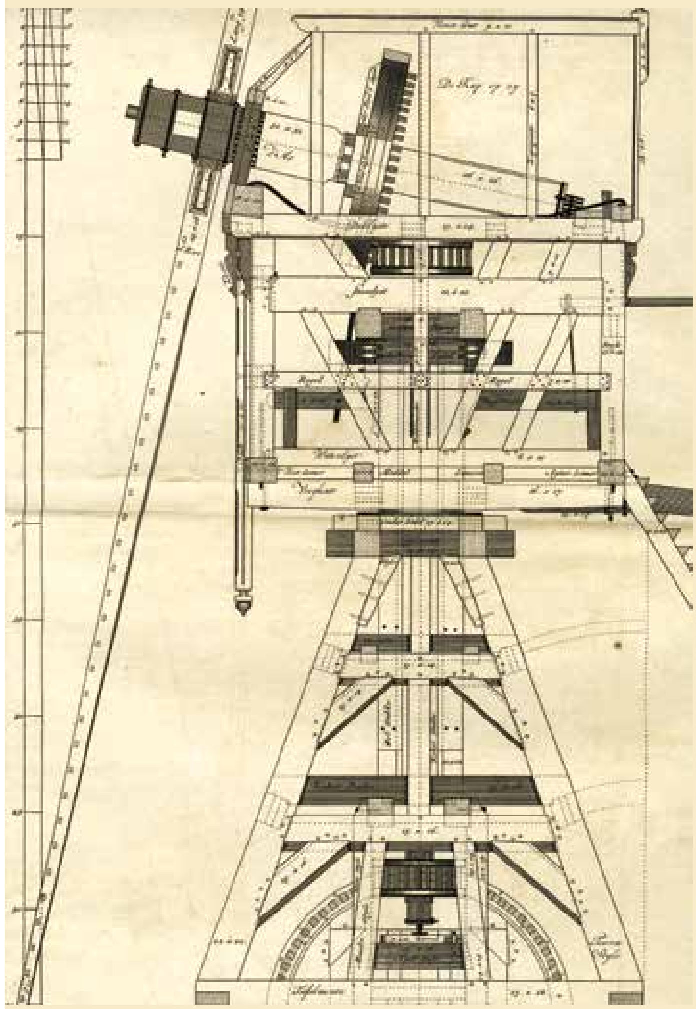
In the very early days, large wind turbines had a spotty record. One 131-foot-tall monster, mounted by NASA on Howard's Knob in Boone, North Carolina, in 1977, made a whooshing sound that rattled windows and annoyed the locals; it was dismantled in 1983. Wind-turbine technology has come a long, long way since then. And from an engineer's point of view, it seems likely, given today's rapidly advancing technology, that the next generation of big turbines will produce power more efficiently and more economically than small turbines can, especially offshore, where each installation requires securing a tower to the sea floor and protecting the whole enormous structure from the ever-present threat of corrosion. The bigger

Marvels of technology, centuries removed

Left: This panoramic view shows a 1.6 megawatt nacelle being tested in the smaller of two drive bays, a whopping 7.5 megawatts.

Below: This drawing, from Jan van Zyl's *Great Universal Mill Book* of 1734, is an elevation of the framework and internal mechanism of a simple sort of windmill called a wip moolen or water wip mill, used for draining low-lying agricultural lands. Nicholas Butler, a historian with the Charleston County Public Library, has been digitizing Zyl's pages. "We have no idea how this book made it to our library," he says, "but it's been here for a long time. Perhaps it was acquired by an early South Carolinian."

Image courtesy of the Charleston County Public Library.



the turbines, the fewer you have to install and maintain.

"Right now, the offshore models are starting at three to four megawatts," Schkoda says, "and the prototypes are in the eight-megawatt range. You just have more wind out in the ocean, and you don't have as many things around, so you can put a larger machine out there. But the drawbacks are that it's a harsher environment, more humidity, more salt, harder to install."

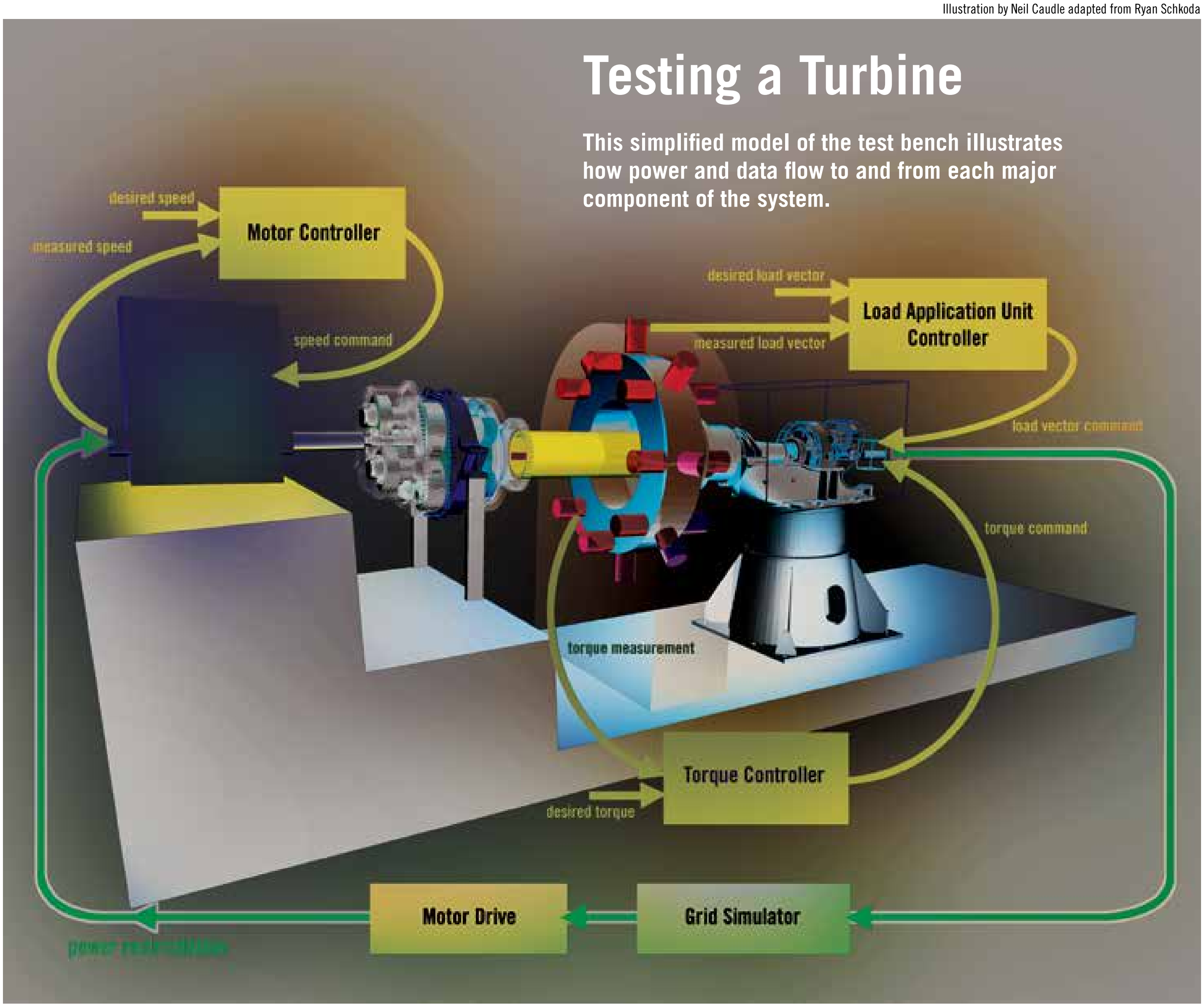
Gearing up for a dry run

But an even more significant barrier to large turbines may well be the problem of predicting their performance and durability. When you design a big, expensive new prototype, how do you test it? You probably can't afford to install it and then wait a few decades to see how it reacts to all possible weather events, including hurricanes. You have to know pretty well what to expect before the you-know-what hits the fan.

"The problem with prototyping a wind turbine and putting it out in the field for testing it is that you may not acquire a lot of useful data," Schkoda says. "First of all, we don't have an efficient way to measure a wind field. The response of the wind turbine depends on the entire wind field, not just the average speed, which is typically what is measured. Also, it's the turbine's response to extreme or rare events that engineers are particularly interested in, which by definition are rare. So even if you wait six months or a year you may not observe the type of scenario you're hoping for, and if you do, you're going to get it once, and that's it."

Even if your company could afford to wait a hundred years for a hundred-year storm, you still wouldn't collect enough data from a single event to learn everything you needed to know about what happened inside the machine, Schkoda says. So Clemson and its partners have attacked this problem by building a pair of test bays, each with a gigantic socket into which the team will plug a nacelle—a unit that includes the turbine's housing and internal working parts, intact except for blades and a rotor. The team will apply power, and spin the drivetrain at various speeds and torques, under various kinds of mechanical stressors and loads. They will use sensors

Illustration by Neil Caudle adapted from Ryan Schkoda



mounted throughout the nacelle, along with computers logging data in the control rooms, to monitor what happens every step of the way.

"Operating the turbine in a laboratory setting versus in the field offers a big advantage in terms of data acquisition," Schkoda says. "We have, in total, seven hundred and fifty channels of low-, medium-, and high-speed data acquisition available on each test bench. Acquiring this quantity and quality of data in the field is far more difficult than on a test bench."

Testing, beyond the routine

So this is one big part of Schkoda's job: to make sure the software he's crafting can detect what's happening, moment by moment, in a futuristic wind machine. How does the shaft react to a sudden change of torque? How are the teeth in the gearbox meshing, as the speed drops or rises? Are the onboard controllers reacting fast enough to adjust the pitch of the blades for the changing direction and force of the wind?

Dozens of variables like this affect the turbine's performance, the wear and tear on its parts, and the payoff in usable power. So Schkoda studies the whole system, along with its parts.

"We look at how the main shaft interacts with the bearing, interacts with the gearbox, interacts with the generator, because you won't be able to see that just by looking at gearbox testing at the gearbox manufacturer or main-bearing testing at the main-bearing manufacturer. You really have to get them all together, and you have to stress the whole nacelle to see how it responds."

Some of the stresses and loads are routine. The industry prescribes various benchmarks that turbines must meet before they're ready for a wind farm. These test protocols, Schkoda says, usually involve applying static or slowly varying loads. But the real world of weather is never so neatly prescribed.

"A wind turbine operates in a very dynamic environment, and the failure modes we're seeing in the wind industry reflect that fact," Schkoda says. "At the testing facility we can replicate this dynamic environment by controlling the wind, so to speak. We can drive the turbines statically and dynamically, replicating the loading scenarios it sees in the field."

Unpacking a lifetime of weather

So another part of Schkoda's job is to learn how to stress the nacelle in all kinds of highly realistic, irregular ways, and that presents an even more formidable and intriguing set of problems. How do you simulate, in the circuits of computer and a few million lines of code, the forces of nature? How do you compress, into weeks or months, several decades of simulated weather events?

Schkoda hands me an orange hard hat and leads me into the "multibody simulation lab," a room equipped with racked CPUs and several monitors. There he introduces me to Amin Bibo, a member of his team.

"The idea here," Schkoda says, "is to give test engineers, test operators, and customers the exact same interface to either of the two test benches that they would have in the control rooms, but in a simulation environment by replacing the physical equipment with real-time simulation models. This gives us an opportunity to study proposed test profiles and evaluate the simulated system responses prior to attempting anything on the actual test bench."

Neil Caudle

Ryan Schkoda explains the array of computers and displays he uses to model the performance of wind turbines.

He allows me to fiddle with the controls, increasing the force and direction of a simulated wind. I can watch, on the monitor, an animated graphic of a nacelle, accurate to its last detail, reacting to the forces I am wielding on a whim, like some pitiless wind god from Greek mythology. As the wind speed increases, the nacelle on my screen reacts. Virtual controllers adjust the pitch of virtual blades to maximize energy capture.

"You never have a nice, beautiful, uniform flow coming into the wind turbine," Schkoda says. "It's always going to be at least a little turbulent, meaning you'll have an imbalance on the rotor. One of the things we would like to study at the facility is this imbalance and how to mitigate the resulting loads so that wind turbines reach their design lives."

Coding the known to predict the unknown

To simulate the whole range of possible environmental conditions, and their dynamic interaction with the nacelle, Schkoda creates computer-based models for each system of interest. The software tools he uses (including MATLAB/Simulink and SIMPACK) are standards in industries such as aerospace and automotive engineering; they help Schkoda model the complex interactions of multiple moving components. But there's very little off-the-shelf software to help him simulate the special conditions of next-generation nacelles or the custom-built test benches his facility will use to evaluate drivetrains. For that, he has to fashion new models and write a lot of original code.

Over the last two years, Schkoda has been able to produce or acquire models of all the major components he'll need to study each test bench. And he's been using some of those models to help with the commissioning of the test bench—the rigorous period of testing and debugging that proves the system worthy and ready for business. For this phase, the guinea pig they're using is a General Electric 1.6-megawatt nacelle, one of the company's most popular units.

"We're beginning to get data from the test benches and are using the data to validate the models," Schkoda says. "We're comparing side by side the predicted response of the model versus the actual response of the test bench. It's very exciting."

