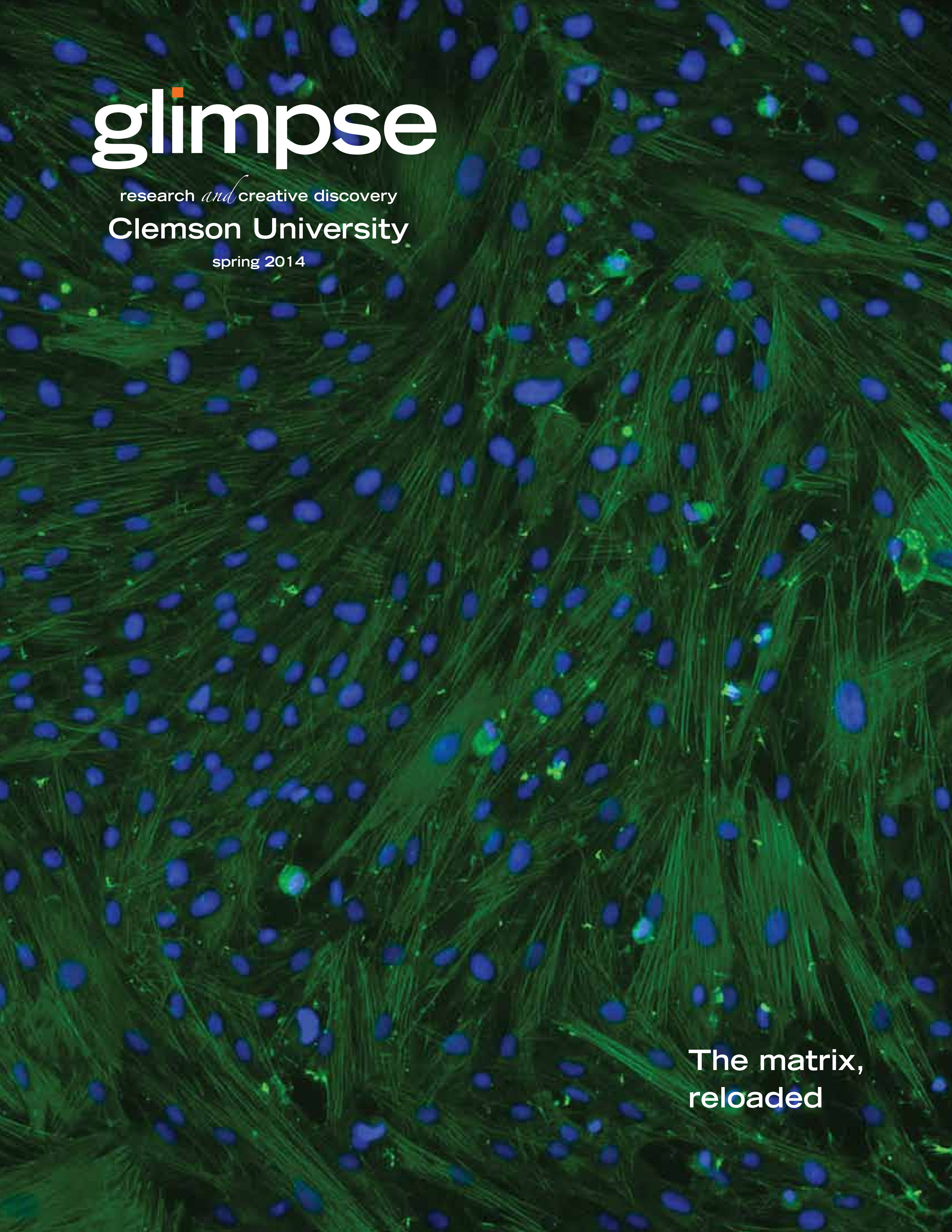
glimpse

research *and* creative discovery

Clemson University

spring 2014



The matrix, reloaded

Benjamin Hines

the matrix

What if medical science could extract a bit of excess body fat and use its stem cells (shown in the cover image) to transform a matrix of collagen fibers and create a new heart valve or some other vital part? That idea has opened a world of possibilities in the labs of Dan and Agneta Simionescu. Page 12.

glimpse

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Mugging for the camera, rows of handcrafted originals are on the trading block in the Acorn Gallery on campus, ready for takers. The price of a mug? One story.

Patricia Fancher, a Ph.D. candidate in rhetorics, communication, and information design, and Brent Pafford, a potter and master's candidate in fine arts, are testing the idea that coffee mugs and other such inanimate companions become "potent objects" as we weave them into our rituals, our stories, and our lives. Page 52.

in this issue

The quest and the climb

As a public university, Clemson strives to help the state and nation compete in "the knowledge economy," as people have called it. We hear debate about what that economy entails, but several points seem clear: The knowledge economy is global, it is driven by information and innovation, and it changes rapidly. This, by the way, also describes the nature of modern research.

Today, knowledge is far more than a static set of facts. It's a dynamic ability, an active mindset, a way of thinking that constantly tests old assumptions, digs for new information, forges new connections, and builds a broader, deeper understanding. In short, knowledge is a quest and a climb, not a summit we attain and then stop climbing.

I cannot think of a better example of this approach than the work of Dan and Aggie Simionescu (cover story, page 12), two extraordinary scientists who are regenerating tissue to repair failing heart valves and many other body parts. Their research is truly global, with collaborations around the world. It thrives on change and innovation. By working with surgeons in the Greenville Health System, Dan and Aggie never lose sight of the real-world practicalities of helping patients and saving lives. And, at every step of the way, Dan and Aggie's students absorb not only the facts of science and engineering but the habits of working that will help them succeed.

Here is what Martine LaBerge, department chair in bioengineering, has to say: "Dan and Aggie Simionescu exemplify the value of partnership. They have built strong collaborations with clinicians and scientists across the U.S. and in several countries, and with these collaborations they are showing how the new translational biomedical research is changing the way medicine is done. Their work is also a catalyst for students, at both the graduate and undergraduate level. Dan and Aggie are two of the best educators in the department. At Clemson, we educate thinkers and leaders, and research is vital to that goal. Our students are the point."

In this issue of *Glimpse,* you will find multiple examples of the principle that students are the point. Take a look, for example, at Curtiss Fox (page 10), whose research as a Clemson student led to a sophisticated new simulator for testing and improving the electrical grid we depend on for power. Today, Curtiss is director of operations for the Duke Energy eGrid, managing the very technology he helped to conceive. Or sample the top-quality work of student filmmakers in Digital Production Arts (page 39), whose animations measure up to the rigorous standards of their mentors at DreamWorks. Or consider several examples of how students and their mentors are using computer-based simulations and robotics to improve patient care (pages 8, 50, and 56).

In each of these examples the value of research goes far beyond the final product. Our students are acquiring the habits along with the know-how. They are learning the quest.

R. Larry Dooley
Interim Vice President for Research

zoom in

Structure for life

In a section of artery, living cells (blue) populate fibers of the matrix (green), forming new tissue. Dan and Agneta Simionescu have developed a method that could vastly improve implants to repair failing parts of the body. See page 12.

Simionescu lab

Sandy Kawano

Mudskippers are amphibious fish that can use their pectoral fins to walk on land and are especially adapted to intertidal habitats, where they hide under wet seaweed or in tidal pools. Richard Blob and Sandy Kawano study the fish to learn how animals made their way onto land.

Traveling through time

Channeling a childhood love of dinosaurs, Richard Blob analyzes the movements of living animals to understand shifts in evolution and their consequences in the present. by Rachel Wasylyk

While vertebrates today live in a wide range of environments, all of their ancestors originated from aquatic habitats. Animals with limbs tended to shift toward life on land while those with fins often did not make the same transition until much later in evolutionary history.

Sandy Kawano, a Ph.D. student working with Richard Blob, set out to determine what made certain animals successful over others during this momentous event. "We want to figure out how the move from fins to limbs contributed to animals living on land, and what the consequences of the anatomical changes observed in the fossil record were," Kawano explains.

By comparing the forces that act on fins and limbs as animals travel over land, the researchers hope to understand why limbs were more successful in the transition to life on land. Kawano used a multidimensional force plate to measure horizontal and vertical forces on two species of vertebrates. Mudskipper fish use two fins to propel their bodies along the ground, much like a human walking with crutches. Tiger salamanders walk by moving their front and back limbs on opposite sides of the body in a pattern similar to that of a dog. Kawano found that both animals experienced vertical forces from the ground in response to the pressure they exerted on the plate.

Sandy Kawano

Sandy Kawano studies fossils of *Seymouria,* 270 to 280 million years old, to learn how animals became fully terrestrial. *Seymoria* was an amphibian, but its reptilian features helped it live on dry land. These specimens are at the Carnegie Museum of Natural History in Pittsburgh.

But the horizontal component of the force on the mudskipper was significantly angled towards the body, while the force on the salamander only exhibited a slight angle. These differences in distribution affect how the skeleton bears the forces. With less stress on their appendages, vertebrates with limbs may have found it easier to transition toward life on land.

The physical differences in appendages may have led to the subsequent changes in the animal's morphology and its place in the ecosystem, Blob says. "This is an exciting possibility to begin to understand, much like a time machine to the past."

Insights into the past

Comparing living animals to fossils presents numerous challenges. Because morphology changes gradually, fossils are often only snapshots of a larger picture and may not reveal critical information about the organism's size, shape, weight, or habitat. Scientists use patterns evident in living animals to infer the functions of animals preserved in fossils. To do this, scientists extract data from the forces exerted on the living specimens and map them on the structures of the fossils. In this way, Blob is able to infer whether a specific creature might have been able to support its body on land using its appendages. Through a thorough analysis of numerous species that span the transition from aquatic to terrestrial animals, the team may be able to pinpoint a window of time when an evolutionary change occurred. "It's like an enticing puzzle to figure out when major events happened in the past," Blob says.

From fossils to models

Blob and his team are now focused on analyzing a broad range of fossils to narrow in on the window of time that the transition occurred. Taking a cross section of the specimen is a good way to examine the morphology of a fossil, but may render the sample useless to others. Since these remnants are typically rare and highly cherished, the researchers needed a new and more effective evaluation method.

Collaborating with the Clemson School of Architecture's digital design studio, Kawano used a 3-D laser scanner to create computer models of the fossils. From here, the image can be imported into an animation program to perform in-depth analyses of the fossil morphology and even estimate probable range of movements of the bones. The models become like virtual marionettes, allowing scientists to implement and test theories on the digital creations.

In the future, the researchers say, a 3-D printer, which uses printing technology to build up solid objects in three dimensions, could help scientists recreate physical samples of existing fossils. This would allow researchers to enlarge, cut, analyze, and reproduce specimens without destroying the original fossils. Numerous museums are interested in pursuing such endeavors to replicate and distribute models to other exhibits, and Blob plans to pursue this aspect of the work. So his time machine to the past could soon have a lot of new passengers.

Richard W. Blob is a professor of biological sciences in the College of Agriculture, Forestry, and Life Sciences. Rachel Wasylyk, a 2012 graduate and former editor of Decipher, *a student-led research magazine at Clemson, is now a marketing coordinator and freelance writer based in Charlotte, North Carolina.*

This research was made possible by grants from the National Science Foundation (IOS 0517340 and 0817794), Sigma Xi, Clemson University (Stackhouse Fellowship and Professional Enrichment Grant), the American Society of Ichthyologists and Herpetologists (Raney Award), and the Society of Vertebrate Paleontology (Estes Award). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of NSF.

Sandy Kawano

A mudskipper (left) uses two fins to propel its body, as though using crutches. A tiger salamander walks by moving its front and back limbs on opposite sides of the body, as a dog does. Measuring the mechanical forces in each helps researchers make "snapshots" of evolutionary change.

Craig Mahaffey

Students Peyton Bullard and Austen Hayes test the new video game, Duck Duck Punch.

Punching out impairment

This video game will help stroke patients regain arm function.

After a stroke, the name of the game is rehabilitation. But for many stroke survivors, the routines of rehab may soon include a new kind of game: Duck Duck Punch.

Written for patients to use with personal computers, the video game is a playful answer to a serious problem: What is the best way to help survivors regain function?

Larry Hodges, a professor in Clemson's School of Computing, leads multiple projects in medical informatics, and his research group teams clinicians and computer scientists to create software systems to improve health care. With graduate students Patrick Dukes and Austen Hayes, Hodges collaborated with Michelle Woodbury at the Medical University of South Carolina (MUSC) to create a rehabilitation game for stroke survivors.

"On average there are approximately eight hundred thousand strokes per year in the United States, and over 75 percent of stroke survivors have some form of arm movement impairment," Hayes says. "Current rehabilitation exercises target the one in four stroke survivors who have moderate impairment, and stroke survivors are only provided with two to three months of therapy due to insurance."

Duck Duck Punch, which patients play on a computer with a Microsoft Kinect sensor, is designed to help stroke survivors regain upper arm movement. After a therapist calibrates the system for the correct level of impairment, the patient begins playing the game, reaching out to punch carnival-style ducks as they appear on the screen.

Ten stroke survivors participated in a pilot study at MUSC. At the end of the study, the researchers found significant improvement in arm mobility.

"Patients wanted to come back day after day, participating in sessions much longer than they usually would with better results," Dukes says.

Duck Duck Punch took second place in the Kinect Fun Labs Challenge, one of eight competitions held as part of the tenth annual Microsoft Imagine Cup. Over 500 teams from around the world initially entered the competition by writing a project proposal. Some 100 teams were then asked to submit working software, a user's manual, a written paper, and a video describing their application. The top three teams were awarded a free trip to the final competition, in Sydney. Of the 24 teams who were awarded first, second, or third place in one of the eight competitions, only two were from the United States.

Dukes and Hayes are currently working with the Clemson University Research Foundation on licensing Duck Duck Punch and plan to launch a start-up company to market the product.

– Brian Mullen and Peyton Bullard

Larry F. Hodges is a professor in the Human-Centered Computing Division of the School of Computing, College of Engineering and Science. Brian Mullen is the communications director for research. Peyton Bullard is a senior majoring in marketing.

Virtual patients, actual learning

A simulation helps nurses talk to kids.

Simulations, it turns out, are handy not just for treating patients but for talking with them as well. Currently, the most commonly used training method for student nurses to practice their patient interviewing skills is reenacting written scenarios with classmates, where one student acts as the patient and the other acts as the nurse. But some student actors are better than others, and computer simulations, researchers thought, might improve the training.

Larry Hodges, professor in Clemson's School of Computing, and two graduate students, Toni Bloodworth Pence and Lauren Cairco Dukes, are working with Nancy Meehan from Clemson's School of Nursing and Arlene Johnson from The College of St. Scholastica to develop a computer-based simulation to help nurses learn how to interview patients.

The simulation, called SIDNIE (Scaffolded Interviews Developed by Nurses in Education), is designed to teach nursing students how to interview pediatric patients by providing interview practice with guidance and feedback from a virtual agent named Sidnie.

"The nurses are graded on two criteria, first that the terminology used is age appropriate and second that it's unbiased, since children are easily influenced and persuaded," Cairco Dukes says. "The method has the potential to provide an efficient pathway for nursing students to achieve some level of competence in interviewing techniques before they reach the clinical setting."

SIDNIE is now being used by Clemson's School of Nursing for experimental evaluation. The students plan to publish their findings and make them available to therapists and patients.

–Brian Mullen and Peyton Bullard

Craig Mahaffey

Lauren Cairco Dukes runs through a practice interview.

zoom in

Peter Kent

The Intelligent River project's first flight of buoys hits the Savannah River. Brian Johnson (front) and Robbie Moorer are research specialists from Coastal Carolina University, contractor for field deployment on the project.

Checking the vitals of a river

Hundreds of sensors along the 312-mile Savannah River will collect and transmit real-time data about water quality and quantity to scientists in a wide-ranging study of river ecology.

It's a step in the Intelligent River project, in which Clemson University researchers are teaming up with Coastal Carolina University colleagues to deploy and monitor the sensing devices.

The data-collection system will include a network of remote sensors to collect, store, and send data on river conditions ranging from water quality and flow to storm-water runoff and pollution discharges. Wireless transmitters will send data on temperature, water clarity, dissolved oxygen, and other environmental indicators to Clemson. The information will be processed and posted on the Internet, where anyone can monitor the wellbeing of the river.

The Burroughs and Chapin Center for Marine and Wetland Studies at Coastal Carolina will provide watercraft and technical staff to deploy the equipment, replace field equipment as necessary, and assist in routine maintenance.

"CCU's Center for Marine and Wetland Studies has extensive experience in deploying and operating a wide range of scientific instrumentation in diverse environments," says Gene Eidson, director of Clemson's Institute of Applied Ecology. "We are excited to have them as a partner."

–Peter Kent

Learn more about the project:
www.clemson.edu/public/psatv/env/intelligent-river-overview.html
For the Spring 2012 story in Glimpse: *www.clemson.edu/glimpse/?p=29*

Craig Mahaffey

One of two test bays designed to put wind-turbine drivetrains through their paces. This one can handle equipment rated at up to 15 megawatts.

Power up

Researchers and companies put wind power to the test and work toward a smarter grid.

Getting serious about wind energy on a commercial scale means amping up the performance of turbines and other power-generating equipment. It also means transforming the electrical grid to take advantage of new energy sources.