Once he's sure that he has a good match between what his models predict and what actually happens on the test bench, he'll begin to extrapolate, to model things that have not yet been tried on the bench, to predict what will happen during actual testing.

Gaining on the competition

Schkoda leads me next into the control room, where a squad of engineers monitor computer screens adjacent to the 7.5-megawatt test bay. The General Electric nacelle, mounted a few steps beyond the glass of one wall, hums like a hive full of well-mannered bees. He shows me the test control station, where an operator can sit and ask for certain speeds and torques to be applied on the test bench. Down the way, computers acquire data, logging various measurements from the test bench and from all of the electrical systems in the building, to make sure the power's flowing where it should. The room is configured so that a private company could set up its own equipment beyond a partition, to have whatever privacy it might need.

Once they commission the test benches and gear up for full-scale testing, Clemson engineers and corporate partners will run one of only two such facilities in the nation. The other site, operated near Boulder, Colorado, by the National Renewable Energy Laboratory (NREL), collaborates with Clemson to advance the science and engineering of wind-turbine drivetrains.

"We work closely with NREL to provide testing services that are valuable to the wind industry," Schkoda says. "We collaborate on various levels to improve the testing capabilities available in the United States."

Because of the facility's dual role—academic research plus full-scale commercial testing and modeling—Schkoda, his colleagues,

Neil Caudle

In the control room, engineers monitor tests on a 1.6 megawatt nacelle.

and their students all learn to work with a foot in each realm. They have to develop their research programs and simulation capabilities at the same time they're wielding wrenches and screwdrivers, helping to install and commission the test bench.

Both roles are urgent because the U.S. wind-turbine industry can't afford to lag in the field much longer. Europe, Schkoda says, is probably a decade ahead of the U.S. when it comes to incorporating wind into its energy portfolio, and several European countries have developed wind-turbine testing facilities. But Clemson, Schkoda says, will have the technology and the know-how to help American industry close the gap.

Guarding the data

We pass a room full of high-capacity servers awaiting rivers of data from the test benches, and Schkoda mentions the security measures required to protect the numbers.

"Those test results are very valuable to customers," Schkoda says, "and we protect them accordingly."

Clemson has contracted with Savannah River National Laboratories, which manages data security for nuclear facilities, to handle data acquisition and transfer. Encrypted data will flash through fiber-optic landlines to corporate clients or to Clemson researchers working on main campus.

Our last stop is the 15-megawatt drive bay, where we climb a set of steel treads to a catwalk and look out on a massive, gleaming disk studded with hydraulic actuators. The actuators will apply loads to the main shaft, when testing begins here. From this vantage point, the drive bay looks like a setting from science fiction. The building itself is a machine chock full of high-voltage electronics, seven half-megawatt motors to pump hydraulic fluid, and whole rooms full of switches, transformers, converters, filters, and more. When a big nacelle is up and running, the power it generates has to go somewhere, and in this case the operators have two options.

"We can either switch into the electric grid, and push that power right into the local grid, or we can circulate it back to the drive motors and recycle the power," Schkoda says, "so that we only have to draw enough power to cover the losses due to friction and heat."

The team can also model the turbine's interaction with a power grid, using the facility's in-house grid simulator, the Duke Energy eGrid (see the sidebar, page 41), led by Clemson's Curtiss Fox. Having the eGrid handy is a huge advantage, Schkoda says, because manufacturers and power utilities need to know how a new turbine will behave when connected to an actual grid. It's not enough to test the nacelle in isolation, as a stand-alone device. You need to evaluate its performance as one node on a highly complex, dynamic network delivering power where people need it.

Full circle

After we stash our orange hardhats and make our way back to the building's front hall, we stop for a moment to look across the street at the Lasch Center, where the *Hunley* rests in its pool. One hundred and fifty years ago, state-of-the-art engineering produced an iron-hulled submarine powered by

Neil Caudle

Ryan Schkoda in the 15-megawatt drive bay. Big turbines will yield more efficient power, if they can prove themselves on the bench.

men turning cranks. And here we are, only a few generations later, standing inside an enormous, machine-like facility that makes the *Hunley* seem as tiny as a wind-up bathtub toy. It's a stark illustration of how far engineering has come.

"It's unbelievable how much things have changed in only a hundred and fifty years," Schkoda says. "As an undergrad I did an internship with General Dynamics Electric Boat and had an opportunity to work on our navy's Ohio-class submarines. Comparing one of those ships to the *Hunley* really highlights that point."

In the *Hunley's* day, you heated your house with wood or coal. And you fired up your steam-powered sawmills and warships and locomotives with wood or coal. And you filled your lamps with oil. Because those were the machines of their era and the fuels available to hand. The windmills of the previous century? Gone.

But the wind has come full circle, here in Charleston. And wind machines may once again prevail. It's the right city, at the right time, for an ambitious young engineer who'll keep the lessons of history close at hand while he builds for the next hundred years.

"When I came here two-and-a-half years ago as a postdoc, this facility was a construction site," Schkoda says. "It's incredible to see what everyone's hard work has been able to accomplish since then. We have a very talented group of engineers working on the project and the facility has come together beautifully. This is a very exciting time for all of us, and we're just getting started."

Ryan Schkoda is a research scientist and a faculty member in mechanical engineering, College of Engineering and Science. He is based at the wind-turbine drivetrain testing facility, which was dedicated in 2013 as the SCE&G Energy Innovation Center, part of the Clemson University Restoration Institute (CURI).

Nikolaos Rigas, who helped lead the design and implementation of the center, is the executive director of CURI. Andre Mander is the director of operations for the center, which received a grant of $45 million from the U.S. Department of Energy and substantial support from SCE&G, Duke Energy, the State of South Carolina, and other public and private contributors.

The team operating the wind-turbine drivetrain testing facility includes a director, two test engineers, an electrician, a machine specialist, a postdoctoral fellow, and Schkoda. This team collaborates closely with the eGrid team, which includes a director, three research scientists, and an engineer, to "push the equipment and advance the state of the industry," Schkoda says.

The title of this article, "Defining the Wind," is borrowed from Scott Huler's book about the Beaufort scale of wind measurement (Crown Publishers, 2005).

Ramping up for renewables

Now that the wind machines are up and running, bring on the sun.

Clemson's wind-turbine drivetrain testing facility is one step toward building a national powerhouse in renewable energy research and development. Next up? The sun.

"We designed and are building a full-scale photovoltaic emulator," says Nikolaos Rigas, executive director of the Clemson University Restoration Institute (CURI), which oversees work at the North Charleston campus. The emulator, attached to the Duke Energy Electric Grid Research, Innovation, and Development (eGrid) Center (see "Power Up," *Glimpse,* Spring 2014), will simulate output from a photovoltaic (PV) array up to two-and-a-half megawatts—equivalent to a commercial-scale solar farm.

"This way we can do studies related to the large-scale PV systems without the need to have an actual PV array at the site," Rigas says. "But more importantly, it will allow us to control the array, so we don't have to wait for partial shading of the array by the sun, for example. We can program the device to emulate that for us."

Like wind energy, solar energy offers strong potential but serious complications for the utilities that manage the nation's electrical grid. Electrical production from wind and solar energy ebbs and flows somewhat unpredictably, a drawback for power grids designed for the regularity of plants powered by nuclear energy or fuels such as gas and coal. Also, a photovoltaic (PV) system generates electricity in direct current (DC) but requires an inverter to translate the DC power into the alternating current (AC) used on existing power grids.

Solar's growing role

"When there wasn't much solar out on the electrical grid, the utilities didn't care what solar plants did or didn't do," Rigas says. "If they dropped out or had a fault, it didn't matter, because the amount that supported the grid was so small. But now, when you're having larger and larger percentages of the grid supported by photovoltaic arrays, utilities are expecting them to stay connected during transient events and to provide support."

That means the industry needs "smart inverters" that could communicate with the grid and react more intelligently, rather than just taking the sun, converting it to power, and putting it out onto the grid, Rigas says.

To conduct the research necessary to help develop these smart inverters and other PV technologies, Clemson needed access to a large-scale photovoltaic array. "But instead of building a photovoltaic array, we're building a device to emulate it," Rigas says.

Like the virtual test bench Ryan Schkoda has been building in the wind-turbine testing facility, the virtual PV array will use computer-based simulation to model its performance and its behavior on the grid. And like the wind-turbine facility, the photovoltaic component will accommodate corporate clients who will plug their new technologies into the system for testing. So in one location, Clemson and its partners will have the capacity to model and test, on a commercial scale, next-generation technologies for the two leading sources of renewable energy in the U.S.: solar and wind.

A magnet for students

It's a business model that works, Rigas says, not only for economic development but for teaching and research, because students and faculty researchers are directly involved in every aspect of the enterprise.

"Every single person employed at the facility is dedicated to supporting student education and research," Rigas says. "It's built into everybody's job description."

It's an approach with powerful appeal for students at every level, from high school kids working as summer interns to undergraduate and graduate students working side by side with corporate clients, faculty, scientists, and engineers. In December, Clemson broke ground for the 50,000-square-foot

Craig Mahaffey

Nikolaos Rigas: "Instead of building a photovoltaic array, we're building a device to emulate it."

Zucker Family Graduate Education Center along the waterfront at CURI. Rigas expects that the facility, which will feature an energy-efficient design, will be open for graduate engineering students in Fall 2016.

Following the car

The model for this blend of educating students, public/private partnerships, and conducting research in a commercial-scale facility didn't happen by accident, Rigas says. It follows the example set by the Clemson University International Center for Automotive Research (CU-ICAR), which also includes corporate partnerships and the kind of dynamic testing and modeling required to engineer the automobiles of the future.

Imtiaz Haque, executive director of CU-ICAR at the time, helped Rigas craft the model along with a successful proposal to the U.S. Department of Energy, which provided $43.5 million, the center's largest source of funding. "Doctor Haque was key in the development of this center," Rigas says. "CU-ICAR had full-scale vehicle test facilities that Doctor Haque was involved with designing and building. So the concept that you see here was actually built off the experience at CU-ICAR."

–Neil Caudle

Nikolaos Rigas is the executive director of the Clemson University Restoration Institute (CURI) and a research professor in the College of Engineering and Science.

Imtiaz Haque is the executive director of the Carroll A. Campbell Graduate Engineering Center and Founding Chair of the Department of Automotive Engineering at Clemson University's College of Engineering and Science.

Work on the new photovoltaic emulator will be led by Jesse Leonard, a research scientist who earned his Ph.D. working with a grid simulator at Florida State University. His project is part of the Duke Energy eGrid, whose director of operations is Curtiss Fox.

CURI reports to John Ballato, Clemson's vice president for economic development.

Ryan Schkoda

Air-core inductors, coiled in yellow insulation, simulate events on a large power grid.

Tuning the gear and the grid

Whatever the source of renewable energy, electrical power on a commercial scale moves on a grid. The Duke Energy eGrid tests new equipment "in the loop," to learn how generators, controllers, converters, and various other elements perform together in a working grid.

Curtiss Fox, director of operations for the eGrid center, first envisioned the grid simulator when he was a Clemson graduate student and intern at the Clemson University Restoration Institute (CURI). Fox uses a large amplifier—an arbitrary waveform generator—to supply realistic electrical loads. Drawing only a few volts of energy supply, the amplifier can produce up to fifteen million watts. In a room carefully sealed against intruders, coils of air-core inductors replicate the inductance of power lines across a large electrical grid. Here, researchers can study events as they would transpire over many miles of grid, simulating, for example, the physical faults that occur when a falling tree knocks one power line against another line or drops it on the ground.

But don't even ask about touring this room full of yellow-sheathed inductors.

"We're trying to do exactly what the codes say *not* to do," says Ryan Schkoda, as we peer through a heavy-duty wall of glass. "We're doing it as safely as possible, and the faults are happening inside equipment designed to handle them. And the key to enter this room is inside the breakers. So if the power's on, you can't even get to the key."

Schkoda and his collaborators use the eGrid to observe how wind turbines interact with the grid. "Instead of having tens or hundreds of miles of power lines, you can put these air-core inductors in series with the supply voltage and make the wind turbine think the power is coming from nearby or from far away, depending on where you set the switches," he says. "So if you do have a fault, say in the nacelle—maybe the converter shorts out or maybe the gearbox breaks and the high-speed shaft has to stop—the resulting electrical forces depend on the grid you're attached to."

The grid's reaction can be very different, he says, if you're close to a city versus in the countryside at the end of a distribution line. So Fox and the eGrid team use a real-time digital simulator to study the dynamic conditions on a power grid. On their computers, they can track and evaluate the kinds of problems that are unknown to most consumers but bedevil utilities on a regular basis: fault ride-throughs, harmonics, and various other exotic phenomena.

In the effort to increase renewable energy, this has long been a missing link: the ability to tune both the grid and the generating equipment for safer, more efficient operation. For Ryan Schkoda, having the eGrid will help ensure that wind-turbine testing accurately reflects the realities of the grid. "As we move into dynamic testing," he says, "we're planning it one hundred percent with the eGrid."