None of that happens without extensive R&D, which is what Clemson has powered up at the Clemson University Restoration Institute (CURI) in North Charleston. The behemoth shown above is one of two test bays designed to put wind-turbine drivetrains through their paces. This one can handle equipment rated at up to 15 megawatts, many times greater than today's typical 2 to 3 megawatt wind turbines.

Companies will use the facility, dedicated in November as the SCE&G Energy Innovation Center, to test new drivetrains as well as energy-storage and grid-management systems. The first of those companies, GE Power & Water, is expected to begin testing its next-generation wind turbine drivetrain this spring.

Clemson faculty members and students will use the center for a wide range of energy-related research, including wind, solar, and traditional sources of energy along with topics such as energy storage and security. Support from Duke Energy and the South Carolina SmartState program will provide three faculty positions focused on research and technology development related to energy.

The center includes a simulator called the Duke Energy eGRID, a laboratory for testing various electrical devices "in the loop," to learn how generators, controls, converters, and other elements perform together in a working grid. Curtiss Fox, now director of operations for the eGRID center, first envisioned the grid simulator when he was a Clemson graduate student and intern at CURI.

In a statement, U.S. Deputy Secretary of Energy Daniel Poneman said, "The Clemson testing facility represents a critical investment to ensure America leads in this fast-growing global industry, helping to make sure the best, most efficient wind energy technologies are developed and manufactured in the United States."

–Neil Caudle

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.

Craig Mahaffey

The new testing facility in North Charleston will accommodate academic research as well as industry partnerships.

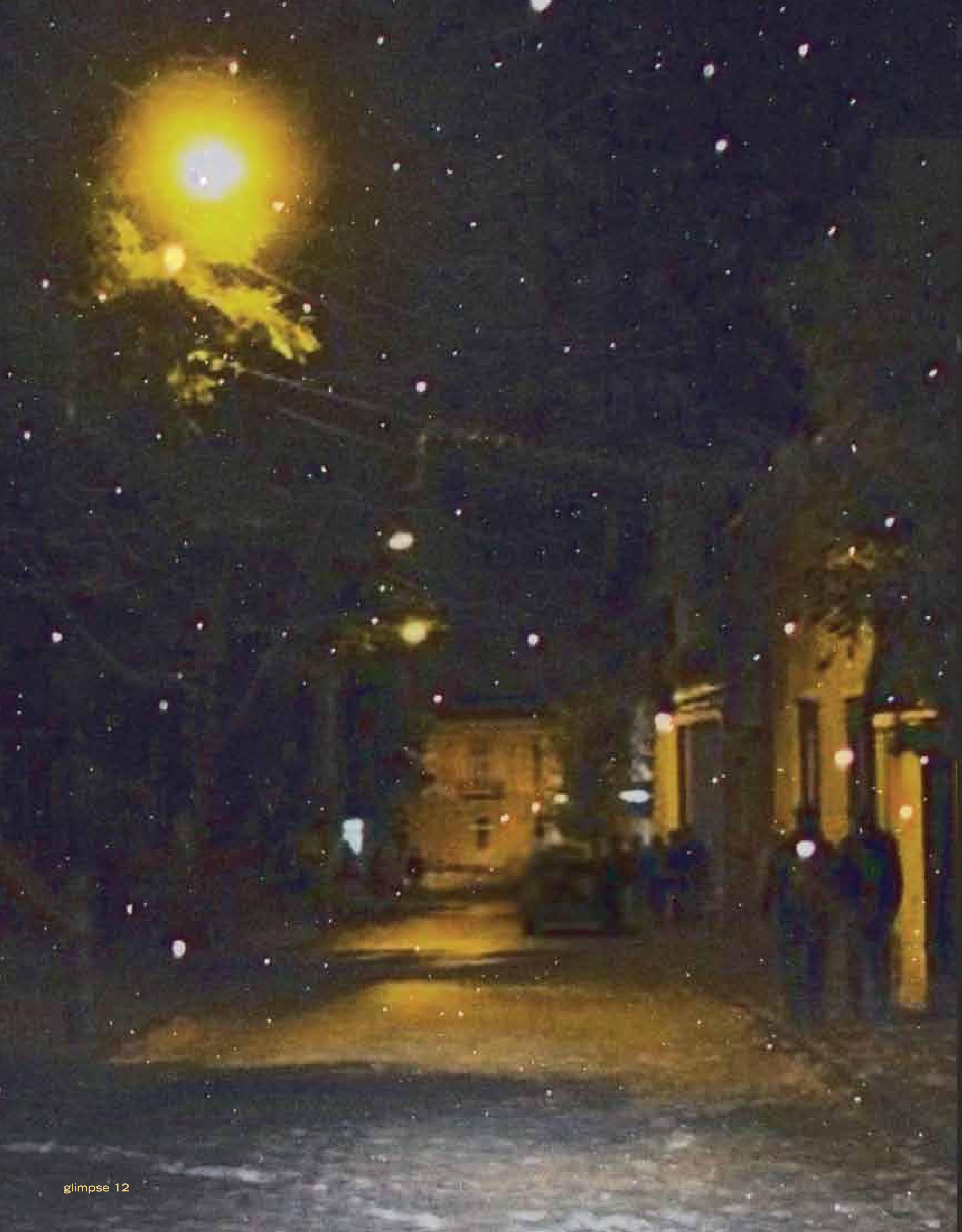
Craig Mahaffey

Tuning up the grid

Curtiss Fox, whose Ph.D. was his third degree from Clemson, developed a 15 megawatt Hardware-In-the-Loop (HIL) grid simulator to troubleshoot power interruptions and reduce the kinds of risks that worry the energy industry as it tries to integrate new technologies into the electrical grid.

Fox's Ph.D. thesis examined what the industry calls low voltage ride-through, the ability of electrical equipment to keep working even when there are brief disturbances caused by lightning strikes, fallen trees, or animals. When the lights flicker or short out, it's because the flow of electricity has been disrupted. Now, as director of operations for the Duke Energy eGRID, Fox oversees an advanced simulation system capable of modeling grid conditions anywhere in the world.

"These projects are only a stepping stone for the research and innovation that will be needed for the grid of the future," Fox says. "I hope to continue to contribute to those efforts."



the matrix, reloaded

Dan and Agneta Simionescu found magic in the matrix, and it's helping them fashion a new way to heal.

by Neil Caudle

Dan and Aggie in college.

It was late, and snow flurries danced in the empty streets of Bucharest. Dan and Agneta had finally finished their work for the day—a liver-enzyme assay that had kept them in the lab until midnight. They were two Romanian undergraduates, studying biochemistry. They were falling in love.

More than three decades later, they remember that night when the world was alive with so many swirling possibilities. The world is still alive that way for them. As it is for their students. As it is for the surgeons who volunteer time to be part of their research. As it is for those who hear the story of their work.

This story is a romance. It begins with two students who fall in love and learn, together, how to mend a broken heart.

To get started, let's go back to Romania, during the early 1980s. The newlyweds were working side by side in a lab in Târgu Mures, in the heart of Transylvania. On the bench was a heart valve constructed from bovine pericardium, the sack-like tissue that covers the heart of a cow. Their boss, Radu Deac, a cardiovascular surgeon, had recruited Dan and Aggie Simionescu, offered them jobs and a lab and a house, because he believed they could help him save lives. Many of his patients needed heart valves, and Deac did not have enough valves to give them.

"He would send them home, and they would die," Dan recalls.

In those days, he says, heart-valve replacements were new on the market, and very expensive, and the Romanian government wasn't buying enough of them to meet the need. Deac had seen, in his travels, a new type of heart valve, designed by another Romanian, Marian Ionescu, that seemed to have promise but with room for improvement. "I know how to make these valves out of cow tissues," Deac told Dan and Aggie, "and you can help.'"

So the Simionescus, educated as biochemists, began to learn, on the job, the new skills of biomedical engineering. The work was so consuming that they could almost forget, during the long days and nights in the lab, the heartbreaking hardships of Romania in the 1980s.

Deac, stringent and exacting, continuously altered the design as the team tested and tailored each valve. "We had made for him, in the machine shop, a little device to test the valves," Dan recalls. "We would wait for him in the evenings, and after ten hours of surgery he would come into the lab, and he would mount the valve we had made during the day, and he would test it individually, by hand, to see how it functioned. After stringent quality control, maybe one in ten valves received the stamp of approval and were prepared for implantation."

Aggie still remembers very clearly her first glimpse of Deac's patients. "I went into the hospital to meet with him, and I saw some of the patients in their pajamas. I felt a bit unwell, because I was very young and I had never been in that part of the hospital before. I realized for the first time who we were working for, and that this was a huge responsibility."

Each day, the couple worked as though the patients watched them, waiting and hoping. Gradually, the tweaking and testing paid off. The heart valves were working; patients were going home to live their lives.

"It took us about five years to prepare those valves," Dan says, "and we made about a thousand of them. So our careers started by saving a thousand patients."

Learning from the failures

The Simionescus spent another five years helping Deac develop a method for repairing valves with bits of tissue snipped from the patient's own pericardium, the sack around the heart. Meanwhile, a few of the patients with artificial valves implanted before 1980—twenty or thirty of the one thousand, Dan says—returned to the hospital because their replacement valves were failing. The team tried to learn from these failures and improve the new valves, a line of research that became the basis of Dan's Ph.D. project.

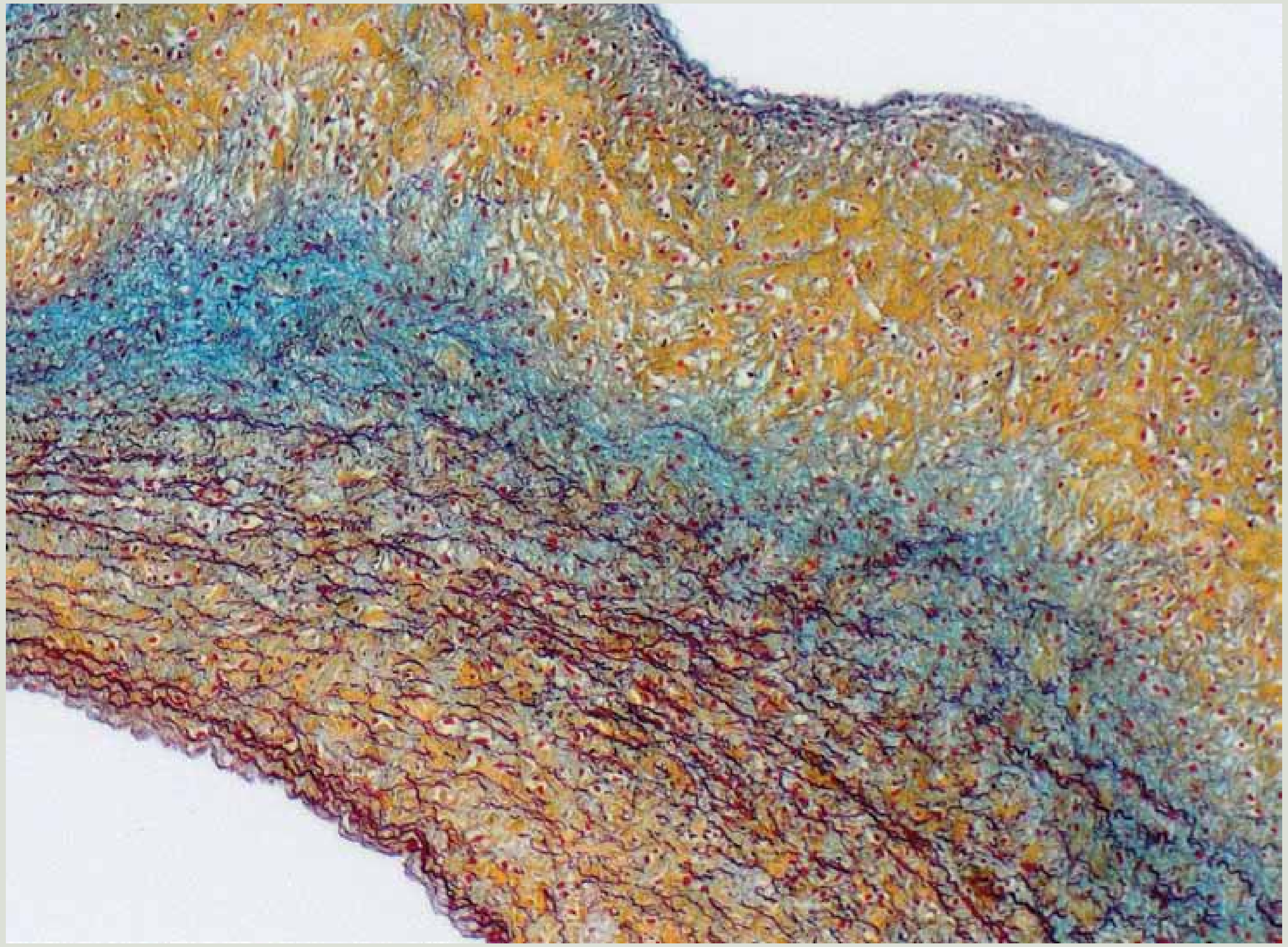
"By finding out how they failed, we realized that there were ways we could make them better," he says. "The heart valves failed because they started to calcify. You could find real stones that were built on them."

Before they calcified, the failing valves would begin to deteriorate and thin out. Aggie, conducting research for her Ph.D., discovered that certain kinds of enzymes were degrading the tissue.

The main trouble, the couple realized, was that the heart valves they'd been making relied on tissues with dead and dying cells—the best available option at the time. In those days, the team treated the tissues with a chemical that would prevent rejection by the human body. The chemical killed the cells, but the tissues remained strong and intact, working fine for years with very slow degradation. "Once the cells were killed," Dan says, "they became little points where calcium started to be deposited, and it grew there, like a crystal."

Radu Deac (right) with Dan and Aggie at a conference in 1997. In the 1980s, Deac hired them to help him make heart valves. They still work with surgeons, to stay focused on the needs of the patient and the realities of the clinic.

Simionescu lab



Patterns in the flow

This section of heart-valve tissue has been stained in five colors to highlight various components. Purged of living cells, what's left is a matrix, a structure of mostly collagen fibers. The Simionescus populate the matrix with stem cells and grow new tissue.

So these heart valves, which had saved so many lives, were not the final answer. By the time the Simionescus found their way to Clemson—Dan in 2001 and Aggie a few years later—they were ready to try something new. They brought with them several old habits worth keeping. For one thing, they would continue to work as a team, stronger together than apart. They would continue to collaborate with surgeons—people who, like Deac, understood what patients needed. And they would work with the patient in mind.

A true romance requires more than attraction and common interests. It is a daring adventure into the future, into big, ambitious dreams. In their new country, Dan and Aggie Simionescu began to pursue a big, ambitious dream.

"Imagine," Dan says, "that one day you could go to the hospital and have your own stem cells collected from you as a patient and that your own cells could be used to regenerate a new heart valve, new cartilage, or new tendon, and the surgeon could implant the new part in you. It would be yours, made of your own living cells. This is the future. And this is what we are doing."

The dream is on the verge of coming true. Which brings us to the science.

The heart from Snow Creek

Romance is not always a matter of moonlight and roses. Sometimes it requires the services of a slaughterhouse, where the heart of a pig goes on ice.

Each year, the people from Snow Creek Meat Processing in Seneca, South Carolina, take a field trip to campus, to see for themselves what goes on with the products they pack up and send to the lab. Take the pig heart, for instance. Dan will make use of its valve. His students will cleanse it with detergents, wash away its cells, and remove every trace of its pigness—proteins the human body would reject. What's left when the cleaning is finished will be an empty framework, neutral and inert—a well-ordered absence of life. Call it a matrix, a lattice, a scaffold. It is a weave of tough collagen fibers, a netting that holds life together, for any sort of animal, including us.

Nature has a frugal way of reusing a structure that works, handing it down from species to species over millions of years. When that happens, biologists say the structure is well conserved. The extracellular matrix and its collagen are well conserved. Humans have it, and so do the critters around us. In the matrix, at least, we are one.

Dr. Fred Nelson performs brain surgery on a rat at Clemson's Godley-Snell Research Center. With his help, the researchers are testing implants for replacing stroke-damaged brain tissue.

Surgeons help guide the research

Lots of research programs show promise, but not many are so promising that ten busy surgeons volunteer their time to contribute. That's the case with the tissue-regeneration studies led by Dan Simionescu.

"What Dan and his team are doing is incredible," says Dr. Chris Wright, a thoracic surgeon and chief of medical staff affairs for the Greenville Health System (GHS). "More than anyone I know, he has bridged that gap from basic science to application, and it's really going to pay off for patients. I'm convinced of that."

Wright began working with the research team about five years ago, after he attended a symposium where Simionescu presented his work on a vascular conduit. Simionescu introduced him to his student, Lee Sierad (see the story on page 20), and Wright decided to help Sierad develop and test regenerated heart valves. He serves on Sierad's thesis committee and guides the clinical aspects of the research. Wright enjoys working with the students, he says, not only because he can help them understand the clinical applications of their work but also because they teach him engineering.