The Duke Energy eGrid is a collaboration of Duke Energy and Clemson University. TECO-Westinghouse partnered with eGrid to supply the amplifier described in this article.

a blood test for breast cancer

by Anna Simon

Fluorescent image of cancer cells on specially shaped fibers. The glowing red dots are human breast cancer cells, the blue dots are human breast metastatic cancer cells, and the green are human benign breast epithelial cells. Image by Suzanne Tabbaa.

My mother, Faye Simon, was a breast cancer survivor. The cancer returned years later and took her life. My dad uttered only five words as we left the funeral home: "Cancer is a cruel disease."

Suzanne Tabbaa envisions the day when a routine blood test would catch breast cancer before it spreads and could help doctors monitor cancer cells during treatment.

As Tabbaa works in labs on the fourth floor of the Rhodes Research Center to develop this diagnostic tool, she describes a family friend who lost her life to cancer. Her friend's mom had shown no symptoms when a routine exam led to the discovery of Stage IV cancer. It already had "spread everywhere," Tabbaa says.

Could Tabbaa's research have helped her friend or my mom? I don't know. Success so far in research holds hope for early detection and noninvasive monitoring of treatment for future breast cancer patients.

Each year more than 200,000 cases of breast cancer are diagnosed in the U.S. and more than 40,000 people die of the disease, according to the Centers for Disease Control and Prevention. While breast cancer is the most common cancer in women, the statistics also include men.

The blood test would be a simple screening, like the blood tests that millions of Americans undergo regularly to check on cholesterol, iron, and other health markers, Tabbaa says. The test could be done from the same blood sample as those routine screenings.

It would be a simple tool for early detection, to catch recurrences, provide a noninvasive alternative to tissue biopsies, and help doctors see if treatment is working, Tabbaa says.

Medical research with textile roots

Tabbaa started this research as a doctoral candidate and graduate research assistant in Clemson's Institute for Biological Interfaces of Engineering. She graduated in December 2014 and continues her work as a postdoctoral bioengineering researcher at the institute.

The process is rooted in Clemson textile research. "We're basically taking a method from the textile industry and using it as a cancer diagnostic," Tabbaa says.

Wicking fibers are used to transport fluid and capture cancer cells that are in the fluid, Tabbaa explains. These fibers are grooved and rough to the touch. The shape is part of the formula that makes the process work, a design donated to

Clemson by Eastman Chemical Company. Tabbaa stops at an extruder, a piece of machinery that makes the specially shaped fibers. She hands me a piece of material that looks and feels like a strand of uncooked spaghetti with irregular notches hacked into it.

Several strips of this material extend from a well of liquid on the counter of another lab. Cells that have been placed in this liquid nutrient solution are able to travel up the fibers, Tabbaa says. She uses the fibers to separate cancer cells from normal cells, capturing the cells in a special cap that is the heart of a Clemson patent application for the process.

Physical differences between normal cells and cancer cells keep benign cells from traveling as far as the cancer cells, which are smaller and "squishier," enabling them to move farther along the wicking material, Tabbaa explains. The process also separates nonmetastatic cancer cells—those that might be in a tumor but either haven't migrated yet or don't have the capacity to migrate—from metastatic cells. The metastatic cells travel the longest distance on the highway of absorbent fiber placed in the beaker, Tabbaa says. Each of the three types of cells—benign, nonmetastatic, and metastatic—can be identified by protein markers expressed along the wicking fiber.

We walk down the hall to another lab. Tabbaa places a sample under a microscope and turns off the overhead lights. Normal cells glow green, nonmetastatic cancer cells glow red, and metastatic cells glow blue on a computer screen that shows what Tabbaa sees through the microscope.

James Turner

Suzanne Tabbaa was trying to boost the blood supply to bone grafts when she noticed that the fibers she was using wicked cancer cells.

Bone-graft work yields a surprise

Tabbaa stumbled upon the possibility for a blood test for breast cancer through earlier work on bone-graft material. She was looking for a way to get blood flow, which carries necessary nutrients, to the central core of large bone grafts such as spinal fusions and large fractures. She investigated the use of wicking fibers as a synthetic vascular system to carry blood to the center of the grafts.

"I started looking at bone cells moving through a wicking process and that led us to wonder how cancer cells move," Tabbaa says.

Tabbaa discussed applying the wicking fiber technology as a blood test for breast cancer with her mentor, breast cancer tissue researcher Karen Burg. It seemed to make sense, and Tabbaa's research took a turn.

The patent application filed by Clemson includes processes applicable to diagnostic blood tests and tissue engineered bone grafts, Tabbaa says.

So, when could this blood test be available at your local doctor's office? It's generally difficult for researchers to predict when a technology could move from the lab to the marketplace. There are a lot of ifs. Maybe five years, maybe ten, if all goes well, Tabbaa says.

When that time comes, Tabbaa has a marketing plan. She has developed a four-year process to put low-cost test kits, priced at about $10, on the market for clinics and other medical care providers. In April of 2014, her plan won the first place audience award and second place judges' award at a Society for Biomaterials annual conference business plan competition. The day when she can put that plan into action is still a ways down the road.

The next steps are to move from liquid solution to blood, and then to actual patient blood samples. Clemson received a $150,000 grant from the Avon Walk for Breast Cancer to further this research. The grant abstract states that this "clinically applicable, easy-to-use diagnostic test" is "predictive of breast cancer risk and can be used to monitor breast cancer changes over time."

When Tabbaa went to an Avon Walk for Breast Cancer event in Charlotte to receive the grant, she was further motivated by the personal stories she heard from the breast cancer survivors and patients she met there. "It's seeing the application and knowing that you have a chance to help people through your work," Tabbaa says.

Suzanne Tabbaa was awarded a Ph.D. in bioengineering in December 2014. Her advisor, Karen Burg, is now vice president for research at Kansas State University. At Clemson, Burg was the Hunter Endowed Chair, a professor of bioengineering, and a professor of electrical and computer engineering, in the College of Engineering and Science.

Information about technology from Tabbaa's work is available from the Clemson University Research Foundation (CURF). CURF is a 501(c)(3) nonprofit corporation dedicated to maximizing the societal impact of Clemson University research through commercialization of intellectual property. For more information on CURF and a portfolio of technologies available for licensing go to clemson.edu/curf.

When a warrior can’t go it alone

by Neil Caudle

It’s their job to go where no one should have to go. To see what no one should have to see. To do what no one should have to do. And afterward, if they’re lucky, they get to come home.

But for some, that last, lucky step turns out to be the hardest one to handle. Because they haven’t spent months or years decompressing from the terrifying depths of combat, from the loss of their buddies. They haven’t spent months or years training for the day when they tumble back into the slipstream of what used to seem normal and safe but no longer does: life at home.

On camera, a soldier with the rank of specialist in the army talks about his return from Afghanistan:

> When I first got back I was in a state of denial. It hadn’t really hit me that my buddies were really gone. I drank heavily…First it was only on the weekends, on leave, and then it was almost an everyday thing. When we realized that it was a problem, that it was interfering with work, we started to really see the symptoms of PTSD: not sleeping, not eating, fits of anger, nightmares, flashbacks…

Tom Britt has heard versions of this story many times. As a captain, he served as a research psychologist assigned to the Walter Reed Army Institute

A CH-47 Chinook helicopter flies over Kabul, Afghanistan, June 4, 2007. DoD photo by Cherie A. Thurlby.

of Research, first in Heidelberg, Germany, and then in Silver Spring, Maryland. After he left the army and found his way into academia, he spent two decades studying the mental health of soldiers. He has edited two books and a four-volume series on military psychology. And most recently, he's been evaluating a new kind of training program designed to help military units support soldiers who need help with mental health.

The project, he says, is pushing him onto new ground.

"After you've done academic research for years you start to say, 'Well, you know I'm contributing to the scientific literature, but am I really doing anything to help anyone?'" he says. "And so when this opportunity came up, it was something I wanted to do, but I was stepping outside of my comfort zone. I think everyone who's been working on the project realizes how difficult it is to design training that will change attitudes and change the climate of units. It requires a whole different skill set."

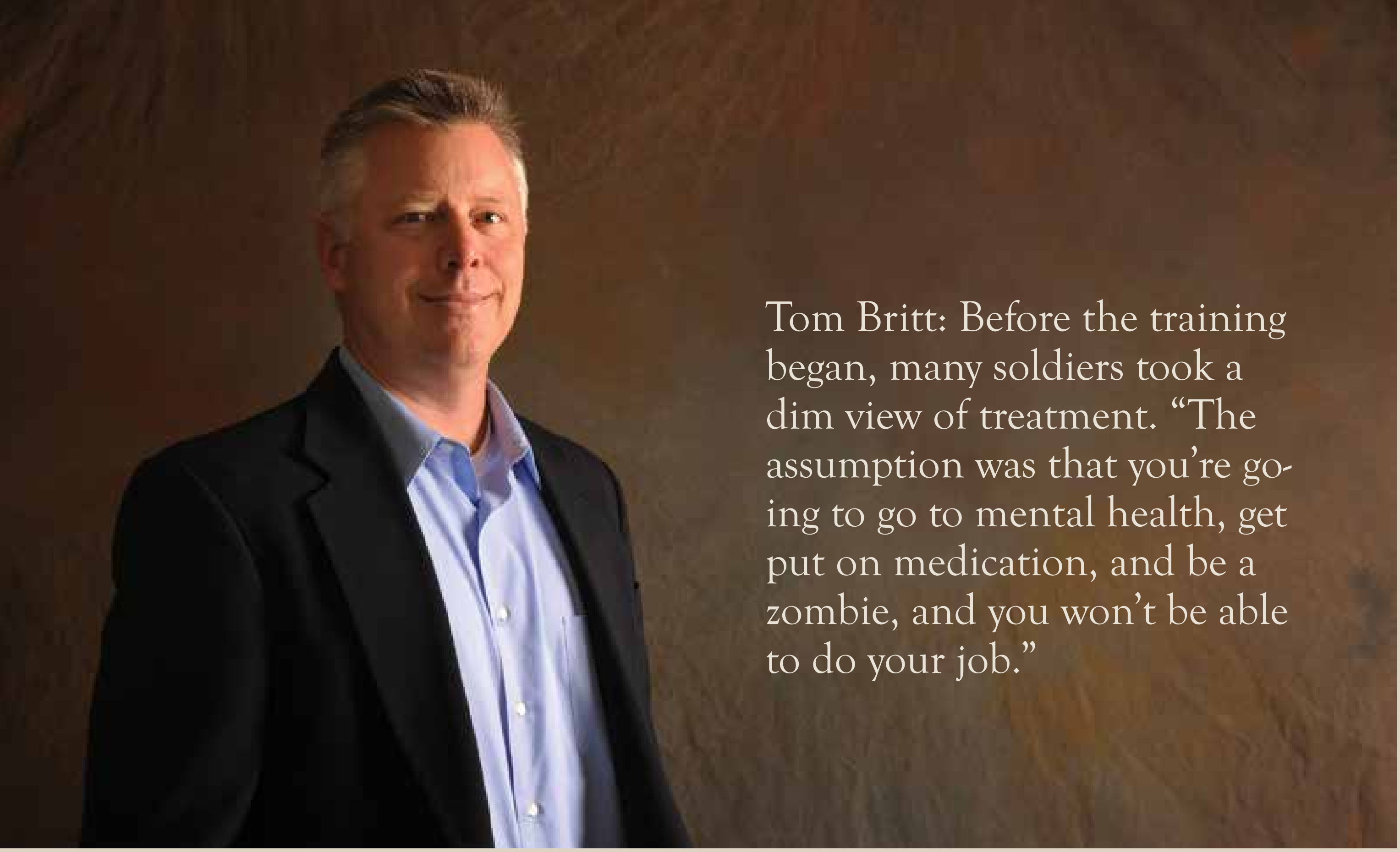
That's because the attitudes Britt and his team want to change are probably as old as warfare itself.

The slaps felt 'round the world

In August of 1943, General George C. Patton visited U.S. Army field hospitals in Sicily and, in two separate incidents, slapped, threatened, and condemned as cowards shell-shocked young privates he found among the wounded. When General Dwight Eisenhower learned about the incidents, he relieved Patton of command of the Seventh Army and ordered him to apologize.

Patton's tirades, eventually reported in the press, made him infamous back home, but his hostility toward soldiers with mental illness was pretty much the norm. Many of Patton's fellow officers saw no problem with his attitude, and soldiers cheered his old-school toughness. In the military culture of Patton's day, it was common to dismiss any soldier complaining of "battle fatigue" or "nerves" as a coward, a shirker, or a weakling.

Times have changed. The army today officially recognizes post-traumatic stress disorder and various other mental health problems as legitimate, treatable ailments that can happen to



Patrick Wright

anyone, no matter how dedicated or courageous. The military produces public service announcements to air this message, and leaders go on the record to acknowledge that they themselves have received mental health treatment, and that there was nothing weak or shameful about it.

And yet, down the ranks, where young recruits strap on their Kevlar and venture out to face the enemy, the message doesn't always come through.

"There is this kind of sense that the climate has improved, and it probably has," Britt says. "But we saw in our qualitative research, when we did focus groups of soldiers of different ranks, that this stigma is alive and well."