"I really think that the technology and their approach will develop a heart valve different from anything we have now," Wright says, "because it will be dynamic and will grow with the individual. It's not an artificial valve; it is truly a replacement."

Wright's colleague at GHS, Dr. Fred Nelson, a neurosurgeon, works with Natasha Topoluk (see the story on page 19) to regenerate brain tissue damaged by stroke. On the Clemson campus, Nelson surgically implanted scaffolds seeded with stem cells into lab rats disabled by stroke, and Topoluk assisted. The team spent twenty-five hours in the animal lab over three days. The procedures were microsurgery and very exacting; there's not a lot of room to maneuver in the head of a lab rat. Nelson laughs. "Why they couldn't use a New York subway rat, I don't know."

After the procedures and a recovery period, "there was marked improvement on the functional scale," Nelson says about the rats that received the implants. "I think this is a promising possible treatment for stroke."

What motivates him to devote so much time to research? In addition to the potential to help human patients, he finds it rewarding to work with students and academic researchers, he says. "I think the science is fascinating, and I like the people."

"I really think that the technology and their approach will develop a heart valve different from anything we have now. It's not an artificial valve; it is truly a replacement."

–Dr. Chris Wright

Many of the projects mentioned in these pages are patented or patent-pending technologies available for licensing and are managed by the Clemson University Research Foundation (CURF). CURF is a nonprofit corporation that facilitates the transfer of Clemson University's intellectual property to the private sector for commercial development and societal benefit. For further information on these or other Clemson technologies, please visit www.clemson.edu/curf or email contactcurf@clemson.edu.

And so when the matrix is empty, our stem cells can move right in, like the next round of guests at a freshly cleaned hotel, without fear of rejection. *Mi casa, su casa,* the matrix says. Nothing lifelike remains there. There are no antigens to provoke an attack from the body. There are no dead cells for enzymes to degrade, no dead spots for calcification. And the stem cells make themselves at home.

Stem cells. The term may still carry baggage, for some. Not very long ago, people argued the ethics of using a particular kind of stem cells, those from human embryos. As it seemed at the time, embryonic stem cells were medical science's best hope for regenerating tissues and organs. But over the last decade or so, scientists have learned that several types of adult stem cells, which are not from embryos, are also "pluripotent." They can morph into multiple cell types and help generate many kinds of tissues.

Conveniently, a vast number of these pluripotent stem cells are stashed behind our bulging waistbands, in the fat below the surface of our skin. "Sometimes," Dan says, smiling, "it's good to have a little fat." (Even though he, by all appearances, is lacking.) One day, he says, our fat might save our lives—assuming we don't overdo it. (More about this later.)

If stem cells are actors waiting for their turn on stage, the fat below our skin is a cushy kind of green room. On cue, our stem cells come racing to the rescue, transforming themselves for the roles they are called on to play. For their research, Dan and Aggie can buy the stem cells they need from companies that extract them from fat removed during liposuction. But in the clinic, a surgeon would harvest a bit of the patient's own fat, and its stem cells, through a small incision.

"From a piece of fat the size of a walnut, we can get millions of stem cells," Dan says. "If you amplify them in the lab, you can get twenty million, a hundred million—enough to regenerate a small piece of tissue."

Dan and Aggie say that their collaborators, Jeff Gimble and Bruce Bunnel of Tulane University, have provided invaluable expertise on adult stem cells. "Every day we learn new things about the adult stem cells we find in our bodies," Dan says.

The magic in the matrix

But tissue generation is not as simple as dosing an injury with stem cells. If a wound is massive, stem cells cannot find the remnants of structure they need to begin the repair. They float around and die. If a disease is too virulent, it overwhelms the stem cells, and they cannot thrive. The matrix, Dan says, gives stem cells a place to hole up and get ready to grow new tissue.

Which brings us to a bona fide breakthrough, a discovery that has attracted not only the attention of scientists and engineers but the passionate, personal investment of students and busy surgeons and colleagues. The Simionescus have shown that human stem cells, extracted from the fat beneath our skin, can multiply and populate a matrix, transform themselves, and begin to grow replacement parts biologically the same as our original equipment.

Somehow—and the exact how of this so far remains a mystery—the stem cells read the matrix and learn what to be. Perhaps they detect some kind of chemical signal, or perhaps they are reading the structure itself, but they get the message. Whatever destiny the matrix ordains, the cells make a lifelong commitment. They are transformed. They set off a chain of events that lead to

Today, Dan and Agneta Simionescu have branched out, running separate labs. *But they still use the word "we" when they talk about their work. How do they manage it—working so closely together, after all of these years? Aggie smiles, considers the question for a moment, and laughs. "I don't really know how we do it," she says, "but we do."*

"We always talk," she adds, "and the work is exciting for us both. When we go to conferences and take notes, very often we write down the same things, because the same things are interesting for us. I think we complete each other."

new, living tissue. The heart valve they form doesn't just *look* like a heart valve—it *is* a human heart valve.

"If you looked at one of these valves in a patient," Dan says, "the only difference you'd probably see is the sutures the surgeon would use to implant it."

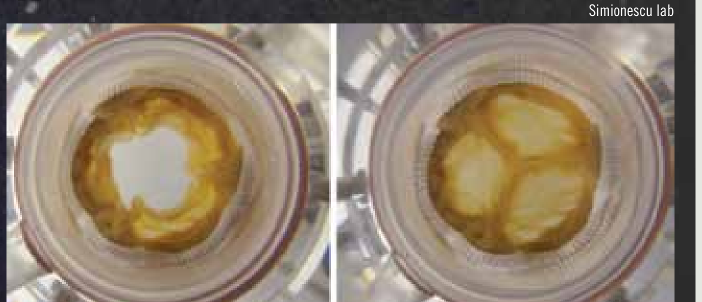
In concept, all of this seems simple. But each kind of tissue is different, requiring its own specialized method for inserting stem cells into the matrix. "The process is called seeding," Dan says, "and it takes a little bit of imagination and trial and error to learn how to put the seeds where they should be. If we do that right, in cell-culture conditions, where it's warm and humid and the nutrients are there, the stem cells change into the right type of cells. It's like the matrix tells them, 'You should become this type of cell.'"

So far, each type of tissue the lab has studied responds to this method. "Every month or so we have a new example," Dan says. One example is an intervertebral disc, the padding between two vertebrae. "We took the discs from pigs, removed all the cells, and we put in human, fat-derived stem cells, and they became intervertebral disc cells in the lab," Dan says. "This may help surgeons treat back pain."

Simionescu lab

Above: Two heart-valve bioreactors, designed and built at Clemson, work in tandem. **Below:** A porcine aortic heart valve open and closed in the bioreactor.

Simionescu lab



Putting the parts through their paces

The lab also makes arteries, cartilage, ligaments, skin, heart valves, and new tissue for stroke-damaged brains. Students develop and test these parts using equipment they build themselves—bioreactors that simulate conditions in the body.

"We have developed a bioreactor for each type of tissue," Dan says. He credits Lee Sierad, a Ph.D. candidate in Dan's lab, for advancing this "extremely challenging" part of the work (see the sidebar on Lee Sierad, page 20).

"So we have a heart-valve bioreactor, for example, which allows you to take a heart valve and seed it with cells, and then subject it to the kinds of things that would happen if it were implanted in a heart," Dan says. "Before too long—in two or three weeks—the tissue matures, the cells change into what we want. We think that this is the way we can prepare a living tissue replacement, ready for implantation."

The bioreactor can also give the growing replacement part some fitness training. "We've learned that some tissues need mechanical stimuli to mature and to grow, to start to regenerate," Dan says. "We can make a better implant by taking the cell-seeded scaffold—an artery, for example—and pulsating it mechanically to make it ready for implant. We call it conditioning. It's like any athletic conditioning." Mechanical stimulation may also help teach the stem cells how to differentiate, to turn into a particular type of tissue, he says.

Through all these steps, surgeons from the Greenville Health System track progress, advise students, and set goals for the work. (See the sidebar, "Surgeons help guide research," on page 16). There are ten of them, at the moment, and they are all volunteers who, as Deac did, see promise in this kind of research. Sometimes the surgeons come to campus to meet with the team or assist with implants in the animals used for testing. Other times, they work with the team in a lab at Patewood, officially the Clemson University Biomedical Engineering Innovation Campus, a joint venture with the Greenville Health System.

The surgeons are essential to the research, Dan says. "Biomedical research has to come from the clinic. It cannot be the other way around. We go and talk to the surgeons, and they tell us about their biggest challenges. If you ask a vascular surgeon, for example, he says, 'Well, the obese, diabetic patient has no arteries. All of them are calcified; they're gone. Can you give us a product, because there is nothing on the market?' So we go to the lab, and we get started."

More than a dose of green tea

I said earlier that our fat could someday save our lives, assuming we don't overdo it. When we lard ourselves with too much fat, we are asking for a world of hurt, especially from diabetes. Obesity and diabetes are the twin scourges of our era, an epidemic growing worse. Uncontrolled diabetes lays waste to the body, calcifying and destroying blood vessels and arteries, killing tissue, ending lives.

As Dan's lab assembles and tests new tissues, Aggie concentrates on the formidable problem of how to regenerate tissues that can repair what diabetes has wrecked. It would do little good to implant a new artery in a diabetic patient, if a toxic soup of fats and sugars and cross-linked proteins quickly attacked the new tissue and turned it to stone. We hear a great deal about the

continued on page 22

Neil Caudle

Natasha Topoluk in the lab: cautious optimism from early results.

Repairing a stroke-damaged brain

So far, stroke is catastrophic. It torches a part of the brain, kills the tissue, and leaves nothing but a gap, an empty hole. The hole does not heal; the tissue does not regenerate. If we're lucky, brain cells may wire around the hole—neurons connecting new pathways. Sometimes, patients can regain some function. Too often, they can't.

As of today, there is only one FDA-approved clinical treatment, an enzyme known as tissue plasminogen activator (TPA). It's useful for only one type of stroke, and very few patients qualify. For the vast majority of stroke victims, a hole in the brain is for keeps. And so far, all attempts to fill that hole have failed.

Natasha Topoluk would like to change that, and she's off to a good start. Topoluk, a Ph.D. student working with Dan Simionescu, got her first taste of research as an undergraduate working with Agneta Simionescu, helping James Chow with diabetes studies in Aggie's lab (see the sidebar, page 21). Later, Topoluk set up shop next door, in Dan's lab, for her graduate work.

Now, with a brand-new master's degree in bioengineering from Clemson, and a Ph.D. in the game plan for 2016, Topoluk and her mentors may succeed where a great many others have failed. Last summer, she and the neurosurgeon who advises her, Dr. Alfred Nelson (see the sidebar, page 16), implanted what Topoluk calls constructs—matrix scaffolds seeded with stem cells—into the brains of three rats with strokes so severe they could not walk.

When I ask her what happened, she takes her time to get the wording right. Speaking with the confidence of a seasoned pro, she says, "We saw almost complete recovery in our animals less than four weeks after implantation."

All three rats, rendered helpless by stroke, started to walk little by little. In less than a month, they regained some of their motor functions and some reflexes. The rats in the control group—which did not receive the construct—did not. So far as we know, no one else has done this experiment. Research groups elsewhere have been injecting stem cells into stroke-damaged brains, but most of the cells do not engraft and eventually die, never yielding neural tissue. Other researchers are using gels to try and hold the cells in place. But gels are not the stem cells' native habitat; the matrix is. So Topoluk and Dan Simionescu are convinced that a matrix seeded with stem cells is a better way to regenerate tissue, even in the brain.

"With the matrix, you can probably keep a cell population in place," Topoluk says. "Then it just becomes a question of how to manipulate that cell population to take on neural-cell characteristics. I'm making it sound simple, and it's not simple, but that's the idea."

The results so far represent an auspicious beginning, but they are not sufficient, if the goal is to help human patients. The research team, Dan Simionescu says, "is cautiously optimistic," but no one is drawing any firm conclusions before the next rounds of animal studies. Topoluk wants to know exactly what happened in the brains of those rats. Did the stem cells in fact transform themselves into neurons, or recruit new cells into the matrix? Did the regenerated neurons connect with the brain cells around them, restoring the pathways demolished by stroke?

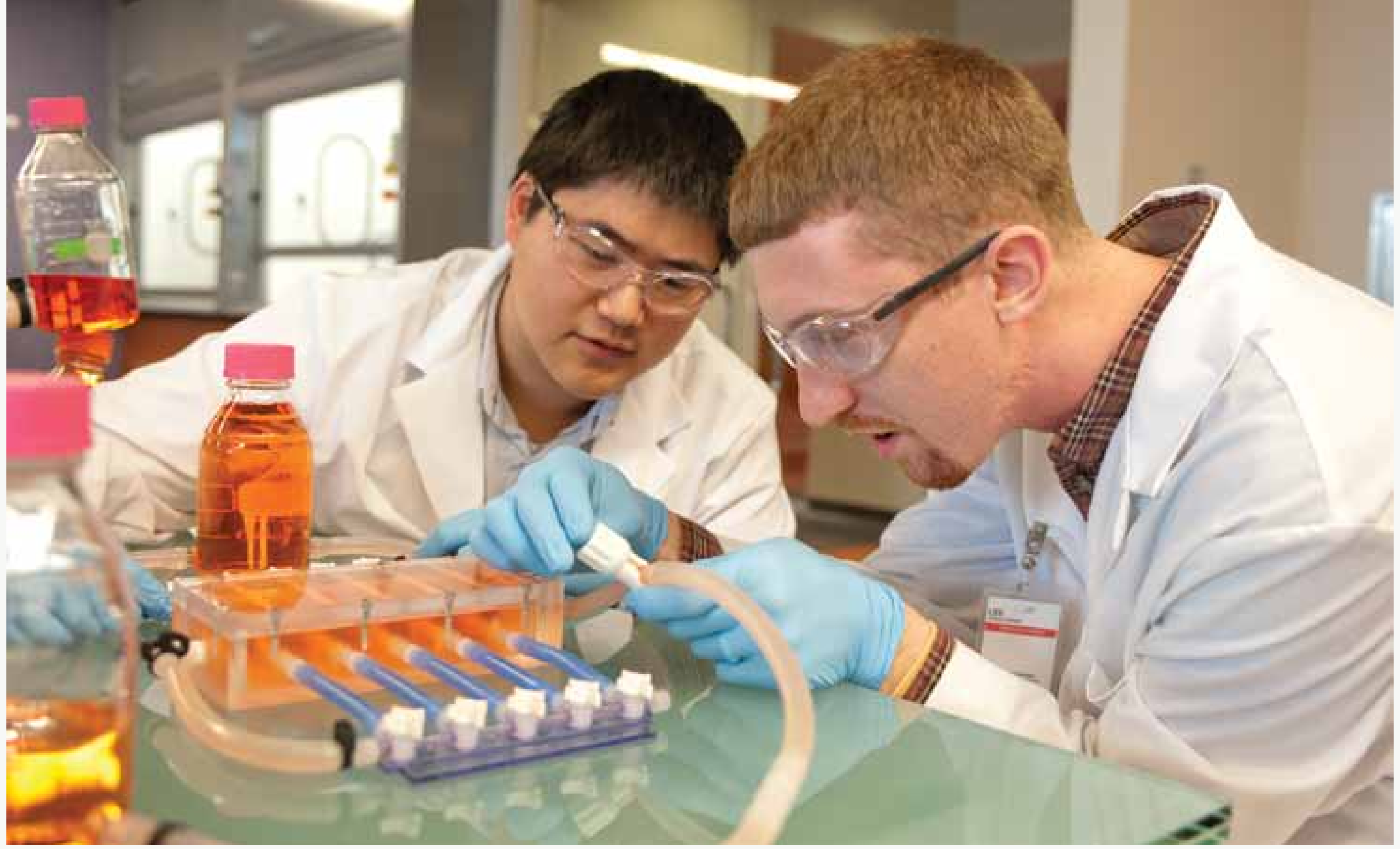
To answer those questions, Topoluk is analyzing the brain tissues, studying the implant areas for proteins expressed by neural cells, which would indicate that stem cells had indeed served a regenerative function in the rats' brains. In the next phase, she will run more experiments, with greater numbers of rats, for statistical significance and to see if she gets the same results. Nelson has agreed to continue to help her.

"We really lucked out with Dr. Nelson," Topoluk says. "He did the implants, he's on my thesis committee, and he even takes the time to review our grant applications. He is *so* enthusiastic and just genuinely interested in what we do."

This spring, Topoluk began an internship with Nelson's department in the Greenville Health System, learning how neuroscience works from the clinician's point of view. Other Clemson students with similar internships have actually scrubbed in to observe surgery in the operating room, and Topoluk hopes to do that too.

"If we can see firsthand what the clinical setting is actually like, then we can better target our protocols and our approaches to get there one day," she says, "so that what we make is actually useful to doctors and surgeons."

Research with laboratory animals, for Topoluk's studies as well as others in the Simionescus' labs, was conducted in collaboration with the Godley-Snell Research Center, headed by John Parrish, university veterinarian. The center includes two surgery rooms and complete facilities for housing and treating laboratory animals.



Craig Mahaffey

James Chow (left) and Lee Sierad (right) work on the vascular bioreactor for testing artery scaffolds, using the Patewood facility.