Learning from the "loony line"

As a captain in the army during the late 1990s, Britt was assigned to help evaluate soldiers coming back from deployment in Bosnia, to examine them for signs of the kinds of mental health problems that plagued many soldiers who returned from Desert Storm. Britt and others developed screening instruments, medical and psychological, and if the soldiers scored above a certain cutoff, they had to talk to either a medical professional or a psychological professional, with a separate queue for each.

"It quickly became apparent which line a soldier was in," Britt recalls. "If you were in the psychological line, soldiers would say, 'Oh, you're in the loony line; they'll take your weapon…' There was this visible stigma associated with being in that particular line. So that got me interested in the topic of stigma."

In one of Britt's training videos, an earnest young specialist talks about his own dread of shame, when he first went to counseling:

> I went in there with the stigma that mental health treatment was something you did not want to get because you kind of get shunned by your peers or subordinates, because they find out, "That guy's going to mental health, so he's got to be crazy."

For many young soldiers, a tough guy persona goes with the job: Never show weakness; never admit you need help. They fall into the habit of concealing their problems, even from themselves. Very often, when a deployment is over and the soldier is back among family again, it's the spouse, a parent, or a close friend who detects the fault lines of illness and pushes the soldier to get help.

But too many soldiers, Britt says, put off getting help until something catastrophic happens—a broken marriage, for instance, or an arrest for driving drunk. On camera, a specialist puts it this way:

> After a failed marriage and… hearing it from people on the outside, civilians, I knew that I needed to get help.

Ideally, Britt says, you'd help the soldier find treatment before his or her life or career hit the ditch. But how do you root out a stigma so thoroughly entrenched?

For one thing, Britt says, you don't stand at a lectern with a laptop full of PowerPoint slides and begin to hold forth, classroom style. If you're talking to warriors whose job it is to rise before dawn, march fifteen miles humping a sixty-pound backpack, traverse a snaky forest during land navigation, and finish the afternoon with a harrowing live-fire exercise, the last thing they'll need is a classroom, a lecture, and a fusillade of bullet points. When Britt's team asked the soldiers themselves what kind of training they wanted, he says they told him emphatically, "We don't want any PowerPoint presentations. We're sick of being PowerPointed to death."

Peer-to-peer training

So the training, as Britt's team conceived it over four years of careful study funded by the Department of Defense, uses videotaped interviews from soldiers and their unit leaders who describe their experiences with mental health treatment—the symptoms of their illness, the barriers and fears they had to overcome to seek help, what to expect from treatment (there is no leather couch), and the results. In randomly assigned squads of ten or so soldiers each drawn from two battalions, trainees in the experimental group watch the videos, discuss the issues, and think about specific actions the unit can take to better support soldiers who need treatment. (In the control group, the participants only respond to a survey.) The model Britt's group has developed for training reflects not only the findings of research but the realities of soldiers' allegiance to their fellow squad members. Very often, Britt says, soldiers learn best from their peers.

Separately, the researchers also train the squads' leaders, noncommissioned officers—NCOs. As one staff sergeant puts it, his duty is to place his soldiers' needs above his own:

> We go to horrible locations around the world, and we're charged with having to bring home our brothers and sisters in arms home to their families safely. That's our job. We can't let that go, here on the home front. So as soon as you identify that there is a problem, or somebody is carrying a burden that they don't need to be carrying, or that they don't have any control over and they can't dismiss, it's your job as a leader, it's your job as a soldier, it's your job as a fellow human being, to take immediate action on that and assist anyone in receiving the help they need.

Before and immediately after the training, Britt's team assesses the soldiers' and leaders' knowledge of mental health issues, along with their perceptions about stigma and barriers to treatment. That way, Britt says, the researchers can tell if the training is having an immediate effect. Initial results suggest that those soldiers and leaders receiving the training show better knowledge of mental health issues, more positive attitudes toward mental health treatment, and less negative perceptions of soldiers who get treatment. Three months later, the team returns to conduct another assessment, to see if the effects persist.

Sweating bullets

All of this takes time, not only for the researchers but for the soldiers involved. And time, on a busy military base, is hard to find. How did Britt manage to clear schedules through the chain of command? Has he had good cooperation from the army brass?

He smiles. "Yes, but it's effortful."

A contact at Walter Reed introduced him to a division surgeon, and that opened some doors. In the early days, Britt drove down to the base many times and briefed the leaders, if and when they hadn't been called away to more urgent business. He recalls the day when he at last pitched his project to the colonel in charge.

"It's fortunate that I was in the army," Britt says, "so I know how to talk to commanders. But when we briefed the brigade commander he didn't show any facial expressions during the entire briefing. So I was kind of sweating bullets and wondering, 'Okay, does he think this is worthwhile, or am I going to get done with this and he's going to say, "This is where it ends"?' But after I was done, he said, 'Just tell me what you need to make this happen.'"

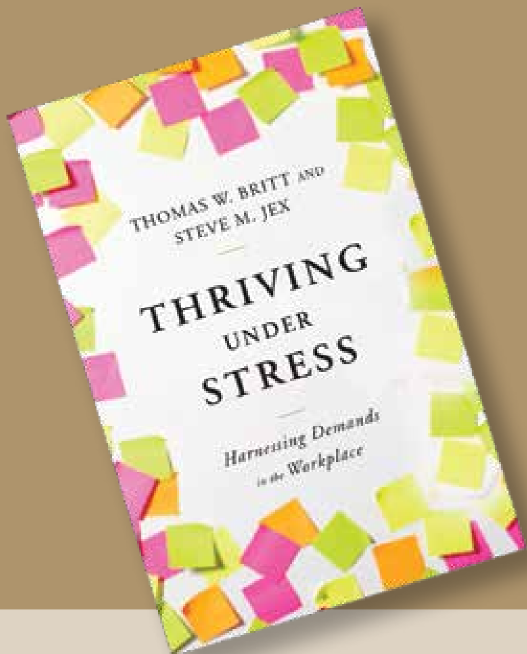
The meetings didn't stop there. Britt's team still had to convince the battalion commanders and their noncommissioned officers that the project was worth their time. "So it definitely takes a lot of work that would not be involved in just analyzing data sets that had been collected through some other method," Britt says.

It's a complex project with many moving parts, but Britt has recruited help from three colleagues—Cynthia Pury and Heidi Zinzow in psychology and Mary Anne Raymond from marketing—and several graduate students in the Industrial/Organizational Psychology doctoral program, including Kristen Jennings, Janelle Cheung, and Anna McFadden. Raymond's expertise with focus groups enabled the team to conduct an early round of qualitative research that uncovered soldiers' preferences and attitudes, a key step in designing the training. With guidance from Britt, Pury, and Zinzow, graduate and undergraduate students collect and analyze results from assessments and track themes that arise during training.

Doubting the meds

One of the themes that emerged from the early focus groups with more prominence than expected involves the use of medications. "It was clear through the qualitative work that

What every soldier needs: someone who has his back. Here, U.S. Army soldiers search for weapons caches during a night operation in Baghdad, Iraq. DoD photo by Staff Sgt. Jon Soucy.



Feeling stressed at work? Maybe it's time to find a higher sense of purpose. Tom Britt's newest book, *Thriving Under Stress,* draws on research into how soldiers and others in highly stressful jobs learn to cope and even thrive. We don't have to be passive victims, he says. "A hyper-concern with the negative effects of stress at work has prevented an understanding of how stress can be harnessed for growth," he writes.

attitudes toward psychotropic medications were very negative," Britt says. "The assumption was that you're going to go to mental health, get put on medication, and be a zombie, and you won't be able to do your job."

Some soldiers also expressed doubts that a squad member under treatment could be trusted to "have my back" in a fight.

Neither of these concerns about medication reflects the reality of modern, effective treatment, Britt says, so the team added new measures in the assessments and new topics for the training.

A specialist relates his own experience this way:

> Being on the proper medication, my anxiety level has been reduced tremendously. I'm not living day-to-day anymore. I'm doing more future planning. I'm back to work, I'm doing what I love to do, I'm helping soldiers, training soldiers. I'm not being selfish anymore.

As he speaks these words on camera, the soldier's bearing is calm and rock-steady, and nothing about him seems weak. In fact, he appears to exude a kind of courage—the kind it takes to admit that he needed help and got it, for the sake of himself, his unit, and all the other people in his life.

Britt and his colleagues, Cynthia Pury, Charles Starkey, and Heidi Zinzow, have written about this kind of psychological or moral courage, a quality Pury, Britt, and their colleagues find apparent in many of the soldiers who seek help. "There's the sense that even though there might be some stigma, and even though I might face personal distress when I'm working through my problems, I'm going to show the courage to get treatment," Britt says.

Resilience and the team

Courage of all kinds, Britt says, is likely to be stronger when it's associated with what he calls resilience, the toughness required to withstand hardship and adversity. Britt, who along with Robert Sinclair edited a book about resilience in soldiers, has long studied the factors that tend to build it up or tear it down. Sergeants in boot camp build resilience by gradually "inoculating" soldiers against hardship, Britt says. But the biggest factors in resilience may be soldiers' confidence that they have a measure of control over their fate, because they are well trained and prepared, and that their mission has meaning and value.

"Soldiers who believe that their work is meaningful and significant are much less likely to show mental health problems in the face of stressful or traumatic events," Britt says. "But if you're in combat somewhere and you're not well trained, and you don't know what you're doing there, and you have a negative attitude about the mission, then that really serves as a major predictor of soldiers who are going to have mental health problems when they get back."

The bottom line: Don't ask soldiers to fight for no good reason. And if they must fight, make sure they have the training, equipment, and support they need to feel prepared.

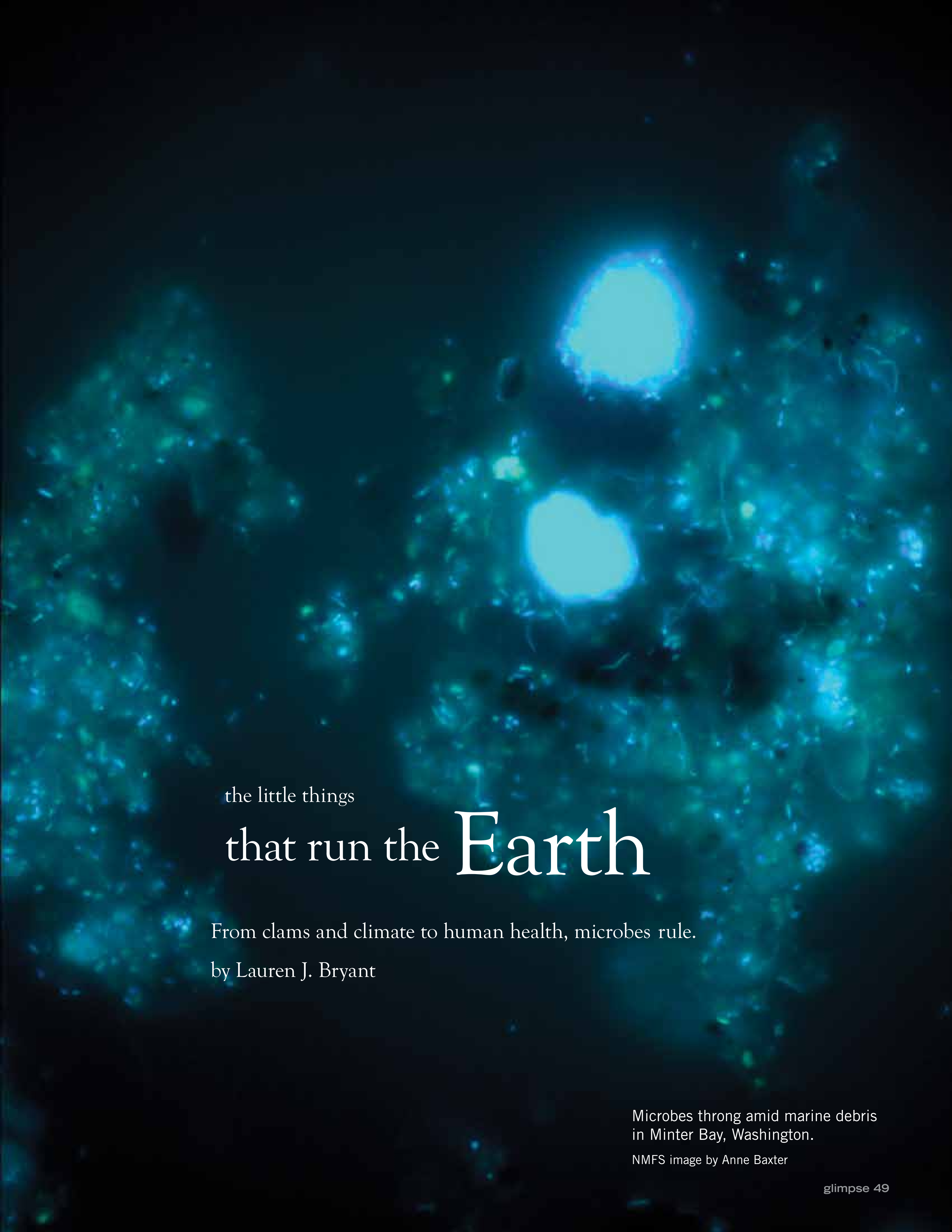
But even with the noblest cause and the best preparation, a soldier deployed into combat will almost inevitably face scary, chaotic unknowns. Most rely on their teammates to help them survive the crucible, to have their backs. So courage and resilience, as Britt sees it, are not just attributes of an individual. They also arise within the group, from the comradery and cohesion that makes each member stronger.