Putting new parts to the test

Lee Sierad likes to cook, so if it takes a while to launch the business he's planning, he could always find a job in a restaurant somewhere. In high school, he worked his way up from dishwasher to line cook, so he knows his way around the kitchen. But the business he'd really like to start would design and build bioreactors, devices that could simulate conditions in the body and help bioengineers regenerate and test replacement parts. In a way, a bioreactor is a kind of test kitchen for tissues designed to help people heal.

Sierad, who is in his final year of work on a Ph.D. in bioengineering, built his first bioreactor as part of his master's project, working with Dan Simionescu in the Biocompatibility and Tissue Regeneration Laboratories.

"It's a system to pump fluid through a heart valve, the way it works in the body," Sierad says. With its chambers, pumps, and valves, the bioreactor can simulate blood flow, and the pressures and rhythms of a beating heart.

But Sierad isn't just testing new heart valves; he makes them. With guidance from Dr. Chris Wright, a cardiac surgeon with the Greenville Health System, Sierad tailors heart valves taken from pigs, removes their cells, and mounts a cell-free, scaffold-like matrix in the bioreactor, where he can seed the matrix with stem cells and kick-start their transformation into new tissue.

"Dr. Wright gives me a lot of input on the end requirements of what our replacement valve should look like," Sierad says. "That's extremely valuable, because we're researchers, and we don't have much idea what goes on in an operating room."

The heart valves have performed like champs in the bioreactor, and the team is ready for tests in large animals. Sierad and Simionescu, collaborating with surgeons in Romania, are implanting the heart valves in sheep. Large-animal studies of this kind are a necessary step before trials in human patients.

"That's a big hurdle, and we've made good progress on it," Sierad says.

Meanwhile, Sierad is concentrating on another part of the circulatory system, the aorta, a heavy-duty artery that distributes oxygen-rich blood to the body. Because it is so strong and thick, the aorta presents special problems for tissue regeneration. For one thing, it's tricky to remove all the pig cells hidden deep inside its layers.

"Aortic tissue has fifty to a hundred layers of elastin," Sierad says, "and those layers are so tightly woven together that they prevent the solution from reaching the structure." Working with Laine Shaw, a senior in bioengineering, Sierad has developed a specialized system to target different portions of the aortic group and perfuse fluid through them to remove the cells.

"Laine has done a tremendous job developing the device," Sierad says. "That's a huge advantage for us, to be able to build the devices and understand the mechanical engineering—fluid dynamics, pressure, and all the other aspects—it's a lot of engineering."

This kind of technical problem solving appeals to him, but so does the potential to help people heal. The culture of the lab and collaborations with surgeons such as Chris Wright keep everybody thinking about the patients.

"If we are able to do this then people who are on the organ-transplant list, who are just waiting, will have another option for extending their lives," Sierad says. "That's the whole reason I got into bioengineering in the first place, rather than say, aerospace engineering. I could really make a difference in people's lives, rather than just make their flight smoother."

"We're trying to make tangible, off-the-shelf products."
–James Chow

Defending implants from diabetes

It is difficult enough to engineer a matrix populated with stem cells, and use it to replace a body part. It is difficult enough to design that matrix to fade slowly away as the patient's own tissues and cells take over and make the part their own. But if the patient has diabetes, the degree of difficulty goes way, way up.

"We can barely make this work in a healthy, normal patient," says James Chow, a Ph.D. student in Agneta Simionescu's lab. "In a patient with diabetes it would fail catastrophically."

Chow, who plans to finish his Ph.D. in May, has been working with Aggie Simionescu for years, ever since he took a course from her in bioengineering. In the simplest terms, his goal has been to develop matrix-based constructs that can resist the onslaught of diabetes, to help patients survive.

To understand what's at stake, consider what diabetes does. It attacks tissues and cells with inflammation and oxidation, crosslinking proteins and disrupting the functions of cells. Chaos ensues. "The cells lose their identity and their function," Chow says.

He finds evidence that this onslaught may also involve a Maillard reaction, the same chemical process that browns meat in a frying pan. In a diabetic body, sugars react with amino acids, crosslinking in a way that stiffens the tissues. Blood vessels are especially vulnerable, so a classic symptom of diabetes is circulation failure that damages or kills tissue. Today, the ravages of diabetes are so widespread that demand is huge for replacement veins, arteries, and other components of the circulatory system.

But against a monster like diabetes, a vulnerable new implant would stand very little chance. Chow and Aggie Simionescu think they may have found a silver bullet. It's an antioxidant known as PGG (pentagalloyl glucose), a natural polyphenol similar to the antioxidant compounds in green tea. At Aggie's suggestion, Chow found ways to introduce PGG into the extracellular matrix the team uses to engineer a construct. PGG, he found, could attach itself to the matrix and hang out there long enough to protect the scaffold from attack while the wound healed and tissue regenerated. After several months, PGG detaches itself and gets out of the way.

"We've shown that PGG inhibits harsh inflammation," Chow says. "It's like this perfect antioxidant that can slow down or fight the reactive oxygen species that damage tissue."

He has tested this process by preparing constructs with and without PGG and implanting them under the skin of laboratory rats. In the implants treated with PGG, the matrix survived, and PGG-treated constructs populated with stem cells developed normally.

It's the combination of PGG and stem cells that shows the most promise, Chow says. The stem cells, he explains, not only help form new tissue; they also help integrate the implant into the body by modulating the immune response and promoting anti-inflammatory agents that enable the growth of new tissue.

For all of this work, Chow says, he depends on collaborating surgeons and clinicians, especially those from the Greenville Health System, who keep the work grounded in the real-world practicalities of patients and treatments. He works closely with Dr. John Bruch, an endocrinologist, and with Dr. Christopher Wright, a cardiovascular surgeon, and several other clinicians contribute, as well.

"We're trying to make tangible, off-the-shelf products," Chow says. "This is what we call translational medicine, not just science for science's sake."

Chow plans a career in industry, developing medical devices, and he says his experience running a project in the lab has prepared him well. It's an entrepreneurial endeavor, with many of the complications of running a business.

"You learn to manage a project through all of its cycles, meeting goals, training the students, writing grants, and presenting your work," he says. "Aggie and the clinicians are there to advise me, but it's truly my own project."

Craig Mahaffey

James Chow and Aggie Simionescu examine a heart valve.

About that fear of rejection...

The Simionescus are not the first to show that the human body can readily accept an implant prepared with a matrix, and Dan says that millions of people are living proof. Two examples of common treatments: injections of bovine collagen in cosmetic surgery and implanted pig matrix for skin regeneration.

dangers of oxidation, these days, and find ways to pack antioxidants into our diets. Diabetes unleashes a storm of oxidation, and a dose of green tea is not enough quell the storm.

Even so, antioxidants might have value in tissue generation, Aggie thought. She and her students, including James Chow who expects to finish his Ph.D. this spring, began to study an antioxidant known as PGG (pentagalloyl glucose), a natural polyphenol used in herbal remedies for various diseases, including diabetes (see sidebar on James Chow on page 21). The team began treating the extracellular matrix with PGG and implanting the matrix under the skin of rats with diabetes. The matrix survived. Better yet, when Chow populated the treated matrix with stem cells, the tissue developed normally. The implications are enormous: It might indeed be possible to implant replacement parts that could repair and resist the ravages of diabetes.

The success was not due to PGG treatment alone, Aggie says. "The stem cells have a very good effect, an anti-inflammatory effect. In tissue engineering, you want a little bit of inflammation, because you want stem cells to come in and start remodeling your tissue, but you don't want this to happen too quickly."

Ideally, regenerated tissue would not rely forever on the matrix used to build the implant. Instead, it would begin to regenerate its own matrix, replacing or extending the implanted one. (The Simionescus often use the word *scaffold* instead of *matrix,* to suggest the analogy of building a house: After the house is built, the scaffold can come down.) Aggie's team has found that a recently discovered type of cell assists in matrix regeneration: the type II macrophage.

"For a very long time," Aggie says, "we thought there was only one type of macrophage, but now we know there are two types." Type I actually increases inflammation, because its role is to degrade tissue and clean away debris. But type II macrophages help with healing and regeneration, and they seem to be attracted by stem cells. "We believe that these stem cells send signals to these good macrophages and start regeneration," Aggie says.

But in the case of diabetes, stem cells and their allies aren't sufficient on their own. They need the safe haven of a matrix treated to withstand the onslaught of calcification. So in tests with laboratory animals, the implants that fared best were those with a PGG-treated matrix populated with stem cells.

All of this makes Aggie hopeful that patients with diabetes may eventually have the replacement parts they need. And this, in the end, is her goal. Ever since that evening when she first walked the floor of a hospital ward, she has remembered the point of it all: the patients.

The Valley of Death

No romance can run its course without facing a peril, a nemesis to fight. The Simionescus have never had it easy—in Romania, in finding their way through a new country and a new culture, or even in science, which is always a struggle with setbacks and complications. But they have collaborators who can help them over the technical hurdles—experts in stem cells or the extracellular matrix, surgeons and engineers, for instance. The peril they dread most, at this stage, is the Valley of Death.

They do not mean Death Valley, the football stadium. They mean a chasm that yawns between success in the lab and success in the clinic. As they watch their projects march forward, yielding heart valves and intervertebral discs and tendons and arteries and so much more, they know they are nearing the edge. They will come to a halt at the Valley of Death.

Here is how it works, as Dan explains it: "If you look at the timeline for a product going into a patient, it's split in two parts. The first part is what you've heard about, the research and work in the lab. The second part is clinical trials, testing in patients. In between the two parts is the Valley of Death. And it's scary. Why? That's where you're supposed to do the large-animal testing. The first part can be covered by federal funds. But before you can go into clinical trials, you have to test the products in large animals—pigs, dogs, or sheep, for example. The FDA requires that you do this to prove safety, efficacy, and feasibility. But federal agencies rarely provide grant money for large animals; it's very difficult to get, and the work is very expensive. And usually companies will only fund clinical studies, when the product is ready for patients. We can do work with rats and mice, implant the tissues under the skin and detect if it's antigenic, if there's a reaction. We do this all the time. But then we get stuck. We need a hundred thousand dollars just to run one experiment with ten heart valves in ten sheep. Where do we get that?"

These days, Dan and Aggie are looking for ways to build a bridge across the Valley of Death, working every angle they can find. They spend much of their time writing grants, fighting odds in a time when federal funding is iffy and scant. In passing, Dan even wonders aloud whether people who love football might also like to help repair the injuries it inflicts upon tendons, ligaments, and cartilage.

The most promising prospect so far, ironically enough, has come from where the Simionescus began—Romania. "We applied for a grant, and we got a million euros ($1.5 million dollars) from the Romanian government to test our technology over there," Dan says. "We are working with an amazing group of surgeons, veterinarians, and biologists who will help us implant heart valves in sheep."

Last year, six of these scientists came to Clemson for several weeks and studied the technology.

If those implant studies turn out well, the team could possibly win approval for compassionate implantations—heart valves for human patients who would die without them. And if that works out, maybe, just maybe, American companies would see the potential, would invest in more large-animal studies to help bridge the Valley of Death.

Into the quest of their lives

The Simionescus want this success for the surgeons and their patients, certainly, but they also want it for their students. They want their students to see their hard work cross the valley, to reach the clinic and begin saving lives.

When they arrived at Clemson, the Simionescus were first and foremost researchers and problem-solvers, but now they are teachers as well. When Aggie describes her first experience in the classroom, it sounds very much like her first visit to the hospital ward. Once again, she confronted a daunting new responsibility, one that would change her life.

"Until I came here, I very rarely taught," she says. "At Clemson, the bioengineering students had to take a tissue-engineering course, so Dr. LaBerge [Martine LaBerge, professor and chair of bioengineering] told me, 'You are doing tissue engineering; do you want to teach it?' So I said sure. But then once I began to prepare the course, I was very nervous at the beginning. It was a big responsibility."

Tissue engineering is a complex field that incorporates multiple disciplines— chemistry, biochemistry, biology, engineering, physics, and more. Students take classes in these subjects, and Aggie helps them pull the pieces together and apply what they've learned. But as she teaches, she listens. Students bring energy, enthusiasm, imagination, and ideas.

"I always listen to the students," Aggie says. "I take that part very seriously. They are *so smart,* and they have great ideas. I just love the students."

In both Simionescu labs, undergraduate students from several departments work side by side with the graduate students, participate in group meetings, and appear as coauthors in publications. "This way we educate the next generation of scientists," Dan says. "Our student alumni are now doctors, professors, nurses, lawyers, and entrepreneurs, and more."

And so this story, which began with the first little flurries of romance, ends with another kind of love: a passion for leading young women and men, as Radu Deac did for Dan and Aggie, into the great, swirling quest of their lives.

Dan Simionescu is an associate professor of bioengineering and Agneta Simionescu is an assistant professor of bioengineering in the College of Engineering and Science. Dan Simionescu is also director of the Biocompatibility and Tissue Regeneration Laboratory at Clemson University and director of the Laboratory for Regenerative Medicine, Patewood and Clemson University Bioengineering Translational Research Center. The Simionescu group maintains a website (www.clemsonbtrl.com) and has founded an online journal, Challenges in Regenerative Medicine *(www.researchpub.org/journal/crm/crm.html).*

Graduate students in the Biocompatibility and Tissue Regeneration Laboratory include Laura McCallum, Allison Kennamer, Chris Deborde, Natasha Topoluk, Jason Schulte, George Fercana, Michael Jaeggli, James Chow, and Lee Sierad.

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An international team

Collaborators, past and present

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Chris Wright, U.S.A., cardiovascular surgery
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Henry Zhang
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Jonathan Hill
Devon Bowser
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Harleigh Warner
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Allison Kennamer
Lisa Larrew
Theresa Hafner
Mike Beshay
Elizabeth Fontaine
Nick Rearson
Anna Lou Carter
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Haider Niazi
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Jonathan Schwartz
Jose Chavez
Joshua Biggs
Kaitlin McClure
Katelyn Rye
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Margarita Portilla
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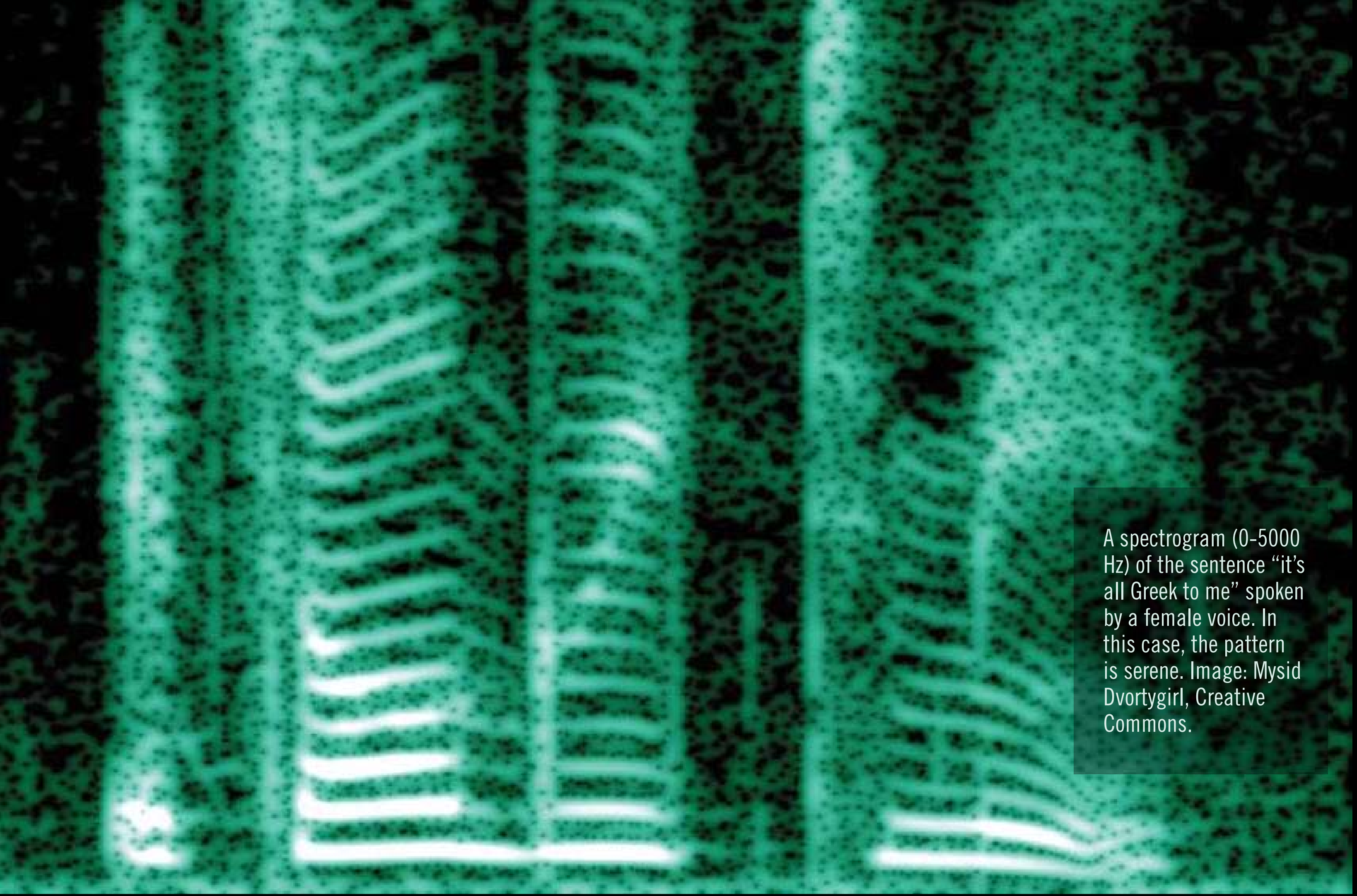


A spectrogram (0-5000 Hz) of the sentence "it's all Greek to me" spoken by a female voice. In this case, the pattern is serene. Image: Mysid Dvortygirl, Creative Commons.

scarring

revenge of the matrix

good vibrations

The Beach Boys hold up better than Joplin, in the matrix. For Ken Webb, the amazingly resilient human voice tells secrets about the nature of scarring and why it grows out of control.

by Neil Caudle

When Janis Joplin, rock's legendary queen of self-destruction, belted out her raspy blues, she was destroying her pipes. Her vocal cords pounded each other so hard that they couldn't recover before the next all-out assault. Slowly, they stiffened with scar tissue, slowly turning rigid and silent as stone.

But for most of us, vocal cords are remarkably resilient. We can scream ourselves hoarse at a football game and, if we don't overdo it, we'll be fine in just a few days. In fact, the resilience of our vocal cords is a marvel of physiology so extraordinary that it hints at the nature of healing. Ken Webb has been finding those clues in what he calls the matrix.

Locked in the matrix

The extracellular matrix is a mesh-like structure that holds tissues and organs together. It is made mostly of collagen, which forms tough, skinny strands. When we are injured, collagen erects a quick scaffold to rebuild the matrix and help tissues heal. Sometimes, we overbuild the scaffold, and that leads to scarring.

"A hallmark of severe scarring is an excess accumulation of collagen," Webb says.

Until we abuse them, our vocal *folds*, as scientists prefer to call them, don't require much collagen to hold them intact. To vibrate freely, they need flexibility, not rigid strength.

Unlike other tissues, a healthy set of vocal folds is resilient enough to recover from constant wear and tear. A Beach Boys tune? No problem. But when we Joplin our voices, we traumatize the tender folds. If the damage is severe, or if we don't give the folds enough rest to recover, collagen accumulates and the scarring begins. It's the body's way of saying, "If you're going to play *that* rough, I'll put on a suit of armor."

The result, Webb says, is vocal pathology—the kind of damage that afflicted not just rockers like Joplin but, at the other end of the Zeitgeist, Julie Andrews.

Built for action

Vibration alone is not really the problem. In fact, our vocal folds grow and thrive with the right kind of vibe. "I think there's a lot of evidence to support the idea that mechanical stimulation promotes tissue-specific matrix accumulation," Webb says. "So in tissue engineering, people use bioreactors to develop the matrix and therefore the appropriate functional mechanics." Engineering a heart valve, for instance, can benefit from pulsation in a bioreactor, to simulate normal, rhythmic flow.

If our tissues are healthy, the matrix can recover from repetitive wear and tear. We can sing a cantata or go for a jog without kicking collagen into overdrive. But in fibrotic disease, something upsets the equilibrium, and collagen accumulates. Webb and his students have been learning what that something is. And their findings have several interesting implications for medical science.

A way to fight fibrosis?

Consider diseases such as pulmonary fibrosis and cardiac fibrosis, both of which are painful and deadly. Renal fibrosis, which attacks the kidney, is especially common in late-stage diabetes, an increasing threat around the world.

The culprit in each of these diseases is an overabundance of collagen, which forms a great many very tough fibers. Scientists think that each disease originates from some form of minor but persistent injury that stimulates an unusually high concentration of growth factors, molecules associated with matrix production.

How are the vocal folds, whose vocation is vibration, able to repair the minor wear and tear resulting from normal speech without developing fibrotic disease? If a vocal fold can protect itself from fibrosis-inducing molecules, why can't a lung or a kidney or a heart?

The answer, oversimplified, is that the phenotypes are different. Our phenotypes—the versions of our physical selves that can actually be observed—reveal themselves when some molecule flips a switch that says, for example, "You will have a healthy lung," or "You will have a fibrotic lung." We store in our genes an instruction set for these and many other phenotypes, with switches to control the selections.

So Webb and his students went looking for the switch.

"Our original direction was to try to use molecular biology to identify a molecular switch, activated by vibration, that would 'turn off' the pathways leading to fibrotic disease," he says, "and then perhaps to design a drug to activate that switch in patients with fibrotic disorders."

In search of a switch

To search for this switch, Webb and Sooneon Bae, his Ph.D. student, took a close look at vocal cords, trying to understand them mechanically as well as biologically. They used a bioreactor to apply mechanical stimulation to living cells, simulating the cycle of tension and relaxation as well as the high-frequency vibration that occurs in our vocal cords.

"Normally when we speak the tissue is tensed or stretched," Webb explains. "It vibrates under tension, and then it relaxes. This is the oscillatory pattern of our speech."

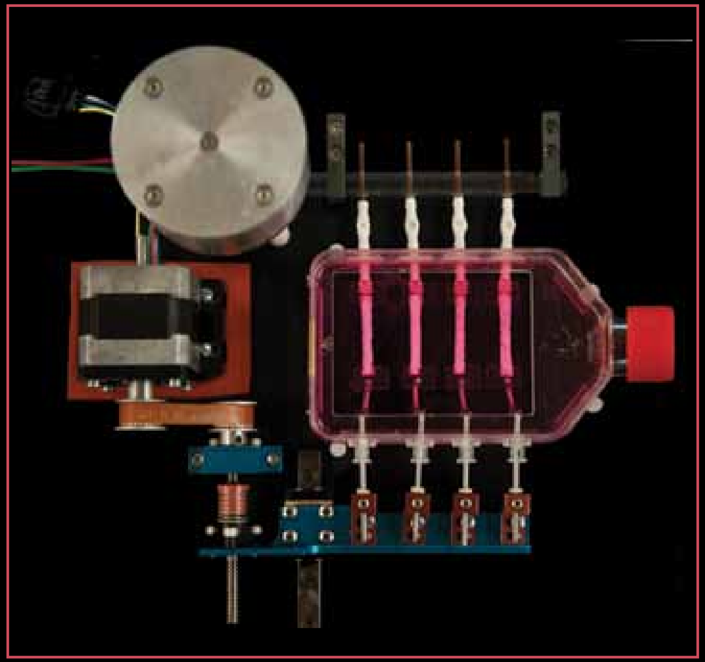
So the researchers built the bioreactor to simulate both the tension and the vibration. One side of the device creates the strain and another uses an electromagnetic speaker coil that vibrates the samples at 100 hertz, in the lower end of the range for human voices.

As Webb and Bae simulated the mechanics, they also studied the biology of what happens to cells under tension and vibration. Webb's collaborator at the Medical University of South Carolina (MUSC), Jeremy Barth, used microarray analysis—a high-tech tool for analyzing the expression levels of all messenger RNAs expressed by the cells. Because messenger RNA molecules carry genetic information from the DNA, the researchers could track how the cells responded to the cycle of strain and vibration.

Patrick Wright

Finding the vibe

Ken Webb (left) and Sooneon Bae, his Ph.D. student, have found evidence that vibration, coupled with the strain of cyclic tension, helps vocal cords remain flexible and avoid scarring. Using a bioreactor Bae built (right), the team tests vocal-fold tissue in various combinations of tension, vibration, and relaxation. Their results suggest the potential for using vibration in treatments for fibrotic disease.



Telltale molecules

The experiments uncovered several clues to what happens in fibrotic disease. For one thing, the team identified a number of cytokines—molecules involved in cell regulation, signaling, and growth—associated with fibrosis.

"When a patient has pulmonary fibrosis, renal fibrosis, or cardiac fibrosis, there are certain molecules that are usually present in higher concentrations," Webb says. "Interestingly, vibration activates those molecules strongly."

But if vibration in the normal range for vocal cords triggers the signals implicated in fibrosis, why does it take a Joplin-like assault to begin forming scars?

Somehow, healthy vocal cords avoid fibrosis.

"Even at later time points the collagen does not become activated," Webb says. "It seems that vibration initially causes something of a pro-fibrotic response that would be detrimental, but at the same time it's somehow inhibiting the normal consequence of these molecules, which would be excess collagen accumulation."

In other words, vibration in the vocal folds fires up trouble but quickly snuffs it out. How and why? The answer, Webb suspects, is that somehow vibration is also inhibiting the normal signaling of these molecules.

His experiments reveal numerous alterations in the signaling pathway for a molecule called transforming growth factor beta 1 (TGF beta 1), a molecule that tends to induce its own negative feedback, Webb says. TGF beta 1 may, in the case of vibration under tension, be self-defeating.

"But that's getting pretty speculative," Webb says.

Negative feedback

Webb and Bae conducted an experiment in which they cultured collagen-producing cells under cyclic strain but with no vibration. The result was lots of collagen. "A week later, you can actually macroscopically test these samples," Webb says, "and they're stiffer."

But when Webb's team combined strain with vibration, the results were very different. There was no stiffening, no apparent excess of collagen. Vibration seems to override the fibrotic signaling normally activated by cyclic strain.

To apply this concept to a treatment for fibrosis, Webb needs to know exactly how this works, at the level of molecules and cells. "We have a couple of hypotheses," he says.

The gang calms down

In normal wound healing, the cells responsible for a lot of collagen production and scarring are called myofibroblasts. In fibrotic disease, these cells tend to gang up in great numbers and hang around too long. But during normal healing, the myofibroblasts chill out, after a while. They ease into what Webb calls senescence, becoming inactive; some of them die.

Other research groups have studied this senescence, and from their results, Webb sees evidence that vibration influences a set of genes that have been linked to the senescent phenotype. "The cells start to secrete certain molecules that affect themselves and their neighbors to down-regulate this matrix-accumulation phase of the wound healing response and turn it off," he says.

Could that happen in other parts of the body? In a fibrotic lung or heart or kidney, for instance?

"We believe that it could be useful in other places," Webb says. "To give you one example, ultrasound is used in bone healing, as an aid to fracture healing. And that ultrasound device may induce some degree of vibration. To my knowledge, the mechanism is not really understood. It's just empirically known that it works."

Webb thinks it is possible that high-intensity, focused ultrasound might provide another approach by delivering vibration and its anti-fibrotic benefits directly to diseased tissues. This approach might even turn out to be more effective than the drug he originally had in mind. He's been talking with colleagues about how to pursue the new angle. Meanwhile, he still needs to figure out, at the level of proteins and molecules, exactly what happens to keep a healthy vocal fold in shape.

For the time being, we'll just credit those good, good, good—good vibrations.

Ken Webb is an associate professor and associate chair of undergraduate affairs in the Department of Bioengineering, College of Engineering and Science.

Speaking of students…

Getting off the dime in the new paradigm

Ken Webb has a message for students—and for the rest of us, too: Times have changed. The paradigm has shifted.

A generation or two ago, Webb says, success usually meant following the blueprint for a good life: Go to college, get a good education, find a good job, and work your way up.

"That's just not as applicable today," Webb says. "You can't count on that job being there, just because you've finished college. Fields like bioengineering are too competitive. Students today, even when they are sophomores, really need to view themselves as entrepreneurs."

That means learning how to launch one's career as an enterprise, with risks and potential rewards, Webb says. "The students who will be the most successful are the ones who realize they will have to build their own skill sets, build their own résumés, and market themselves."

In fields evolving as rapidly as bioengineering, he says, a good way to stay relevant, add skills, and begin to build an enterprise is to do hands-on research and engineering as part of a team, creating new knowledge and products. Webb points, for example, to the senior design program in bioengineering, which has yielded patented inventions, start-up companies, and national awards—an auspicious beginning for any group of aspiring entrepreneurs.

If you ask him about his own research, Webb will gladly walk you through it, and it's clear that he finds it exciting—both the quest and the potential for beneficial applications. But in the end, that's only half the story.

"The best part of the work is mentoring students," he says. "There's nothing more satisfying than seeing a student grow and develop and go out and become successful."

Patrick Wright

Philosopher Todd May says there's more to friendship than transaction.

The Business of Friendship Isn't Business

by Roger Martin

> For me, philosophy has always been about who we are and what we ought to do.
> —Todd May

Is it good that we die, or should we pine for immortality? What makes life meaningful? How many forms does friendship take, and what forces are shaping the kinds of friends we have? Is it possible for America to be a nonviolent nation? Or, to put it vividly, as Todd May did in a *New York Times* commentary after the Boston Marathon bombing, "How has the United States become so saturated in slaughter?"

I shop, therefore I am.
—Barbara Kruger, conceptual artist

Tackling the big questions

These are not questions scientists ask, not questions that a double-blind, placebo-controlled study can easily address. They are questions for philosophers like May.

Because May tackles the big questions, he has a chance of affecting public opinion—or of getting a public hearing, anyway. He is a regular contributor to the Stone, a *New York Times* opinion series launched in May 2010 that showcases the writings of contemporary philosophers on issues as diverse as art, war, ethics, gender, and popular culture.

But he's also a scholar. He's published eleven philosophy books, including *Death* (2009) and *Friendship in an Age of Economics* (2012). Into these, he's woven the thoughts of such academic icons as Michael Foucault, Jacques Derrida, and Jacques Rancière. These days, he's pondering nonviolence.

He sees himself as straddling the two worlds of everyday people and academics. Have his fellow philosophers attacked him, given the preference of many academics to narrow their focus, to stick to their own kind?

May says: "To my surprise, I don't find myself at odds with them. This may be in part because I've also written more specialized articles and so I've established myself in traditional philosophical discourse. But it's also because fellow philosophers see that behind the wider focus there is concern with rigor that they appreciate." This inclines him to take nuanced positions. He clearly has a capacity to anticipate objections and to think against himself.

Is he a public intellectual? Would he agree with Samuel Johnson, the eighteenth-century dictionary compiler, who wrote: "The seeds of knowledge may be planted in solitude but must be cultivated in public"?

Philosophy and the way we live

May resists the label of public intellectual. He says he doesn't buy the idea that philosophy is an either/or matter. Philosophers do not have to choose between talking only to fellow philosophers in a private jargon or addressing the public in a simpler language. Still, in an article, "Michael Foucault's Guide to Living," published in 2006 in the academic journal *Agelaki,* he was clearly talking to his peers in saying that "one of the key problems that philosophy faces is not that it is too oriented to how we live our lives but that it is not so oriented enough."

If you press me to say why I loved him, I can say no more than because it was he, because it was I.
—Michel de Montaigne

In the same article, he advised his colleagues to ask themselves questions like this: "Might what I am writing shape my life or the lives of others in important ways?"

"For me," he says, "philosophy has always been about who we are and what we ought to do."

At seventeen, May was the youngest person ever to have surgery for a herniated disc in the history of New York Hospital. The next day he awoke to find a friend sitting in a chair in May's hospital room. He doesn't remember what the friend said or how long he stayed, but May will never forget the visit, he says.

May uses the story to point to a particular type of human bond. In the 1950s, people in this country, especially women, were encouraged to remain close to family at the expense of outside friendship. That changed, he says, with the upheavals of the 1960s, which forged closer friendship and the type of "deep friendship" he experienced after his disc surgery.

Deep friendship is "other-regarding," May says; that is, it seeks the other person's good for the other's sake, not one's own. Of course there may be other causes for our doing good, such as when we repay a debt out of gratitude or simply as an act of altruism. But in deep friendship, the driving wheel is "passion or affection" for the whole person: "In the end it is the person, not the sum of the characteristics, that one likes in a friendship." And, because one's dearest friends are loved in whole, rather than for some particular quality, they are irreplaceable.

More heart than mind

Such friendship may be summarized in terms of individual qualities, such as looks, mannerisms, voice, and character, but that doesn't really do justice to these relationships; at bottom, they are more a matter of heart than of mind. One wants to share time with these friends. These attractions have about them a sense of mystery. In May's words, deep friendships "involve a desire to be around the other that is uncertain in both the character of the time spent and the reason for spending it. An account cannot be given; one is left with the sense that there is a hole near the center of one's words."

Another characteristic of such friendships is that they "require a past," May says. "The past does not have to be temporally extended: Deep friendships can develop through a short but intense past. For there to be a deep friendship, however, the past must play a founding role."

In a *New York Times* column written in 2010, May wrote that "past time is sedimented in a friendship. It accretes over the hours and days friends spend together . . . The sedimentation need not be a happy one. Shared experience, not just common amusement or advancement, is the ground of friendship."

Deep friendship doesn't mean using others to climb up or cash in.

Neil Caudle

Deep friendship is a matter of Meaning,

May describes other types of friendship in his book, but he draws our attention chiefly to the threat of "consumer relationships" and "entrepreneurial relationships" to deep friendship, which could "slip away from us under the pressure of a dominant economic discourse," he wrote in the *Times* commentary.

We enter into the former, he says, because of the pleasure they give us now. We engage in the latter, he writes, in hopes that they'll provide a return later.