"Over all the military operations, unit cohesion emerges as probably the best predictor of whether soldiers are resilient in the face of traumatic events they encounter in combat and other operations," Britt says.

That's why his research and training have focused on the basic military unit, the squad, which is also a soldier's foremost peer group and social support network. To reduce the stigma and improve the climate for mental health, Britt says, you have to go straight to the heart of the matter, the squad. You have to make it safe for the soldiers, as individuals and members of a team, to seek the help they need.

In short, you have to have their backs.

Thomas Britt and Cynthia Pury are professors of psychology; Heidi Zinzow is an associate professor of psychology; and Mary Anne Raymond is chair and professor of marketing, all in the College of Business and Behavioral Science. Clemson Broadcast Productions produced the videos used in the training. Cadre from the Clemson ROTC department provided feedback on the leader and unit training.



the little things

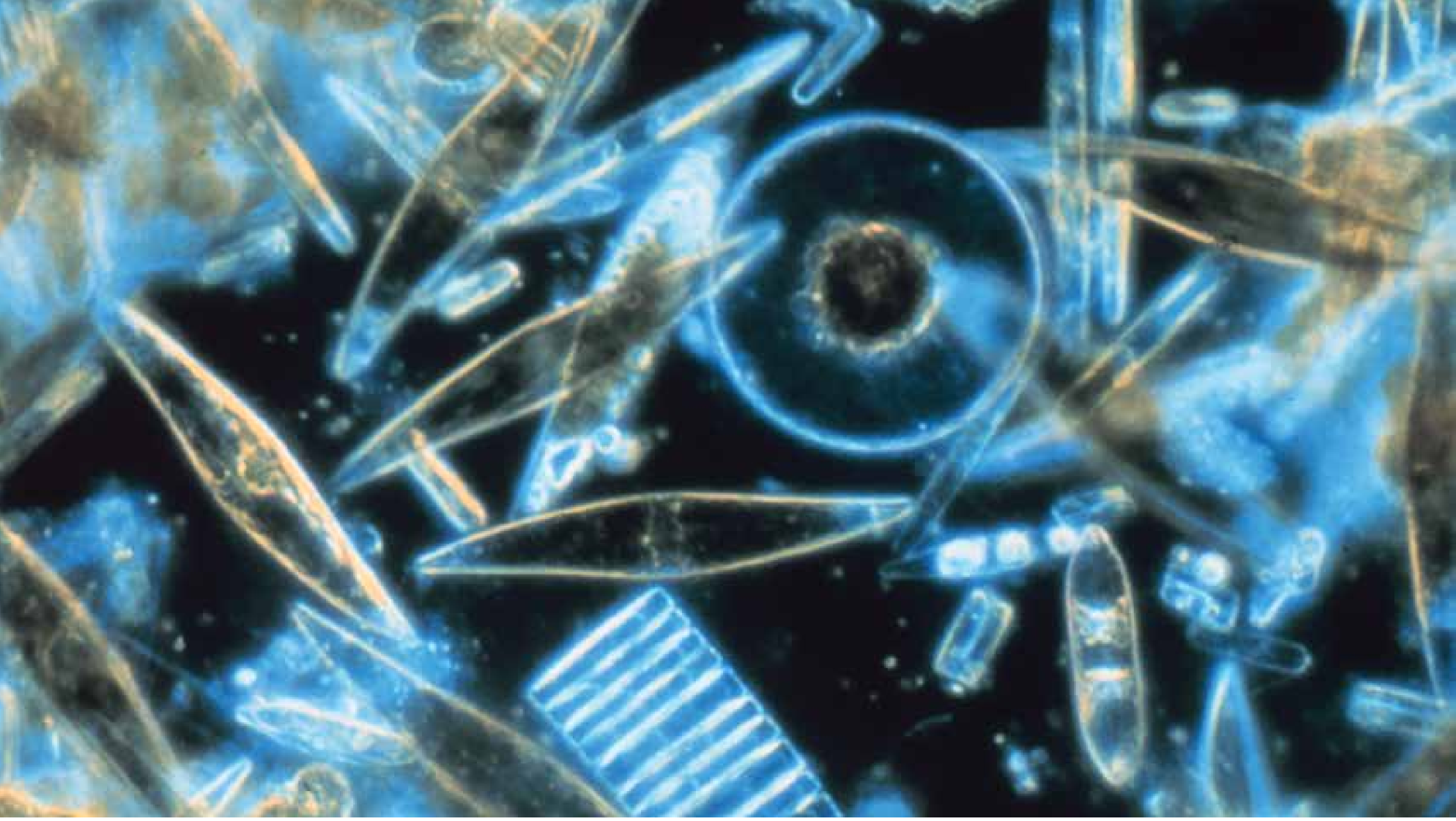
that run the Earth

From clams and climate to human health, microbes rule.

by Lauren J. Bryant

Microbes throng amid marine debris in Minter Bay, Washington.

NMFS image by Anne Baxter



Gordon T. Taylor, Stony Brook University

Funny things are everywhere. Above, diatoms thrive between crystals of sea ice in Antarctica.

The esteemed biologist E. O. Wilson once said, when describing the world's biological diversity, "It's the little things that run the Earth." Microbiologist Barbara Campbell certainly agrees, but she leans toward the description from Dr. Seuss:

> From near to far,
> from here to there,
> funny things
> are everywhere.

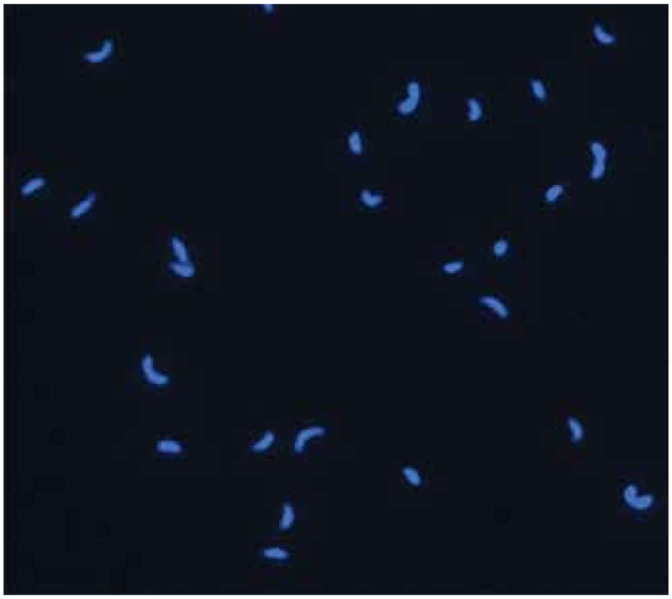
Campbell, an assistant professor in the Department of Biological Sciences, is a microbial ecologist—the funny things that occupy her scientific mind are microbes, the world's abundant microscopic organisms that include algae, bacteria, and viruses. Campbell focuses mainly on bacteria found in marine environments, especially in estuaries—where river and ocean meet—around the Delaware and Chesapeake bays.

Why this fixation on little, funny things?

"Microbes rule!" Campbell exclaims. "They're everywhere, and we can't live without them."

We can't live without them because microbes play essential roles in everything from regulating human health (think of the gut microbiome) to sustaining the natural cycles on which the life of plants, animals, and the earth's entire biosphere depend. In short: Little things add up, big time.

Thomas Lankiewicz and Matthew Cottrell, University of Delaware



Pelagibacter ubique, **one of the most abundant microbes in the ocean, magnified about one thousand times and stained blue.**

"I tell my students, 'What's great about microbes is they are so diverse and can do so many different things,'" Campbell continues. "'And what's bad about microbes is they are so diverse and can do so many different things.' Microbes are hard to study because they are so small and so diverse, but that diversity also makes them powerful."

Campbell's own description of how she accomplishes the difficult study of microbes has a Seuss-like simplicity. "I look at who they are and what they're doing," she says. The reality is a bit more adventurous and high tech.

On deck

Campbell (along with her frequent collaborator, David Kirchman, of the University of Delaware) takes two main approaches to investigating the behaviors of bacteria in coastal estuaries. First, she spends a fair amount of time on deck—on ship decks, that is, such as that of the R/V *Hugh R. Sharp,* a coastal research vessel in the University-National Oceanographic Laboratory System fleet whose home port is at the University of Delaware.

During research cruises, the scientists and students aboard collect samples twenty-four hours a day, typically every three to four hours, with the goal of learning how bacterial activities change over the course of a day and at different water salinities. They conduct experiments and analyses using the ship's laboratories. In between the sampling and analyzing, Campbell says, the researchers "read, talk science, or head up to the bridge to get a great view of the water."

Campbell has been out to sea five or six times since 2011 to conduct microbial research in estuaries. Her most recent trip occurred in late October 2014. "That one was a little rough," she says. "A nor'easter was coming up along the coast, so we had to not do some things we'd planned on."

These sea voyages, rocky or no, are necessary, Campbell explains, because "about ninety-nine percent" of microbes cannot be isolated and grown in a typical laboratory setting. It's just not possible to replicate the exact requirements for the microbes' growth—their necessary nutrient sources, for example, or the optimal temperature. And even if the right conditions could be created, artificially grown microbes would still not be preferred because they would be outside of their natural environment. That natural environment is important, Campbell says, because microbes are "a lot like us."

"Microbes can't live alone, typically," she says. "They're like us; we're always interacting with other people. Microbes interact with other microbes, for food sources and such. But there's a lot of interaction between microbes that we just don't recognize yet."

A universe in a drop of water

On dry land, Campbell and her students study the water samples collected at sea using the methods of metagenomics and metatranscriptomics. Essentially, metagenomics is the study of the genetic material from a community of uncultured microbes (microbes taken directly from their environment). Metatranscriptomics refers to the study of RNA molecules in groups of interacting organisms.

"We sequence all of the genes in all of the microbes in our sample," she says, "and then we go back and figure out what those genes are. We can determine the types of bacteria that way. We determine who's there by looking at what genes they have."

Next, Campbell looks at what the bacteria are doing. Currently, working with a grant from the National Science Foundation, Campbell and her colleagues are looking at bacterial growth rates. To date, Campbell has found that the different microbes vary their activity and growth. Contrary to what scientists predicted, some abundant bacteria in estuary environments are not very active, while other, rarer bacteria are growing, and faster than expected.

What do these faster growth rates mean? Campbell has lots more data to analyze before she can answer that question with specificity, but there's no question that this kind of investigation into microbial activity is significant.

That's because, as Campbell says, microbes rule. Quite literally. Microbes dominate, inside our bodies and out. Scientists use various calculations and comparisons to convey the vast number of bacteria that exist—more than 10^{30}, some say (inside the human body alone, there are 10 times more bacterial cells than human cells), or more than all the stars in the Milky Way. Campbell uses the familiar context of the ocean. Every milliliter of seawater—about 1/5 of a teaspoon—contains somewhere around 1 million microbes, she says, and "oceans average about four kilometers [a little over two miles] in depth and cover seventy percent of the Earth's surface. So, if there are a million microbes per milliliter…it's very hard to comprehend."

Cycles of life

Beyond their sheer numbers, these countless microbes also play essential roles in keeping our world going. Microbes are the linchpins of Earth's biogeochemical cycles, a term that generally refers to the circulation of elements from Earth to atmosphere and atmosphere to Earth. Think of the carbon cycle, for

Ashley N. Jones

Barbara Campbell in her laboratory: so many microbes, so little time.

example: Plants absorb carbon dioxide from the atmosphere and release oxygen through photosynthesis; organisms, including humans and bacteria, consume carbon for energy, then return the carbon to the atmosphere when they breathe and to the ocean and earth when they die and decompose.

As the National Research Council puts it in its publication *The New Science of Metagenomics: Revealing the Secrets of Our Microbial Planet*, "microbes are essential for every part of human life—indeed all life on Earth . . . The chemical cycles that convert the key elements of life—carbon, nitrogen, oxygen, and sulfur—into biologically accessible forms are largely directed by and dependent on microbes."

Mason Jones

Above: An array of sampling equipment called a rosette is lowered into the Delaware Bay.

Below: Members of the scientific crew aboard the R/V *Hugh R. Sharp*.

Michael Gonsior, University of Maryland

So what happens when something disrupts these trillions of bacteria carrying out essential processes on which all life depends? That's what Campbell wants to find out.

The bacteria that Campbell studies consume organic matter, just like humans do, and respire, or release, carbon dioxide. Understanding their varying growth rates is important, she says, because the faster microbes grow, the more they contribute to biogeochemical processes.

Campbell hypothesizes that rates of bacterial growth are sensitive to different environmental conditions, such as changes in the amount of light, temperature, or nutrients in the water. When there are more nutrients in the water from land runoff and when the water is warmer, she explains, the bacteria are more active and consume more carbon before the carbon can sink to the bottom of the ocean. And the more carbon the bacteria consume, the more CO_2 they release, she says, "which is going back up into the atmosphere."

If the impact of an invisible microbe releasing a bit more CO_2 seems trifling, just recall the numbers: 5 million microbes in a single teaspoon of seawater. With Campbell's more accurate estimates of "who they are and what they're doing," especially how environmental changes affect bacterial activity, her basic-science research will enable others, she says, "to better estimate outcomes under different environmental conditions including future climate change that may involve dramatic swings in water availability through droughts and floods, sea level rise, and increasing temperatures."

Cows and clams

Campbell's study of bacterial growth rates is just one of the ways she and her lab partners explore how tiny bacteria have huge effects on human health. In a related study that also uses samples collected from coastal and bay waters, Campbell is evaluating water quality, particularly levels of fecal contamination. The FDA uses levels of the bacteria *Enterococcus* as an indicator of water quality, Campbell explains. *Enterococcus* is typically found in human intestines and feces; the problem is, she says, it's also found in a wide range of animals, not just in humans.

"The bacteria can come from cows, horses, pigs, wild animals, birds, as well as humans," she says.

That makes it difficult for state and federal agencies to pinpoint where contamination may be coming from, so Campbell is applying gene-sequencing technologies and statistical analyses to water samples to help answer that question.

"We can make inferences from the genetic data about which bacteria come from humans, cows, etcetera," she says. "It's important to know where the contamination is coming from because then we can say, this is normal contamination, or it's from human sewage. That would allow the state to figure out how to best address a problem."

Likewise, Campbell is exploring how bacteria hanging out in the gills of clams influence the condition of vital coastal

Mason Jones

Sunset from aboard the R/V *Hugh R. Sharp* as the team takes samples in the Delaware Bay near Delaware City in October, 2014.

ecosystems. In a study funded by the NSF's Dimensions of Biodiversity program, Campbell collaborates with Annette Engel, of the University of Tennessee, and Laurie Anderson, of the South Dakota School of Mines and Technology, to consider the impact of environmental changes on lucinids, a common species of clam found in Southern coastal marine environments.

The clam's gills contain symbionts, bacteria that live in mutually beneficial relationships with the clams and the seagrass beds that the clams inhabit. As part of its natural growth process, Campbell explains, seagrass produces sulfide (a potentially toxic chemical compound containing sulfur). The symbiotic bacteria use the sulfide to turn carbon dioxide into sugars, and the sugars are used by the clams for growth. This three-way process is integral to the health and well-being of the seagrass beds. If sulfide levels get too high, the seagrass stops flourishing.

Working with the symbiotic bacteria, Campbell is again reading genetic material in the samples to see who's there.

"We're looking at the variation in types of microbes present in seagrass beds versus non-seagrass bed environments as well as what the symbionts are actually doing and how they are contributing to what types of processes," she says.

Like her research on bacterial growth rates in estuaries, understanding the activities of an invisible organism in maintaining the seagrass environment can have huge benefits. Seagrass beds act as marine "nurseries," Campbell notes, harboring all manner of small fish and other sea creatures. Maintaining the health of seagrass beds is critically important to the entire ecology of coastal systems.

About the unknown

Despite the power and plentitude of microbes, scientists still know very little about them, although that's changing fast. Until about ten years ago, the scientific technologies needed to support the kind of research Campbell is carrying out didn't exist. Since then, she explains, next-generation gene-sequencing technologies have emerged, which allow genetic information to be determined in much greater detail at far faster speeds and much less cost. In addition, new supercomputers, such as the high-performance Palmetto Cluster at Clemson, and new informatics technologies now enable researchers to make sense of the massive amounts of data being generated.

For many years, Campbell says, because of past limitations on culturing and sequencing, scientists thought a milliliter of water contained only about a thousand species of bacteria, because that's all that could be cultured and identified. Now, says Campbell, "we know there are a million bacteria in that ml of water, and they are not all of the same type. And the next ml might have some of the same bacteria, but it always has new ones too. It's a *very* diverse environment, so we have to sequence a lot to figure out who's there. And as the technology gets more precise, we'll find more and more."

You might say all those millions of microbes give Campbell job security. There are many unanswered questions about how microbes work, which is fine with Campbell. She's an active collaborator; she knows how to get her research funded (her formula: "Learn how to structure your science, then sell the importance of your work in answering things that other people need to know, then follow up and do the work."). Most of all, though, she really, really likes asking questions.

"Just ask my mom," Campbell says with a rueful laugh. "As a kid, I was always asking questions.

"I'm just interested in the unknown," she continues. "I like asking questions about a lot of different things, and I can ask those questions in a lot of different ways."

As Dr. Seuss put it: "Think and wonder, wonder and think."

Barbara Campbell is an assistant professor of biological sciences, College of Agriculture, Forestry, and Life Sciences. Lauren Bryant is a writer living in Bloomington, Indiana.

growing the citified tree

by Neil Caudle

The road to hell, a tree might say (if trees could talk), is paved with good intentions. With all the best intentions, we pave our roads and walks and parking lots, and plug in some saplings, and wonder why they die, overheated and parched.

"It's always intrigued me," Paul Russell says, "how we take a tree from a nursery in this really happy condition, with healthy roots, and we dig it up and put it on a truck, and we move it to an urban environment with different living conditions, and we expect it to thrive and do well. It just isn't normal."

Russell is a landscape architect, so he thinks of urban trees as elements in a pleasing, enduring design. Even in a city—*especially* in a city—people like the deep, cooling shade and rustling leaves of big trees. Think of downtown Greenville, for instance, where in summer the canopies arch over Main Street, gratifying passersby with shelter from the heat and glare. Even in winter, graceful branches sculpt the space and make it more alive.

Those big, healthy trees also gratify the merchants, who have seen their businesses grow right along with the trees. People *like* trees, so trees are good for business.

But dead or stunted trees do not gratify anything, except perhaps an infestation of fungi or bugs. So Russell wondered, how do we make a tree healthy and happy, when it's planted in a city or suburb? How do we know what kind of pavement

Facing page: Greenville's tree-shaded Main Street has helped revitalize the city's downtown businesses. But not every urban tree finds a home amid asphalt and concrete.

Neil Caudle

to use around it, and how near that pavement should come to the base of the trunk?

To answer those questions, Russell needed an engineer, and he happened to know one. Brad Putman is a civil engineer who studies various paving materials and how to make them stronger, more durable, and more environmentally friendly. He is also a friend of Russell's. Their kids trick-or-treat together every Halloween. So the two hatched a plan. They would study this problem together. They would figure out how to measure, in a systematic way, the relationships between pavements and urban trees.

"We're starting out with a control-type study looking at baseline," Putman says. "We want to know how the pavement behaves first. How does the water get into the soil, and what is its distribution? And then, when the tree gets in there, how does that change the game? How does the tree behave?"

Recon from the root zone

Students passing through the courtyard between Lee Hall and its gleaming new addition, Lee III, stop to puzzle over a row of wood-framed boxes resting on a bed of gravel. The boxes, eight feet square and four feet tall, don't seem very massive, at first glance, but each one, full of soil capped with a layer of pavement, will weigh about 20,000 pounds.

The researchers and their students plan to install sensors at multiple locations in each box, to track moisture and temperature, using technology developed for the Intelligent River project (see the cover story, *Glimpse,* Spring 2012). For that project, a high-tech effort to document and monitor the health of the Savannah River watershed, Putman worked on a green-infrastructure retrofit in Aiken, South Carolina. As the retrofit's pavements expert, he helped design and monitor the porous pavements the team installed downtown, with special attention to protecting some venerable old magnolias. After monitoring the pavements for several years, Putman and the Intelligent River team confirmed that the retrofits had improved storm-water drainage throughout the city, reducing the potential for sudden jolts of polluted storm water that damaged the environment downstream.

"These porous pavements also have the ability to filter out a lot of the contaminants," Putman says, "so the water is not just running into the curb and gutter and picking up all of this stuff along the way, and then dumping into the storm sewer and going into the nearest water body."

The idea for his research with Russell is to test various types of paving materials, collect baseline data about their performance and their effect on the soils below, and then to plant the trees.

"We're going to use *Acer buergerianum,* the Trident maple," Russell says. This species of maple has a reputation for tolerating urban environments, and its form will complement the architecture of Lee III, Russell says.

By adjusting the experimental variables—pavement type and its distance from the trunk, soil composition, water, and nutrients, among others—the team will narrow down the options to those that work best and test them in a real-world setting, perhaps in the parking lot of the South Carolina Botanical Garden.

Not a black-or-white issue

When it comes to choosing a tree-friendly pavement, conventional wisdom doesn't always get it right. Anyone who's crossed a road or sidewalk barefoot on a hot summer day knows that white concrete reflects more heat than black asphalt. So if asphalt burns our feet, it must be hotter and worse for the trees, right?

No, not necessarily, Putman says. We have to think about the tree's entire environment, above and below ground, not just the surface of the pavement.

"Everybody always says asphalt is bad for the heat-island effect, but really it just has to do with the pavement, whether it be concrete or asphalt," Putman says. Research in Phoenix, Arizona, and elsewhere has shown that urban heating has more to do with the thickness and density of the pavement, and therefore its thermal mass.

"When you go to an urban area that has more of these very dense materials, it's going to soak up the heat, and it's going to have a much tougher time dissipating that heat at night," Putman explains. "For example, it's going to be hot here in Clemson just as it is in Columbia during the middle of the day, but the real difference is nighttime, when it's going to cool off quicker here at Clemson as opposed to Columbia, where you've got all this thermal mass that's trying to give up its heat but can't do it effectively."

Putman has found that certain kinds of porous pavement, including porous asphalts, may contain 20 percent of their volume as voids. Through these voids, air and water can move, and the pavement has less thermal mass to hold heat.

Modern pavement technologies now offer numerous options, and Putman and Russell will test several of the most promising: porous asphalt, pervious concrete, and permeable pavers, which are pavers with wide joints. The permeability is important not only because it allows air and rainwater into the soil but because it tends to moderate the temperature. Several feet deep in the soil, temperature remains almost constant, so if air can flow through the soil, natural geothermal heating and cooling will tend to moderate temperatures in the tree's root zone, keeping it cooler in summer and warmer in winter, Putman says.

Environment by design

A successful urban tree installation is not as simple as just choosing a permeable pavement and sticking a tree in a hole, Russell and Putman say. The soil may itself be the number-one factor in a tree's health and survival, and not all soils are created equal. In many urban settings, poor, compacted soils will have to be replaced with specially formulated soils engineered to drain, circulate air, maintain good structure, and provide sufficient nutrients. Sometimes, this is a difficult sell, Russell says, for budget-conscious clients.

"The biggest challenge I have is trying to convince someone to spend hundreds of thousands of dollars on soil," he says. "People don't get that."

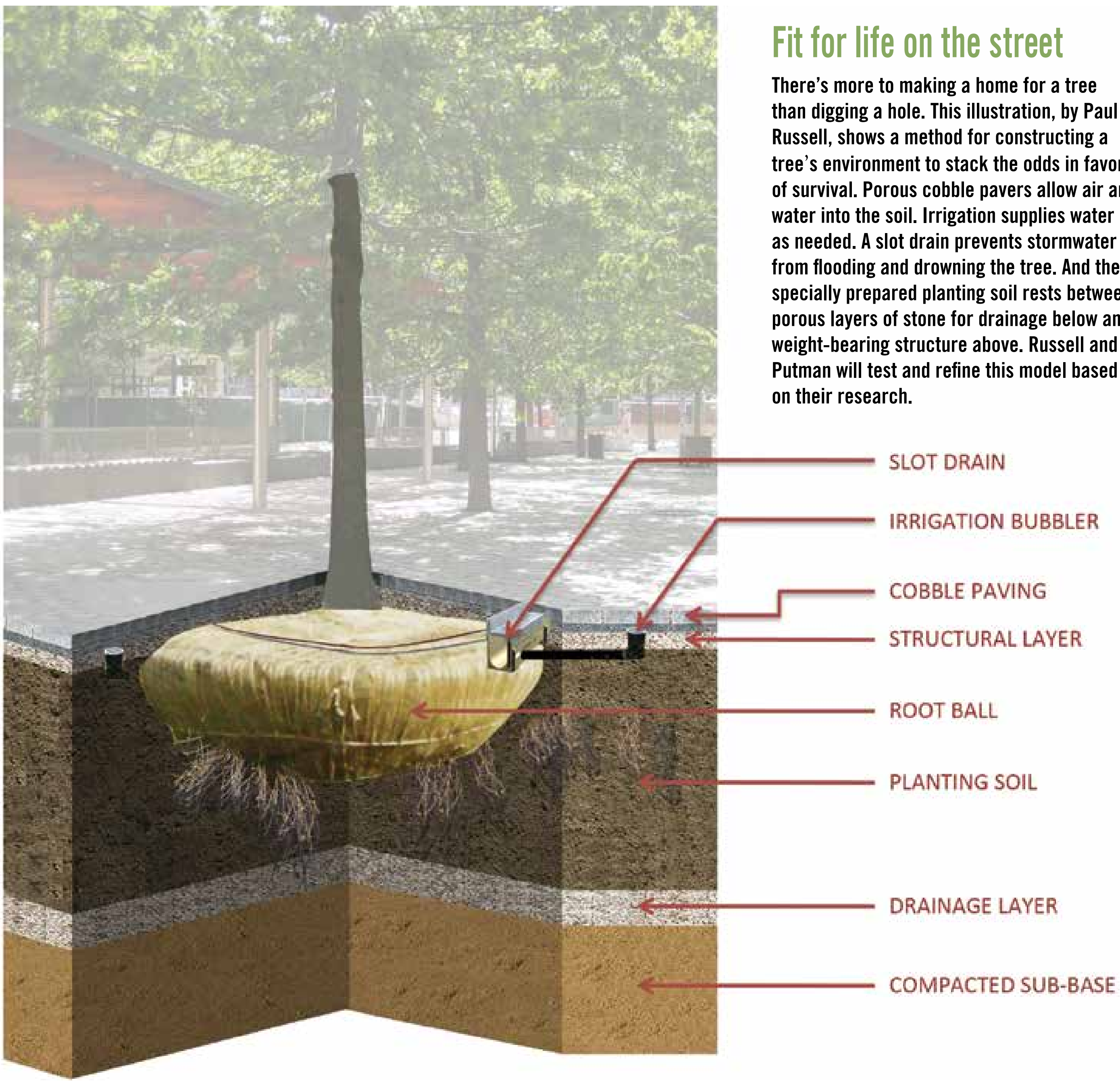
The landscape itself must be carefully designed and constructed to manage water infiltration and maintain the tree's environment. Poor installations or flaws in the paving material itself can defeat permeability and suffocate the tree, Putman says. "If you've got a lot of sediment-laden runoff flowing across these parking lots with permeable pavements, you're going to clog them up."