These aren't new motives for friendship. Aristotle identified pleasure-based relationships millennia ago and wrote: "It is not for their character that men love ready-witted people but because they find them pleasant." May says that Aristotle characterizes this type of relationship, focused on momentary enjoyment, as appealing to young people. When May writes about "entrepreneurial bonds," he describes what Aristotle called useful friendships: "Those who love each other for their utility do not love each other for themselves, but in virtue of some good which they get from each other." For Aristotle, May says, "this brand of friendship is often the province of the old, who need assistance to cope with their frailty."

Entitled consumers

To illustrate consumer relationships, May refers to a student type he's observed: Students who think classes should be entertaining and bring their laptops to class in case the prof doesn't deliver "are tilting to the consumer side." And, he says, an increasing proportion of his students, "but still very much a minority," feel entitled to a decent grade without much effort.

> We might say of friendships that they are a matter not of diversion or of return but of meaning.
> —Todd May

The entrepreneurially minded student, thinking about the future need for a letter of recommendation, might cultivate quite a different sort of relationship, talking with the professor after class or visiting during office hours. Such a student might also do a lot of networking, seeing others as potential resources.

"While writing this book," May writes, "I was in a café where a man next to me was explaining to his girlfriend that 'all relationships are transactional—you give something to get something.' That's entrepreneurial in the sense I describe it."

None of us, in May's estimate, engages exclusively in just one type of friendship, but deep friendship, he believes, is threatened by the rising status of these other forms of relationship.

Mistrust and the neoliberal

Why do the spirits of the consumer and investor insinuate themselves into so many of our bonds? The subtitle of May's book pinpoints the cause: neoliberalism.

Don't confuse "liberalism," in the George McGovern sense, with "neoliberalism," which is close in meaning, oddly enough, to "neoconservatism." In a general sense, neoliberals mistrust government's ability to regulate or stimulate the economy. A reading of history from the neoliberal perspective would criticize what May terms "welfare state capitalism," which dominated American politics from the end of World War II until the election of Ronald Reagan in 1980, finding it inferior to a vision of a nation driven by economic freedom and individual responsibility.

But for May, a nation that extols unfettered markets lacks an important element: "We are told to be shoppers for goods or investors for return. Neither of these types of lives, if they are . . . dominant . . . strike me as particularly meaningful."

Neoliberalism has also inflicted a more tangible loss. May cites the well-documented growth in the wealth gap between rich and poor during the neoliberal age: Between 1979 and 2004 the income of the bottom 60 percent of workers dropped about 5 percent; the earnings of the top 5 percent rose 53 percent.

Consumer and entrepreneurial orientations are individualistic and self-seeking, so both make a tidy fit with neoliberal ideas. Question: If May is troubled by the corrosive effect of the neoliberal spirit on deep friendship, does he also regard human connection as more important than autonomy, social responsibility more crucial than individual responsibility?

His answer is nuanced: "If we subdue the individual to the group, we threaten to return to some of the failed experiments of the twentieth century. Alternatively, if we align ourselves with the individualism of neoliberalism, we lose the social glue required to make a more vibrant and caring society. Right now in the U.S., we are tilted more toward the problem of isolated individualism than an overweening social solidarity."

The dark side of individualism

Individualism in and of itself is "not entirely a curse," May writes. Many artistic, scientific, and technological advances "have their roots in the striving of individuals." But individualism is also one of the reasons the United States has "become so saturated in slaughter," he wrote in a *Times* piece after the Boston Marathon bombing. "The deep reason [for interpersonal violence] lies in our competitive individualism," whose dark side "is a wariness of others and a rejection of . . . social solidarity."

Deep friendships breed trust, allow us to tell each other the truth as we see it about each other, and tend to be a great equalizer. Friends don't pull rank on friends. That's what makes these friendships a possible basis for political solidarity movements, May thinks.

"I have been in a number of solidarity movements," he says. These include serving as faculty advisor to a campus organization for gays and lesbians. He's also supported Palestinian rights and, in the 1980s, took part in movements protesting apartheid and U.S. intervention in Central America.

As usual, he adds caveats to his position that deep friendship serves political movements. For one, deep friendships may be too exclusive. And not every element of a deep friendship will be called upon by a movement, May says.

Yet he says that when bonds run deep, "I learn how to go about the commitment of trusting others. I learn what it is like, how it works, what I can do to foster it, what some of its limits are."

> (Nonviolence) demands the acknowledgment that we are all fragile beings, nexuses of hope and fear, children of some mother and perhaps parents to others: that is, no more and no less than fellow human beings in a world fraught with imponderables.
> —Todd May

Equality and democracy

May says that besides trust, deep friendship can engender another quality of mind important to political solidarity with others: a sense of equality.

But isn't a sense of equality problematic for those who want to launch a political movement? Isn't leaderless politics an oxymoron? What would the civil rights movement have been without Martin Luther King, Jr.?

"The movement might have been fine without Dr. King," May says, then qualifies: "This is not to say that he didn't have an important role to play." May remembers that Ella Baker, also an organizer, said that "it was the movement that made King, not the other way around."

"Movements are only successful when they have people working behind the scenes," May says. "That work does not have to be hierarchical."

Ultimately, May says, the sense of equality that arises between friends is more than a platform for political movements. It's the basis of democracy.

"We need to educate people to take seriously the equality of one another so that [they] can begin to listen seriously to others and learn from them," he says. "From this one can build decision-making processes that are less contentious. In short, one has to educate the members of a polity toward respectful interaction."

And what's the way to train people to regard each other as equals in a society as status sensitive as ours? In his *Times* piece on nonviolence, May notes that one way to see someone as an equal is to recognize his or her humanity.

"It demands that we who act do so with a firm gaze upon the face of the other. It demands the acknowledgment that we are all fragile beings . . ."

Some day.

Maybe.

Todd May is the Class of 1941 Memorial Professor of the Humanities in the Department of Philosophy and Religion, College of Architecture, Arts, and Humanities. Roger Martin is a writer and editor based in Lawrence, Kansas.

not Entrepreneurial bonds.

What Is Character and How Do We Get it?

by Lauren Bryant

Last fall, after I said goodbye to my twin daughters at college, after I hauled their refrigerators and microwaves, smoothed their sheets, and lectured them one last time about "making good choices," I hugged each of them tight and turned away thinking, *So this is it. All I can do now is hope something I've said or done in the last eighteen years sticks.* In short, I could only trust that my daughters had good character.

But how could I know for sure? Where does character come from, and what makes it persist? What is character, really?

Patrick Wright

Philosopher Charles Starkey says you can't find character in a static list of traits. You need values, and those involve emotion.

Philosophical questions, to be sure, for which philosopher Charles Starkey has some answers. Starkey is one of a few philosophers participating in The Character Project, an international and interdisciplinary research initiative with the aim of moving the study of character forward. He's also an associate professor of philosophy in the Department of Philosophy and Religion. Starkey has long been interested, he says, in "age-old questions about human behavior, how we behave and how we ought to behave"—in short, questions about character.

Traits and values

Since the age of the ancient Greeks, philosophers have been discussing character; in the last twenty to thirty years, Starkey notes, broader interest in character traits—fostering good ones, avoiding bad ones—has surged. Think of Robert Bellah's *The Good Society*, William Kilpatrick's *Why Johnny Can't Tell Right from Wrong*, William Bennett's *Book of Virtues* (a book I recall my daughters receiving as toddlers), or the recent *The Social Animal: The Hidden Sources of Love, Character, and Achievement* by David Brooks.

Amid this resurgence of interest—"Responsibility. Courage. Compassion. Honesty. Friendship. Persistence. Faith. Everyone recognizes these traits as essentials of good character," reads the back of Bennett's book—Starkey sees a problem. "Everyone" may agree on which traits are good and which are bad, but according to Starkey, there has been little analysis—among academics or in more popular media—of what character traits actually are.

This lack led Starkey to undertake what he calls his "basic research" on character traits. Starkey's goal is to develop a robust new theory about character traits—their components and their relationship to human thought, feeling, and action. His approach incorporates psychological research relevant to human choice and behavior.

So what are character traits? They are not simply virtues, Starkey is quick to point out. Cowardice and arrogance are character traits, but hardly virtues. Neither are character traits simply firm beliefs—like a belief in the force of gravity—or habits, like your nightly devotion to brushing your teeth.

In Starkey's view, character traits are deeply rooted in and determined by values. "Our specific character traits are a product of which values come to the fore and drive our behavior," he says.

Take the character trait of generosity. Your neighbor may be the most generous person you know; that trait of generosity, Starkey explains, involves a value she places on caring about the wellbeing of others. Or consider honesty. A person is not honest if he "consistently but accidentally tells the truth," Starkey says. Honesty involves placing a high value on accurate representation over other values and acting accordingly.

If character traits are tied to certain sets of values, as Starkey holds, and we act in particular ways that represent our particular values, that's good news, I think. If my daughters have absorbed values of responsibility and conscientiousness, that bodes well as they launch themselves from the nest, right?

Yes, but. In Starkey's theory, values can, and do, change.

"Character traits are tied to values, but values are not static things," he says. "The perceived importance of a value is not fixed. Values have a force in our lives, but a value's force can diminish."

The role of emotion

What keeps a value strong, or not? Emotions, says Starkey.

You might think of Starkey's theory about character like a Russian nesting doll: First there is a character trait; within that, a value or set of values sustains that character trait; at the core are emotions—fear, pride, joy, anger, sorrow, and the like.

"Emotions play a central role in maintaining values, and because of this, they are necessary for the possession of character traits," Starkey says.

Emotions underlie our character traits in two key ways, according to Starkey. First, emotions determine what we see and know. Evidence from various studies demonstrates that emotions affect what we pay attention to, how we see the object we're attending to, how much information we process about what we're paying attention to, and how much importance we give to what we are seeing.

For example, negative emotional states cause "funneling" in our field of awareness; fear or anxiety or other negative emotions narrow our focus. At the same time, intense emotions affect how we process what we perceive—sharpening our information gathering, signifying importance, and increasing creation of long-term memories.

"When we have an emotion at a certain time, it affects how we actually see an object and our interpretation of its import," Starkey says. "And of course, how we see, understand, and remember things affects how we end up acting."

The second key role of emotions is, they keep values alive. Starkey likens this connection to examples from psychological conditioning—studies in which a neutral image and a frightening sound are associated, until the subject begins to fear merely the image itself.

Similarly, we come to associate certain emotions with certain values—joy at a display of courage or anger in the face of cruelty. We make these associations as we witness the emotional responses of others to certain acts as well as when we observe the attitudes of others in response to something we do. Such emotional associations reinforce our sense of the value behind the act (of courage, cruelty, etc.).

Without emotional reinforcement of a value's importance, the values themselves fade. By way of example, Starkey points to the decline of "honor culture" (a high value placed on preserving honor and reputation) in this country.

"Honor doesn't have the same level of importance that it did, say, two hundred years ago," Starkey notes. "Honor just doesn't mean what it used to. And because it's less significant, we're less likely to act for the sake of honor."

Neil Caudle

Character draws on Values, which involve emotion.

Can Character be taught? Maybe.

All sorts of values could go the way of honor, Starkey says, but they don't because those values are continually reinforced.

This link between emotions, values, and character raises a question, though: In the United States, we often consider people of "strong character" to be dispassionate, devoid of messy and distracting emotions that may "cloud one's judgment." Isn't all this emotion a bit of a liability when it comes to choosing how we will behave?

Starkey acknowledges that "sometimes acting correctly and thinking correctly involve putting emotions aside." In times of crisis—a crippled airliner, for example—we value the pilot who sets aside terror to focus dispassionate attention on what matters in the moment. For the most part, though, Starkey argues that emotions are by no means dysfunctional.

Think of anger. Most of us would call that a "bad" emotion, but "appropriate anger," Starkey says, is very useful. In situations of injustice, for example, anger can motivate us to address social or political change, where being unemotional could work against us.

"As Aristotle proposed, the key is emotion in the right amount, at the right time, and directed at the right object," Starkey says.

Adaptable but slow to change

In Starkey's view, emotions are adaptable. We can learn to temper what we respond to emotionally and how strongly we respond. This happens through familial, social, and cultural conditioning. All those environments offer feedback that gives us a sense of the appropriate sort of emotional response to a certain value being enacted.

It's something like advertising, says Starkey. We learn through repetition. Our emotions and values are instilled through repeated, overlapping exposures to particular behaviors and reactions.

If emotions and values can be conditioned in this way, then can character be taught, as so many character education programs of the last two decades have asserted? Starkey offers a qualified yes, he says, "but it's a complex answer."

Complex, because instilling a value—making that value salient for a person—is very different from teaching someone a particular belief such as the sun will rise tomorrow in the east.

"Fostering a character trait is not like teaching someone a fact about the world," Starkey says. "Character isn't something that changes easily or quickly."

This is because character traits are deep-seated in us, Starkey says, and "that deep-seatedness takes a lot of work to modify. You have to work and work and work on it."

When it comes to character education, "there is no quick fix and no narrow fix," Starkey says. But changes can be had by paying attention to the values and emotions associated with the character traits being promoted.

"If you want to change character, focus on value and emotions," Starkey says. "Unless the value is repeatedly emphasized in a variety of contexts, 'character education' won't stick. Such education needs to be much more broad-based, supported by a much broader network of family, community, and social reinforcements."

Character education is just one of the areas where Starkey sees potentially helpful applications of his model concerning the fundamental nature of character traits. His work, he says, may also further research on "consciousness raising" about emotional messages in media and how those messages affect our values, for example, as well as support critical reflection on our values and traits, not just as individuals, but as a society. Pointing to the Fascist movement in Germany and the value it placed on authority, Starkey says "My research could help us critically look at how we reinforce and sustain our societal values and how we might change them."

Currently, Starkey's research also involves collaboration with Cynthia Pury in the Department of Psychology. They are developing a new theory of courage, based on a large body of psychological research, including their own studies.

"The only person to be awarded both the Carnegie Medal for heroism and the Medal of Honor was a Clemson graduate [Jimmie Dyess]," says Starkey. "We're working to understand the psychological processes underlying courageous behavior."

I think back to Starkey's description of his original research interest—"questions about human behavior, how we behave and how we ought to behave." We all know people who have surprised us—shocked us by doing "the right thing" after so many years of wrong or by making choices so painful they seem beyond understanding. Starkey's research gives us some insight into where such human behavior comes from, and for better or worse, how it can change.

Meanwhile, with respect to my college-age daughters, time will tell. Their first semester ends soon. I remain hopeful.

Charles Starkey is an associate professor of philosophy and a fellow of the Rutland Institute for Ethics in the College of Architecture, Arts, and Humanities' Department of Philosophy and Religion. He is currently completing a book manuscript covering his theory of emotions, values, and character. His work on the manuscript was made possible in part by a research grant from The Character Project, which is supported by the John Templeton Foundation. Starkey has also been the coach of the national champion Clemson University Ethics Bowl public policy debate team.

Lauren J. Bryant is a writer living in Bloomington, Indiana.

In this frame from "Roboasis," the robot lifts its bottle and heads toward the waterfall.

How to Bottle a Waterfall

What's the cost of a second of film time? If you have to ask, you can't afford it.

by Neil Caudle

> Welcome to the magic and might of film in the digital age.

Seven seconds. Not long, in a film. But if you're one of the few brave souls chosen to toil in a lab while the laundry piles up and your friends assume you've been abducted, you'll learn the real value of a second. A second is worth three hundred hours of mind-bending work.

At least that's the going rate if you're a student of Jerry Tessendorf, whose work in digital animation has established him as a pioneer in the field. Tessendorf contributed to *Life of Pi*, which won an Oscar for visual effects. He knows from experience that a single storm-tossed wave demands a hurricane of work.

"Students have other classes, so I can't ask them for more than about twenty hours a week," Tessendorf says. "I think all of them are doing at least double that right now—at least."

Tessendorf is talking about a fall 2013 project his students called "Roboasis," a seven-second scene from a story. Here's the concept: Our intrepid robot has been deployed to explore a new world and find water. Equipped with a bottle and an old-fashioned divining

You can lead a robot to water, but...

This frame from the short film "Roboasis," created by students in DPA 8600, shows a robot approaching the waterfall, divining rod in hand. The seven-second film includes 86,971 frames and required eleven terabytes of data. That's eleven *trillion* bytes. To see a web-friendly version of the short film, please go to
http://people.clemson.edu/~jtessen/studentFilms.html

Along with Jerry Tessendorf, Timothy Davis and David Donar supervised the project; students included Alex Beaty, John Barry, Brianne Campbell, Liam Glover, Kara Gundersen, Gowthaman Llango, Marie Jarrell, Hugh Kinsey III, Virginia Nearing, and Sarah Runge.

rod, he trundles forth and finds a lush oasis, complete with thundering waterfall. So he ditches the divining rod and readies his water bottle. But uh-oh, there's a tricky little problem of how to bottle a waterfall. Things don't go according to plan.

The clip is comical, human, and visually rich—everything today's audience has come to expect. It's no accident that the production happened at Clemson. With Tessendorf and several other standouts in the field, the Department of Digital Production Arts has established itself as a national leader (see "Making Magic," page 42). And industry has been taking notice.