But Putman is optimistic that standards for pavement mixes and construction details are improving. He and Russell plan to develop, from the results of their research, guidelines for pavements and urban-tree plantings that would help landscape designers and their clients select the right system for each location.

"We'd like to come up with a design idea or design guidelines, apply those and verify those, and then get them out to practitioners to use later on," Putman says.

The task is especially relevant, these days, because the trees in some of our most beloved urban streetscapes are declining. Trees don't live forever, and replacing a row of majestic but fragile old centenarians isn't easy—politically, aesthetically, or otherwise.

One recent example, Russell says, is the loss of giant tulip



Fit for life on the street

There's more to making a home for a tree than digging a hole. This illustration, by Paul Russell, shows a method for constructing a tree's environment to stack the odds in favor of survival. Porous cobble pavers allow air and water into the soil. Irrigation supplies water as needed. A slot drain prevents stormwater from flooding and drowning the tree. And the specially prepared planting soil rests between porous layers of stone for drainage below and weight-bearing structure above. Russell and Putman will test and refine this model based on their research.

Ashley N. Jones

Brad Putman (left) and Paul Russell are using large planters like the one shown here to study the influence of various paving materials on the health of urban trees. The planters will also serve as a test bed for studying the rhizosphere, a thin zone of soil, in contact with the roots, where microorganisms feed and protect the tree. Landscape architecture students designed the planters to accommodate research as well as outdoor gatherings at Lee Hall. Concepts from the research are finding their way into Clemson's entry into the Solar Decathlon Design Competition, whose winners will be announced this fall in Irvine, California. The School of Architecture's entry, called IndigoPine, will include "an integrated planting strategy" for the project's outdoor spaces, Paul Russell says.

poplars at Biltmore Estate near Asheville, North Carolina. The poplars were part of an elegant landscape planned by Frederick Law Olmstead, who also designed some of the nation's most famous urban settings, including New York's Central Park. "Olmstead planted those tulip poplars at Biltmore in eighteen ninety-three and said that the trees would decline in a hundred years and would have to be replaced," Russell says. "He was right. And it cost several million dollars to do that."

Russell and Putman are hoping their work will help communities design and install urban plantings that look good and improve the environment, whether the job is to replace old plantings or establish new ones. The team also hopes that their students will learn what they have learned: that a designer and an engineer can work together, despite their different perspectives.

"I've always wanted to engage our students a little bit more across colleges," Putman says, "because engineering students are always going to be dealing with—"

Russell laughs. "*Dealing* with?"

"*Working* with architects and landscape architects. You hear the stereotypes of architects or landscape architects—"

"What *are* they?" Russell says, feigning indignant surprise.

"Oh, you know, those architects, they want this or that, and it's just not practical. You hear that a lot. And then you hear the architects say, 'Those engineers, they just don't want to be creative.' So it will be interesting to engage our students together, and use this research as a learning tool."

So far, the strategy of teaming landscape designers with engineers seems to work just fine for Russell and Putman. But it isn't always easy.

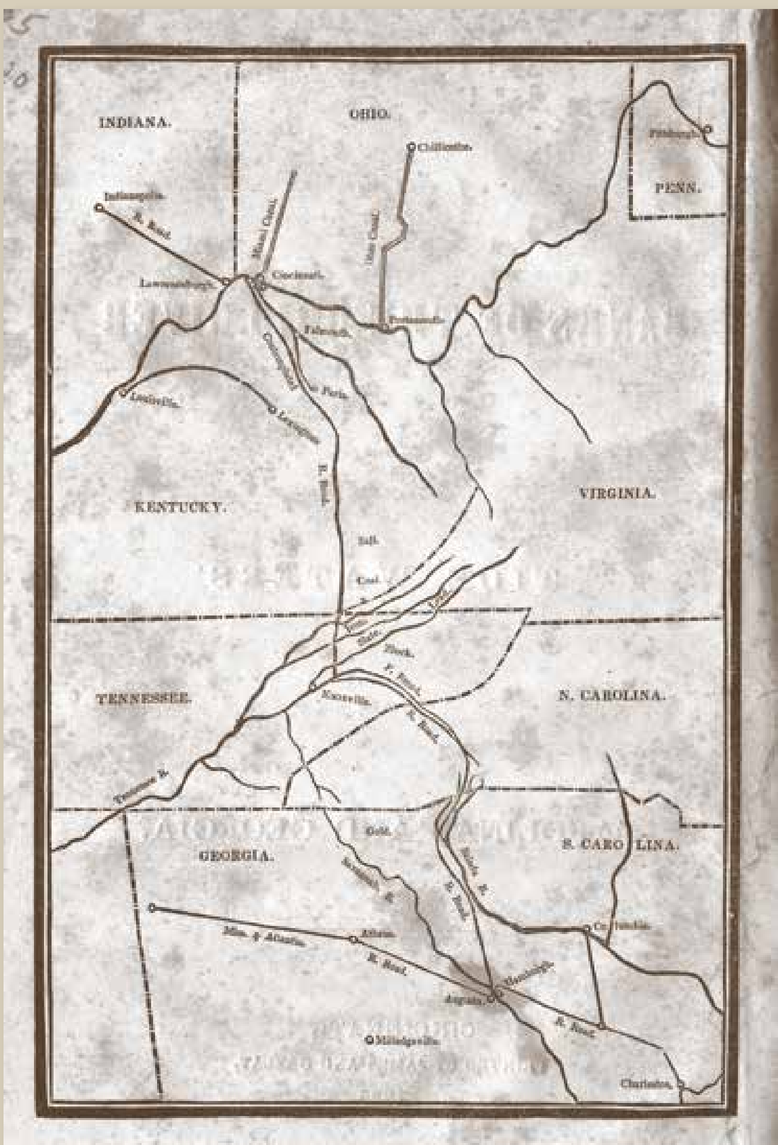
"This is kind of pulling Paul out of his comfort zone and pulling me out of my comfort zone," Putman says, "and we're kind of meeting somewhere in the middle here, where we're both learning from each other."

Paul Russell is an assistant professor of landscape architecture in the College of Architecture, Arts, and Humanities. Bradley Putman is an associate professor of civil engineering in the College of Engineering and Science.

close focus

A railway to reason?

by Frank Stephenson



Left: In 1835, Cincinnati boosters of a plan to build a railroad linking their city to Charleston published a pamphlet that included this rough map of the projected line. The mapmaker included locations of raw materials that the railroad likely would carry, notably coal, iron, salt, slate and "zinck."
Courtesy of the Cincinnati Museum Center.

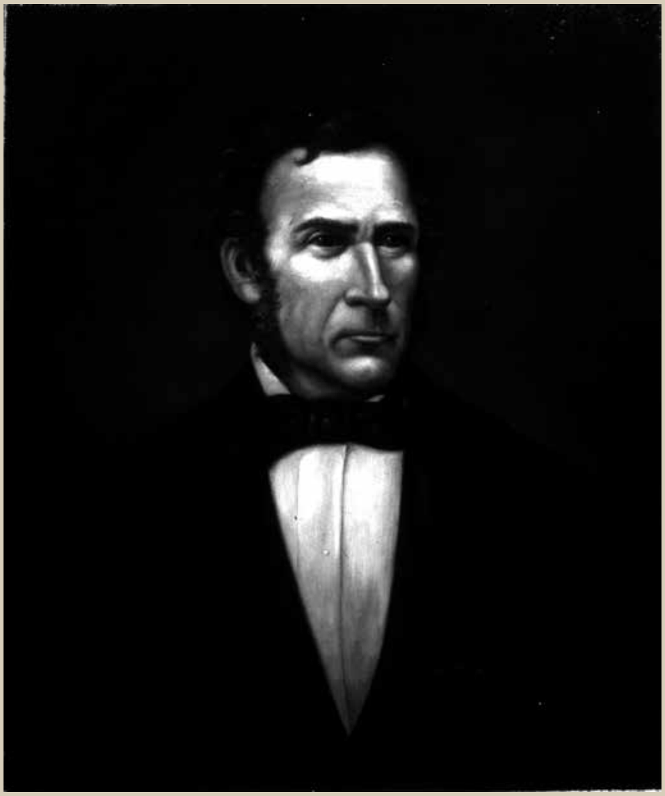
Craig Mahaffey

Could a railroad built from the sea straight to the heart of a young America possibly have saved the country from the catastrophe of civil war? That's the intriguing question posed in a new book by preeminent railroad historian H. Roger Grant. Grant writes that the nation will never know how the boldest railroad-building scheme ever conceived in the nascent days of the United States might have

H. Roger Grant stands at the entrance of an unfinished railroad tunnel near Wahalla, South Carolina. The tunnel now serves as a rock-walled reminder of what might have been.

Images on pages 58, 60, and 61 are taken from *The Louisville, Cincinnati & Charleston Rail Road: Dreams of Linking North and South* by H. Roger Grant (Indiana U. Press, 2014).

Robert Y. Hayne, a former South Carolina governor, coaxed $10,000 from his state's General Assembly to fund early survey work.



Daniel Drake, a Cincinnati physician and tireless booster of the railroad, wanted to link his city to Charleston.

changed the course of events that led to the American Civil War. But his latest book (of thirty)—*The Louisville, Cincinnati & Charleston Rail Road: Dreams of Linking North and South* (Indiana U. Press, 2014)—offers a compelling case that a proposed 700-mile-long rail link between Charleston, South Carolina, and the "Queen City of the West" (Cincinnati's once-famous nickname) might have gone a long way toward defusing a political powder keg that eventually exploded in 1861, tearing the nation to pieces.

Grant's premise is founded on how steam-powered locomotion—a marvelous new technology imported from Europe to the U.S. in the early 1800s—was by the 1830s swiftly revolutionizing both commercial and social life in a growing America itching for better modes of transportation. After seeing the unparalleled commercial success of the Erie Canal in 1825, America had gone on a canal-building binge. Soon hundreds of towns throughout the industrialized Northeast and through much of the Atlantic seaboard were linked by what critics would eventually deride as "dismal ditches." Within a decade, the serious drawbacks of canals (they were constantly at the mercy of floods and droughts and were impossible to build across mountains) had made the prospects of the "iron horse" the new national obsession by business tycoons and civic boosters from New York to Savannah.

Hopes for reviving Charleston

By 1835, Charleston was a 165-year-old seaport rapidly slipping from its once-proud perch as "The Commercial Emporium of the South." Since the close of the Revolutionary War, the city's wealth and prestige had declined steadily, thanks in large part to competition from Savannah, Georgia, which had become a major player in exporting cotton, the South's number-one commodity. Charleston's business community was starving for anything that might help reverse the old city's fortunes.

At the same time, business and municipal interests stretching into the hinterlands had grown tired of being largely isolated from the mainstream of American commerce. Plagued by bad roads, tricky waterways, and a mountainous terrain that defied easy transportation of both goods and people, vast tracts of western South Carolina, northern Georgia, Tennessee, Kentucky, and southern Ohio remained cut off from a lucrative trade route that tended to flow counterclockwise from the industrial North via rivers and canals to New Orleans along the Mississippi River valley.