Last summer, DreamWorks Animation came to campus for a hands-on summer workshop with selected Clemson students. With guidance from DreamWorks mentors, ten students divided into two teams, and each team created a fifteen-second animated film.

"The intent was that the students would produce films that are professional quality," Tessendorf says. "That's one reason the films are so short. The quality had to be professional, and it was."

DreamWorks dispatched two of its supervisors to Clemson for two weeks, and for the entire ten-week workshop DreamWorks mentors reviewed the work remotely, a common practice in the industry, Tessendorf says. Twice a week for ten weeks, students uploaded their works in progress and used software to synchronize frame-by-frame what they and their mentors saw on the screen.

The full treatment

This was a workshop with an emphasis on work. The day officially began at eight a.m. and ended at ten p.m. Welcome to the real world of digital animation, notorious for its punishing schedules. But pushing past the point of bleary-eyed exhaustion often yields an in-the-zone creative outburst absent in a nine-to-five office job, Tessendorf says.

"So the students got that part of the experience," he says. "A few weeks into the workshop they hit this wall you have to pass, and you're so exhausted that you focus on your work and get very productive, because you can focus so tightly, and any distraction away from that work is annoying, and you just don't want to do it. You could actually see that happening with the students. On July Fourth, we had an official day off. Half of them did stay home to do their laundry, apparently. The other half came into the lab anyway, because it's just an annoyance not to be in there doing that work."

But students dare not geek themselves into joyless drones. They have to know what it's like to be human, to laugh and love and cry, because the heart of any good film is a story. So the challenge, as Tessendorf sees it, is both technical and artistic.

Much of what the students actually do in the lab is, at its root, difficult math brought to life. Tessendorf, for example, developed a mathematical model useful for rendering water—and there's an ocean of it in *Life of Pi*. For decades, the industry has been incorporating such advances into software code, helping animators do their jobs. Tessendorf's students use the software, but they also pop the hood and get their heads around the math.

So there's math and hard work behind the cinematic dream, and people who study the trade quickly abandon the notion that digital animation is fake, because you just can't fake the good stuff. You have to feel it and you have to earn it, step by step.

In their simplest outline, the steps go something like this, Tessendorf says: You start with a concept, an idea, and build a model in wireframe—a grid-like shape composed of lines. Then you add texturing, which makes the model look like wood or plastic or whatever you need. Texturing requires artistry to make the surface look natural, with, say wrinkles, or the dents and dings of wear and tear. Today, animators call this surfacing, and the best ones make the likeness seem uncanny.

Putting it all in motion

But no matter how apt the structure and surface, films are first and foremost *motion* pictures. Objects and characters have to move; waterfalls have to plunge with wild abandon. "There's a process called rigging," Tessendorf explains. "You can think of it as adding controls to the model so that you can animate it, and a lot of times that's represented graphically as if there's a skeleton in the model. Different parts of the skeleton affect different parts of the model, so when you move the skeleton, those parts of the model move with it. That's actually a very complex, mathematically intensive process."

This kind of intensity requires high-powered computing. The rapid expansion of computing speed and capacity over the last decade has made it possible for animators to plant hundreds or even thousands of control points in their rigging, instead of the handful they once used. This means a much wider range of smooth, natural motion, Tessendorf says.

So it takes all of these steps—modeling, surfacing, and rigging—to reach the stage called animation. A big part of this final stage is lighting: Carefully simulated light sources yield natural-looking shadows and highlights that track with movements and changing environment. "That's when we add all of the nuanced animations," Tessendorf says. "You put together all the parts and characters into what you want the scene to look like."

To sample the finished product, I found a seat in a darkened screening room to watch the two fifteen-second films his students *built*—a word Tessendorf uses because there's so much construction involved—with guidance from DreamWorks. Each film featured an irresistibly klutzy little robot that bumbles its way toward disaster. And each made me laugh out loud. Somehow, the students had rendered, in pixels, authentic-looking characters moving in natural ways through richly detailed little scenes. They had also rendered a story, a comic and convincing glimpse of our own unruly humanity.

Jerry Tessendorf is a professor in the Digital Production Arts Program, School of Computing, College of Engineering and Science.

Making Magic

For today's blockbusters, the real wizards work their magic behind the scenes, with computers.

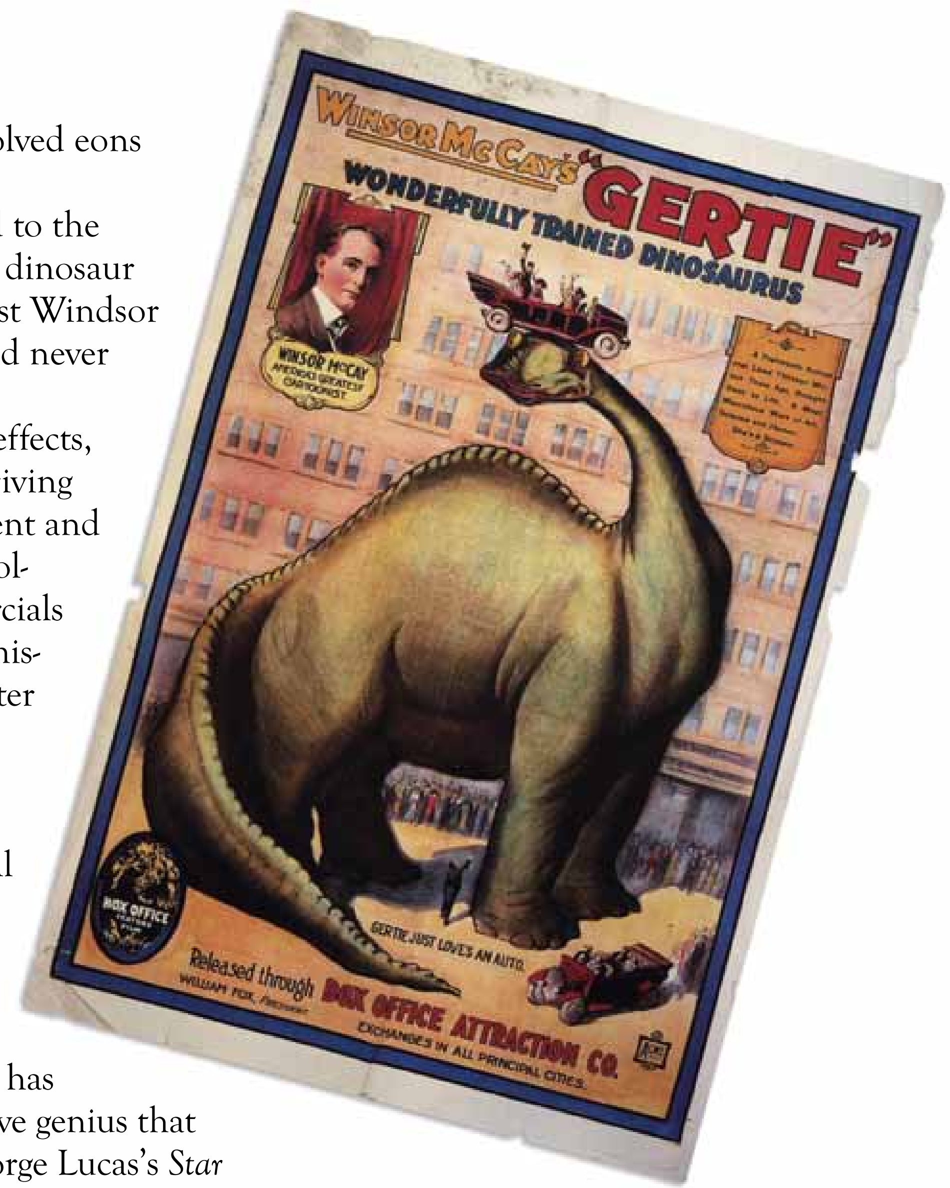
By Frank Stephenson

Film buffs, take note: We've evolved eons since *Gertie the Dinosaur.*

In 1914, moviegoers thrilled to the silent antics of Gertie, an animated dinosaur drawn by New York comic strip artist Windsor McCay. A young film industry would never be the same.

Today, animation and special effects, fused to a good story line, are *the* driving force behind cinematic entertainment and advertising the world over. From Hollywood blockbusters to TV commercials and even digital billboards, the unmistakable stamp of animators, computer graphics specialists, and a host of other techno-wizards is in-your-face ubiquitous. And we *love* it. Of the fifty top-grossing films of all time, all but seven relied on special effects or visual effects, the field's latest, computer-age incarnation.

In the past forty years, the business of special and visual effects has exploded, ignited by sparks of creative genius that gave the world such sci-fi hits as George Lucas's *Star Wars* (1977) and Steven Spielberg's *Jurassic Park* (1993). The business itself has morphed from a handful of small private companies in the United States to an international economic titan, now boasting major centers in Canada, Europe, Japan, Australia, and India.



A poster advertising the 1914 Winsor McCay film *Gertie the Dinosaur.*

Pioneering companies such as Industrial Light & Magic, Pixar, and DreamWorks today comprise just the iceberg-tip of an industry that employs thousands on almost every continent. Thanks to globalization, lightning-fast changes in technology, and widespread economic malaise, all these competing companies are obliged to work harder, faster, and smarter to survive. This means that, as never before, movie moguls around the world need fresh supplies of young—and increasingly adaptable—talent in every phase of digital production.

Traditionally, the top source of such talent has been campus-based art programs that offer special training in various aspects of computer graphics. While that's still largely the case today, there are a few highly specialized programs scattered around U.S. campuses that follow a different tack. These programs intentionally draw from a variety of disciplines to produce graduates ideally suited for working not just in the entertainment or advertising arenas but also in science, medicine, engineering, and a host of other fields increasingly hungry for talent in visual effects.

Of art and science

"There's good evidence that we're one of the top programs in the country."

It's no idle boast that Clemson's Robert Geist drops on an interviewer. He's the cofounder (with Sam Wang, now a retired professor from Clemson's art department) of the university's Digital Production Arts (DPA) program, now into its fourteenth year.

When he and Wang set out to build the program in the late 1990s, they recognized a program run by Texas A&M as the undisputed lead horse in providing the kind of academic training in digital production they envisioned for Clemson. For five years now, the guy who started the A&M program, Donald H. House, has kept an office around the corner from Geist's. A pioneer in computer visualization techniques, House is one of eleven full-time faculty members in the Clemson program. He is also the program's current director.

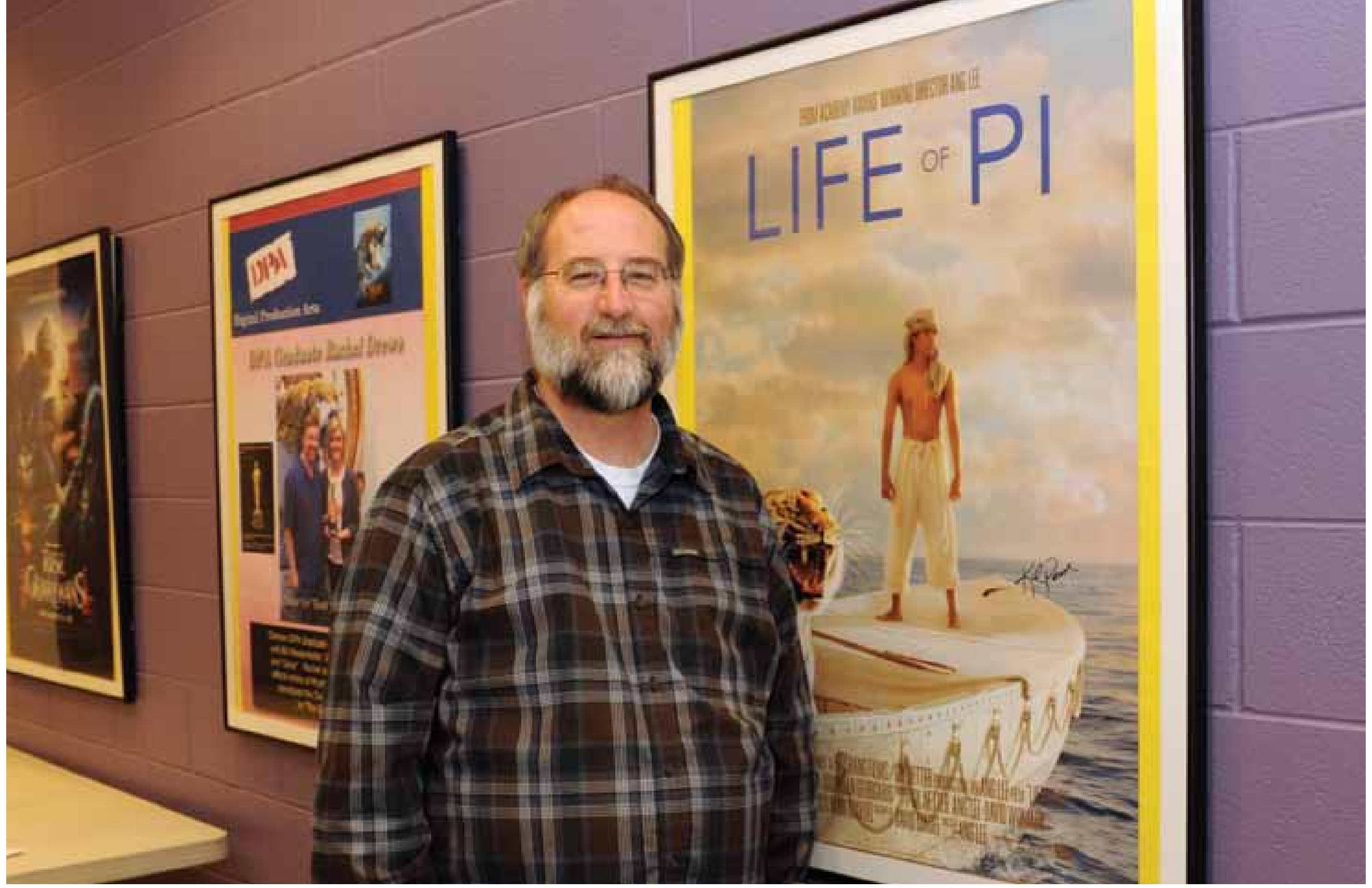
"We're a magnet for [industry] recruiters who come through all the time," Geist adds. "This past summer, DreamWorks held—at their own expense—an intensive, ten-week training program here. They plan to repeat, and other studios plan to do the same. Our students are frequently tapped for major honors."

Just last year, the Academy of Motion Picture Arts and Sciences picked two students in the country for lucrative summer internships in Hollywood. One was from Carnegie Mellon; the other was second-year Clemson DPA student Yujie Shu. The year before that, two of the five students picked by a national search to work on a DreamWorks special project were from Clemson. Marc Bryant, a 2003 DPA graduate, just won a Visual Effects Society Award for Outstanding FX and Simulation Animation in an Animated Feature Motion Picture for his work on the movie *Frozen: Elsa's Blizzard*.

Since the program awarded its first master's degree in fine arts in 2001, names of its alumni have run in the credits of more than

Craig Mahaffey

Robert Geist, cofounder of Clemson's Digital Production Arts Program, is also known as a pioneer in the field. His most recent contributions include work on *The Hobbit: An Unexpected Journey.*



Patrick Wright

Jerry Tessendorf, whose water-simulation software helped *Life of Pi* win the Oscar for Best Visual Effects, expects pro-quality work.

130 feature films industry wide, Geist says. "Frankly, it's gotten to the point now that it's sort of rare not to see some of our graduates listed in the credits of any major picture these days."

And then there's the program's leadership. In 2010, the program attracted Academy Award-winner and Ph.D. physicist Jerry Tessendorf, head graphics scientist at the California-based Rhythm & Hues Studio. Both Tessendorf and Geist have grabbed headlines for their contributions to Hollywood—Tessendorf's water-simulation software helped *Life of Pi* win the Oscar for Best Visual Effects, and Geist's digital map-filtering techniques on *The Hobbit: An Unexpected Journey* helped make that film a runner-up for the same award in the Academy Awards presentation in March, 2013.

Geist is quick to put DPA's rapid ascent into perspective. "When you're talking about being a top program, you have to realize that there's just not many programs of this kind to start with. We're small—only thirty-five students enrolled in the spring semester—and we're highly selective."

Training in the magic arts

What motivated Geist and Wang to start the program was their growing realization in the early 1990s that the visual effects industry—known in the trades as VFX—was on a limitless trajectory with boundless potential for growth and innovation, thanks largely to vast increases in the power of computers. *Star Wars* had wowed audiences by pushing a young field known as CGI (computer graphic imaging) to dazzling light-saber levels audiences had never seen.

But the machines that created those images were kids' toys by the time Geist and Wang sat down for their first serious chat. The two saw a need to formalize an academic bridge between Geist's specialty, computer graphics (Ph.D. in mathematics, Notre Dame, 1974), and Wang's, photography with an emphasis on digital art. Both disciplines faced a palette of technical and artistic power that seemed to grow exponentially by the day.

The many talks Geist had with friends in the VFX industry helped him and Wang formulate both a practical curriculum and a philosophy for starting a program for Clemson. Today's program still reflects those early ideas, Geist says. "Essentially, we're all about matching our graduates with exactly what the industry needs at any given time. Since this is a rapidly changing field, that's a real challenge."