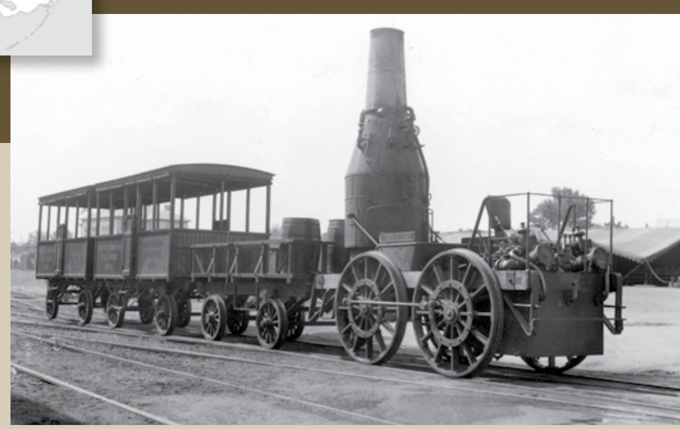
Buoyed by the rapid advancement in steam-powered rail technology (in 1830, a locomotive named *Best Friend of Charleston* steamed into Charleston from New York City and soon took passengers on a headline-grabbing top speed of 25 mph), boosters of every stripe spanning nine states were ready for action. In August 1835, prominent Cincinnati physician and civic leader Daniel Drake started the ball rolling with a call for a committee to essentially rubber stamp his conviction that building a railroad between his city and Charleston was a sound idea. Such a railway, he argued, would "become the first direct link between the Old Northwest and the Old

Map by the Office of Creative Services, Indiana University

Lines for stitching regions together

The exact route for the ill-fated Louisville, Cincinnati & Charleston Rail Road was never precisely determined, but this map shows the most likely path that the line would have taken between South Carolina and the Ohio River.

Below: This photo shows a replica of the *Best Friend of Charleston,* the first steam locomotive to power a regularly scheduled passenger train on American rails. The original showed up in Charleston on Christmas Day 1830. Astonished news reporters wrote that the train "flew on the wings of the wind at the speed of fifteen to twenty-five miles per hour, annihilating time and space leaving all the world behind."



South, facilitating trade of a wide variety of raw and finished goods," Grant writes. Moreover, Drake said that an "iron horse would greatly enhance personal travel, movement of the U.S. mails, and rapid troop deployments."

Drake promised that this "veritable artery of commerce," as he dubbed the project, would be a welcomed tonic for the entire country at a time when regional tension over the issue of slavery was growing by the day. "The north and the south would, in fact, shake hands with each other, yield up their social and political hostility, pledge themselves to common national interests, and part as friends and brethren," he said.

A contagion of passion

Drake's rhetoric and passion soon became contagious among political circles large and small. Quickly buying into the fervor were South Carolina's Robert Y. Hayne, the state's former governor, U.S. senator, cotton planter, and political powerbroker, and J.G.M. Ramsey, a well-established Knoxville physician, banker, and historian.

After Hayne led a successful effort to coax $10,000 from the South Carolina General Assembly to fund preliminary survey work, the concept of the Louisville, Cincinnati & Charleston Rail Road (popularized as the "LC&C") was ready for fleshing out in the traditional manner—a rip-roaring railroad convention.

Since 1830, these festive affairs had become almost commonplace in American communities eager to put their own special stamp on progress. LC&C planners quickly chose Knoxville for the convention site, mainly because of Ramsey's powerful influence and because the town, situated at the navigable headwaters of the Tennessee River, was rapidly turning into a commercial center with bright prospects.

The five-day convention opened on July 4, 1836, with fanfare that combined the national holiday's patriotic zeal with the excitement of the launch of an unprecedented civic enterprise. Never before had there been any serious talk of building a railroad of such length anywhere in the country, much less through a mountain range. Reportedly, the event drew 380 delegates from Ohio, Indiana, North and South Carolina, Virginia, Kentucky, Tennessee, Georgia, and even Alabama.

As the last round of bourbon and barbecue was wrapping up on July 8, the Knoxville convention had a firebrand president (Hayne); an estimate of initial construction cost ($10.8 million, or $222.6 million in today's money); a crude idea of how to set up and run the most ambitious railroad business ever conceived; and, almost predictably, a feisty squabble among delegates about exactly where this monster railway would run from Cincinnati to the sea. The fight came close to killing the whole idea in its crib.

But a last-minute compromise whereby a trunk of the new line would swing through Georgia saved the day. The convention's happy ending prompted the *Charleston Courier* to gush: "What a bold conception! ... For if it succeeds, South Carolina will be prosperous beyond all former calculations, and the Union of the States will be as lasting as the rocks and mountains which will be passed and overcome by the contemplated road."

A weapon to wield against slavery

Clearly, LC&C boosters understood that what they were proposing had more riding on it than the hopes of a better, faster way to get goods to market. They saw the mammoth, cross-mountain railway as a lance aimed at the loathsome boil of slavery that was the central cause of so much national anguish. The railway would be a 700-mile-long magic carpet bringing in new jobs and ideas, an infusion of different cultures, lightning-fast telegraph communication, and at least the hope that North/South grievances could be held in check long enough for the institution of slavery—already in its death throes around the world—to wither away.

It wasn't to be.

"For all practical purposes, it was over by the end of 1839," Grant says. "The LC&C was really the victim of a perfect storm of circumstances."

The first, and deadliest, blow to dash the hopes of LC&C backers was the Panic of 1837, the largest of a series of national recessions that dogged the U.S. economy for decades. Almost overnight, money sources vanished, and along with those, any real chance of raising the enormous capital necessary to push the LC&C forward evaporated.

Against the backdrop of the biggest depression the country had ever seen, renewed bickering over where the railroad would be built reached a fever pitch, pitting state against state and powerful politicians against shareholders. South Carolina's most formidable politician, John C. Calhoun—fierce secessionist and former U.S. vice president—pitched a petty, costly battle against the LC&C company in a bid to make sure the railway went through his plantation along the Seneca River in upstate South Carolina.

The final blow came in 1839 when Hayne, age forty-eight, suddenly caught a fever and died. Without its champion, the tortured effort languished, but the dreams of the Knoxville conventioneers persisted in various forms until well after the bloodbath of the American Civil War. Grant documents in colorful detail how these vestigial projects progressed, some reaching remarkable heights of engineering skill.

In 1859, for example, engineers using black powder blasted a tunnel more than a mile long through solid granite near the town of Wahalla, South Carolina. Planned as the final push through the Appalachians by the new Blue Ridge Railroad Company, a remnant of the old LC&C, for all its wonder the tunnel was never finished. During the 1950s, Clemson's dairy farm used it to age and store blue cheese.

The tantalizing "what-ifs"

As his book attests, Grant clearly enjoys writing about the "what-ifs" in American history. If the Panic of 1837 hadn't happened, if all of the LC&C boosters had sung from the same hymnbook, if the project's very personification hadn't died young, could "Hayne's magnificent dream" really have changed the tragic course of antebellum American history?

Grant points to the transformative power of the Erie Canal—ridiculed early on by critics as a colossal boondoggle—as evidence that a successful LC&C could have had a revolutionary impact on social and political life in the South, possibly even delaying or shortening the tragedy of the American Civil War.

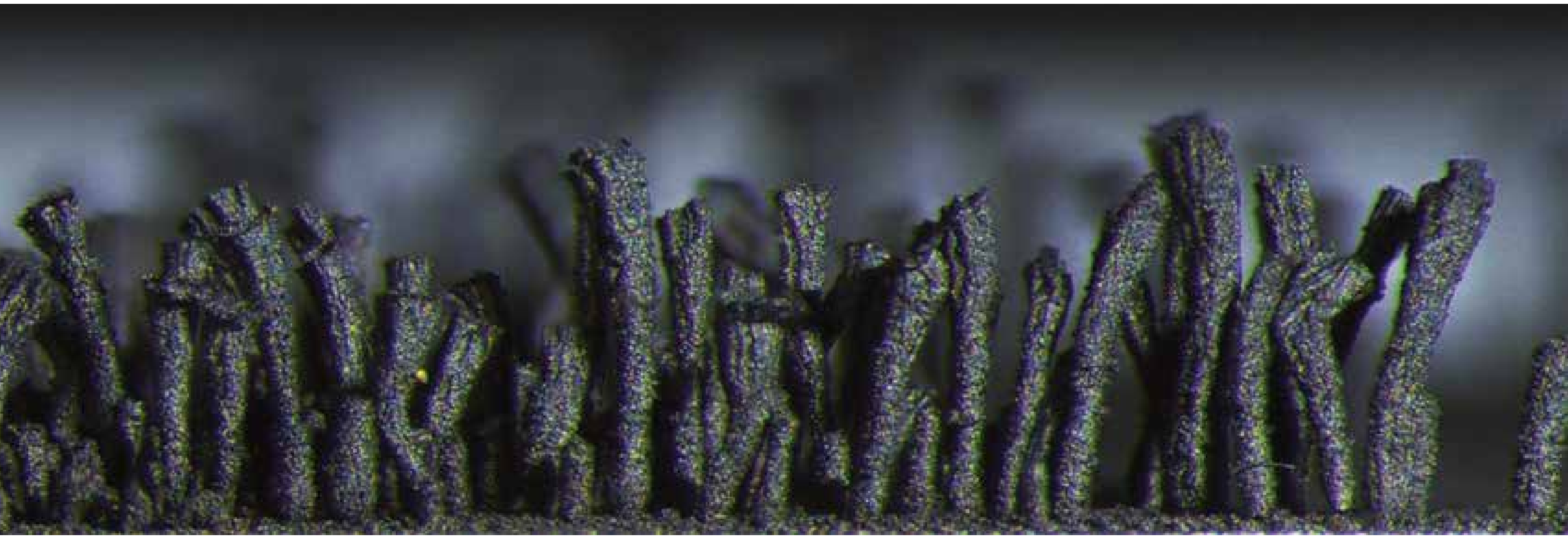
"These rails would have opened up so much," he says. "The LC&C showed the enthusiasm for a dawning new age, for shattering isolation, for wanting to increase commercial intercourse. If you had these links between Ohio and Indiana and Illinois, between the Old South and the Deep South, surely you would develop similar types of business and social arrangements. Just makes sense to me."

It made sense to Abraham Lincoln, too. In his research for the book, Grant turned up a fascinating account of an interview Lincoln had with his chief economic advisor during the war.

Henry Charles Carey asked his boss if he thought that it would be possible to "dissolve the Union" if there were railroads linking the upper reaches of the Mississippi River valley and the Gulf coast as well as ports at Charleston and Savannah.

"No," Lincoln replied. "It would then be entirely impossible."

H. Roger Grant is the Kathryn and Calhoun Lemon Professor, and Centennial Professor (2004–2006), in the Department of History, College of Architecture, Arts, and Humanities. Frank Stephenson is a freelance writer based in Carrabelle, Florida.



Extended Polymer Worm Family. **Image captured by Kryssia Diaz-Orellana.**

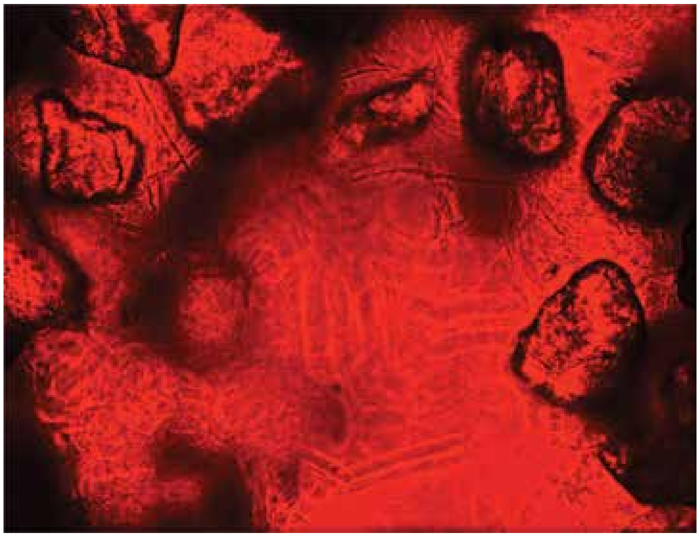
The unseen, vividly visible

Last fall, the Clemson Light Imaging Facility (CLIF), which houses advanced microscopes and people with the expertise to use them, sponsored a competition for the best micrographic images produced at Clemson. Finalists from a pool of 53 entries were on display for voters attending a symposium held at the CLIF on October 28, 2014.

The first-place winner, Kryssia Diaz-Orellana, is pursuing a Ph.D. in chemical engineering, working with Professor Mark Roberts. Her winning micrograph (above) shows microstructures grown on mesh substrates using a new template-free method of synthesis. The tiny worm-like structures are attractive as electrodes for energy storage devices capable of delivering energy at high rates. Diaz-Orellana's research goal is to help engineer polymer materials for the next generation of energy-storage systems.

The second-place winner, Sukhpreet Kaur, is a Ph.D. student in environmental microbiology, working with Harry Kurtz, associate professor of biological sciences. Her picture, of sandstone from a desert in Utah, reveals teeming microbial life beneath the surface of what the naked eye would see as lifeless rock. The entwining filaments of cyanobacteria visible in the micrograph are photosynthetic.

"It is fascinating to see how these microbes are able to survive under the harsh environmental conditions of the desert," Kaur says.



Living Sandstone. **Image captured by Sukhpreet Kaur.**

Terri Bruce, assistant professor of biological sciences and the director and manager of the CLIF, provides technical guidance for micrography at Clemson.

"Pictures like the ones submitted to our micrograph competition can speak to almost anyone about the beautiful complexities that exist in the world around us," Bruce says. "They can serve as a platform from which to launch public discussions about the new horizons in science."

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Sgt. Tierney Nowland, U.S. Army

Who'll have their backs, back home?

U.S. Army soldiers pull security on the roof of a house in Baghdad, Iraq, May 6, 2007. Even for those lucky enough to come home safe and sound, the fighting may haunt them and disrupt their lives, unless they find the courage and counsel they need to get help. Page 44.