While housed within Clemson's School of Computing, the DPA is jointly administered by the university's Department of Art. The terminal degree is a MFA, theoretically attainable in two years. But most students usually require three because of the program's stringent requirements, Geist says.

"To get accepted into the program, students have to demonstrate both a knowledge of and a competency in both computing and art. We basically want people who are both artists and computer scientists at the same time. We want balance, though."

Students don't need to be superb freehand artists, for example, to qualify for admission. Their art talents can be oriented to music, sculpture, photography, or even art history. In the past, DPA students have come in with backgrounds in architecture, engineering, and a variety of science disciplines. But by the time they graduate, the one, irrefutable common denominator is a fundamental grasp of writing computer code, literally the coin of the VFX realm.

"It's common for some of our students to come in with computer skills that need polishing. We have remedial coursework for that as well as in art, which is why for most students the program takes three years to finish."

Geist says that his contacts in industry—which he works vigilantly to maintain—tell him emphatically the kind of graduates they're looking to hire. "They want people who can pick up a pen and sketch out a storyboard and then put that down and knock out a shell [computer] script and not even pause in between."

Accordingly, the program is built around a no-nonsense curriculum that for this past year has featured a rare component—a ten-week summer "boot camp" run by one of Hollywood's most famous VFX companies, DreamWorks. Though the program is an optional extension of core coursework, it's highly popular because students know that it offers them the closest encounter with the real VFX world that they'll ever have on a college campus.

Hollywood boot camp

Robert Helms enjoys a perspective on Clemson's DPA program known to few. A Clemson native, Helms is a 2003 graduate of the program, and, after ten years of steady work in the industry, his ties with his alma mater are closer than ever. For the past few summers, his employer, DreamWorks, has sent him back to Clemson to help run a session of an outreach project directed at select academic programs around the country. At Clemson, it's essentially a highly intensive, ten-week course tacked onto the spring semester. Clemson is one of the few campuses that DreamWorks collaborates with as a means of creating a direct pipeline between the company and the best sources of talent in the country.

A specialist in digital character animation, Helms was hired straight out of the DPA program in '03 by California's Rhythm & Hues Studio, which is now defunct. After three years there, he worked for a London-based company for two years before coming back to California to sign on with DreamWorks—"jumping around," he says, is the rule in a young, fluid industry that of late is more fluid than ever (see "Trouble in Magic Land," page 47).

Helms has seen huge changes both in the VFX industry and within Clemson's digital arts program. DreamWorks, although buffeted by the same market upheavals that now rock the whole industry, likes what it sees at Clemson and is happy to keep investing in it, Helms says.

"Clemson has been turning out students that DreamWorks and other high-end companies have been interested in for some time now," he says. "This costs DreamWorks, so they're very careful about who they do this for."

Students who sign up for the optional program can expect to work up to eighty hours a week on start-to-finish film projects, Helms says. "It's full production, from developing story boards to building props, animating characters, setting up the lighting, learning how the camera works, doing the [computer] rendering, and putting it all together."

Students emerge from the project with yet another "demo reel" and all the computer work behind it for their all-important portfolios, literally their only tickets for good jobs in the industry. Helms says that he's constantly amazed at the quality of what he sees. He believes that much of the credit must go to his alma mater for amassing a technical base that far surpasses anything he saw during his student days.

"What they have here today compares favorably with an industrial setting," he says. "They started out on a shoestring with only a couple of math classrooms and maybe a dozen or so computers. Now, even though they still don't have a huge budget, it's pretty close to what you'd see in the industry."

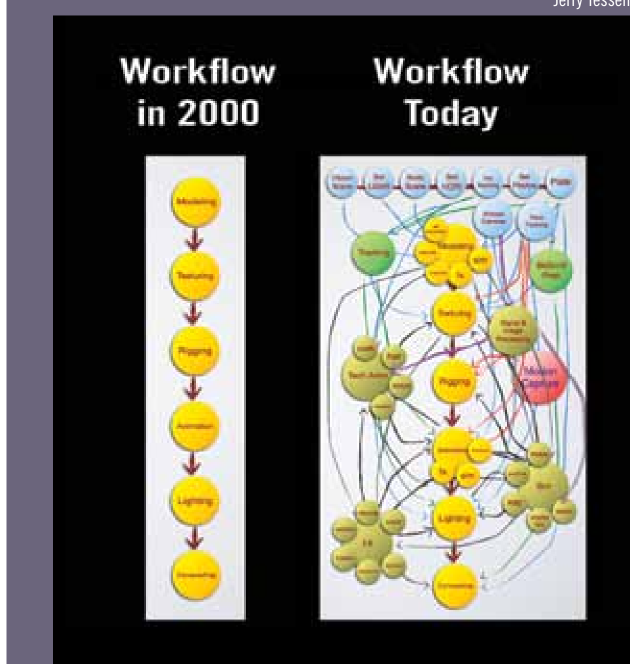
The program now boasts a $6 million phalanx of computer hardware that includes more than 600,000 computing cores that share the industry-standard Linux programming language. The system's speed, which dwarfs that of most mainframe computer-based centers, gives students the power necessary to process the enormous volumes of data that standard, industrial-grade CGI production typically demands. Only a minute or so of a finished CGI film can easily consume a thousand or more hours of computer processing, even with the fastest machines and software available.

The program's professional look and feel benefits from a new screening studio featuring exactly the same kind of cinema-grade projection system that has helped numerous projects win top technical awards in Hollywood. The system gives students a critical tool for studying their digital creations in fine detail on a daily basis.

Helms is only one of several DreamWorks specialists who come to campus each year to help with the outreach program. The program's California-based supervisor, Grazia Como, describes it as "a mutually beneficial talent search." Normally, she says, DreamWorks averages hiring thirty or so top students from around the country each year.

"Clemson's got a great program. We've collaborated with them for a long time and look forward to continuing the relationship," she says.

Jerry Tessendorf



Today's digital production workflow for films is far more complex than it was when the DPA program began. It also requires enormous computing power. Clemson students and faculty members now access 600,000 computing cores, dwarfing most mainframes.

Patrick Wright

Jerry Tessendorf with students in the studio: Despite upheaval, the industry continues to grow, and top graduates are in demand.

The future of magic

Students interested in pursuing careers in the VFX industry—particularly those with aspirations to work in film—are under no illusion about what drives their chosen field. Since the days of *Gertie,* the central goal of special and visual effects artists and technicians has been the same—to cinematically make the impossible possible.

Until the advent of powerful computers in the late 1970s, the bag of tools and tricks available to Hollywood's elite corps of special effects gurus held few options. The unreal was made "real" using a variety of camera techniques such as multiple exposures, rear projection, mirrors, and a host of mechanical, sleight-of-hand tricks that could be pulled off on a live-action set full of the right props. Instead of Faye Wray, the real star of the first *King Kong* film (1933) was a clay model of an over-sized gorilla that enjoyed climbing skyscrapers, all thanks to painstaking stop-action photography.

When computers eventually made it possible to create moving images entirely without cameras, the visual effects industry came into its own. Today, moviegoers not only expect ever-more eye-popping examples of the impossible made not only possible but *believable*, they demand it. This raises the question—is there any limit to what VFX wizards can do?

For nearly three decades, Robert Geist has witnessed the VFX revolution both as an award-winning educator and as a contributor to the industry. He says that the "Holy Grail" of VFX technology is still well beyond reach of even the brightest, most creative minds out there.

"There's an old joke in the VFX industry," he says. "Question: How do you know when you've been working in the VFX industry too long? Answer: When you're walking through a forest on a beautiful spring day, the sun is shining, there's a gentle breeze blowing, the birds are singing, and all you can do is look around, shake your head, and say, 'I'll *never* be able to render this in real-time.'"

Geist is referring to the capability of using computers to make photo-quality, feature-length films that are all but impossible to distinguish from those shot—and immediately projected or broadcast—with a camera.

"Photo-realistic, real-time rendering is possible for restricted shots, but in general it remains far out of reach. VFX companies today are delighted when they can reduce computation time to less than three hundred hours for each second of the movie they're making."

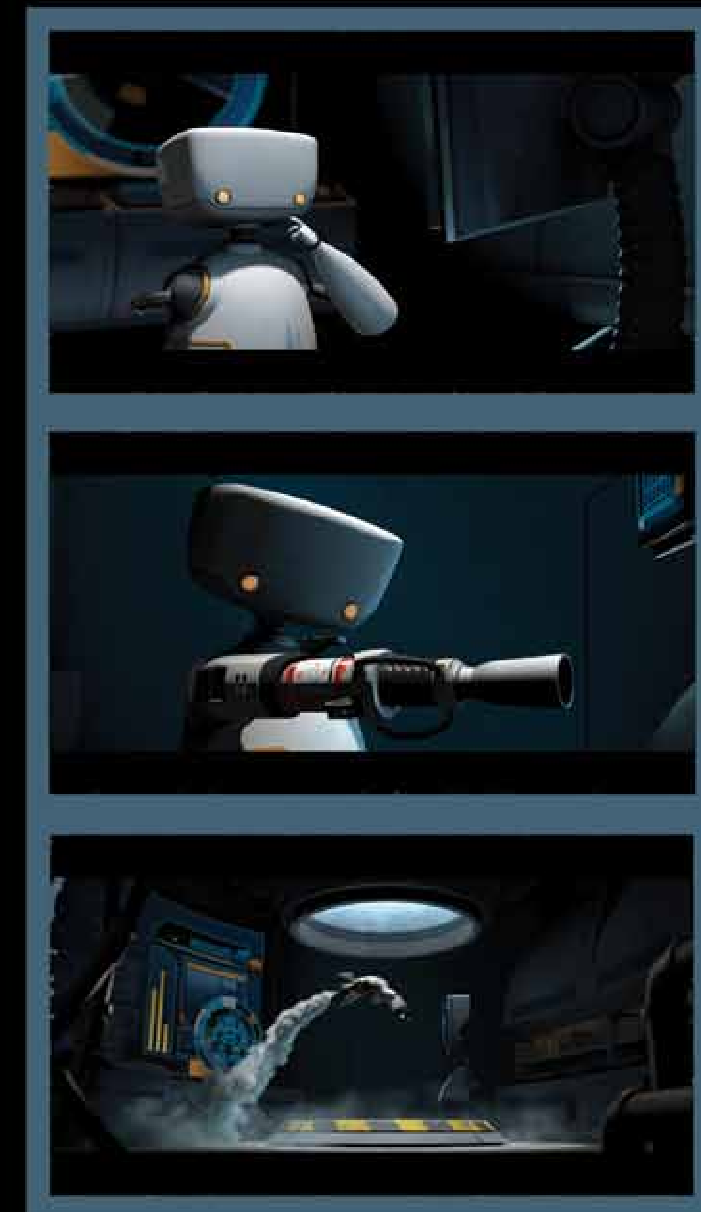
Whatever's ahead for the VFX industry is riding on the same train that brought it from a fuzzy dream only thirty-odd years ago to where it is today—ever-faster computers and better software, he says. "VFX companies don't run out of cool ideas; they just run out of time."

Jerry Tessendorf is professor in the Digital Production Arts Program, and Robert M. Geist III is a professor and currently interim director of the School of Computing; both are in the School of Computing, College of Engineering and Science. Frank Stephenson is a freelance writer who lives in Tallahassee, Florida.

For more about Clemson's Digital Production Arts Program, visit www.clemson.edu/ces/computing/DPA/index.html.

The Trouble with Robots

With help from DreamWorks, two student films turn calamity to comedy.



In "Robo Repair," a robot loses an arm, attaches a high-powered replacement, and goes airborne. Students on the team were Alex Beaty, Amanda Morland, Zhaoxin Ye, Ben Sledge, and Ashley Anderson.

In "QA-ARM-A," a klutz at the controls puzzles over instructions and pushes the wrong buttons. Sparks fly, and things go from bad to worse. Students on the team were Gina Nearing, Mandy Madigan, Karen Stritzinger, Jon Barry, and Timothy Curtis.

Trouble in Magic Land

Today's VFX industry is like the weather. If you don't like it, wait five minutes; it will change.

Not that the movie-going public worries about such things, but the industry that puts the razzle-dazzle visual-effects magic into their favorite films is in gut-wrenching turmoil worthy of a scene culled from the *Iron Man* series.

Nothing illustrates the problems vexing the VFX industry better than the news surrounding the blockbuster hit *Life of Pi.* On the eve of the film's being tapped for an Oscar for Best Visual Effects in February, the company that did most of the VFX heavy lifting on the project, the twenty-six-year-old Los Angeles firm Rhythm & Hues, filed for bankruptcy. The move instantly put more than two hundred and fifty employees—many of whom reportedly had spent a year or more working on *Pi*—out of a job.

Jerry Tessendorf came to Clemson from Rhythm & Hues Studio, where he served as chief graphics scientist. In 2008, he was handed the Academy Award's Technical Achievement Award for his water-simulation software, an outgrowth of his research in fluid dynamics at Brown University (Ph.D. 1984). His techniques have been applied to almost every major motion picture involving water since around 2000, including *Titanic, Waterworld,* and, most recently, Twentieth Century Fox's megahit, *Life of Pi.*

> "We definitely have a problem, but I believe it's one the market may solve."
> —Jerry Tessendorf

Subsidies steer the trade

The demise of Tessendorf's old company typifies the recent upheaval in an industry that once seemed rock steady with an annual growth rate projected at 8 percent. Spawned in the United States in the 1970s by a handful of private companies that contracted their highly specialized services to Hollywood moviemakers, the industry is now reeling from global competition and a chase for subsidies that boost studio profits, Tessendorf says.

At the moment, the lion's share of work goes to locations with large tax subsidies for film production, primarily London, Vancouver, New Zealand, Sydney, and Montreal, Tessendorf says. "There has also been a small 'boomlet' of work in New Orleans and Atlanta from state-sponsored subsidies in Louisiana and Georgia. But North Carolina, which just terminated its subsidies, will see a dramatic downturn in work this year because TV and film productions promptly moved out to freshly subsidized locations."

Because subsidies in California are insignificant, Tessendorf says, the trend has devastated VFX companies and people in Los Angeles and San Francisco. But overall, demand for VFX work in the film industry continues to grow, Tessendorf says, as does the amount spent on it.

The impact of globalization has led to increasingly loud protests by workers within the U.S. industry over the issue of unionization. Among the wide array of enterprises that support the Hollywood movie machinery, the VFX industry is conspicuous for being the only one not represented by a union, a situation that union-boosters say leaves VFX employees defenseless against the pressures wrought by a suddenly vicious global marketplace.

"We may continue to see large companies break up into smaller ones; at least that's what we're seeing at the moment," Tessendorf says.

Tessendorf's biggest worry is over what the tumult means for his students. His most recent graduates face the most challenging job market in the program's fourteen-year history. "When there were a clutch of fairly stable companies, students could expect to get work fairly regularly in Los Angeles or San Francisco," he says. "Now, with many of those [companies] in bankruptcy or moving their work out of the country, we need to find ways to grow relationships with those new companies."

Fractal flames

Even the Clemson program's "star" students have felt the pressure. Yujie (pronounced "you-jay") Shu, an international student from southern China, graduated in August. Her master's thesis—which focused on an intriguing bit of cyber-chicanery known as fractal flame wisps (essentially clever algorithms that give life to computer animations such as the delicate 3-D "genies" seen buzzing around in *Brave,* the 2012 Pixar animated hit)—helped her catch Hollywood's eye in 2012. Shu was one of only two students in the country tapped for the coveted internships offered by the Academy of Motion Picture Arts and Sciences. She spent three exhilarating months working as a card-carrying technical staffer for Industrial Light & Magic in San Francisco.

"This is a bad year for film production," Shu says. "Lots of people in the [VFX] industry are being laid off, and there's not a lot of choices left like there once was. But there are jobs out there—it just takes more work to find them."

Shu was hired several months before she graduated, something she says is "not uncommon" for DPA seniors. NVIDIA, a Santa Clara, California-based company that develops a top line of computer graphics cards—literally the engines that drive the entire VFX industry—hired Shu online without so much as an interview. Shu says the job will help her "stay relevant" for eventual work in film production, her career goal.

Meanwhile, Tessendorf is optimistic that the present upheaval in the industry will soon level out.

"We definitely have a problem, but I believe it's one the market may solve," he says. "In six more months the picture could be very different. The chaos that's going on now could be largely resolved by then, because this industry moves so very, very fast."

–Frank Stephenson

Real-Time Research

What helped make the Oscar-winning *Life of Pi* one of the top-grossing films of 2012 was the film's hairy star—a captivating Bengal tiger whimsically named Richard Parker. Lost on most spellbound viewers of *Pi* is the fact that Richard's performance, instead of being a *tour de force* of animal training, is a stunning example of highly trained mathematics.

Behind almost every exciting frame of the two-hour film lies an invisible sea of cavorting numbers, a digital soup of algorithms that express themselves in breathtakingly realistic scenes that defy quick distinctions between the real and the unreal. Not a single frame of Richard Parker comes directly from a camera; nor does much of the ocean on which he floats for more than half the film.

Such is the state of visual effects (VFX) mastery today, a field that has vaulted from a trifling pastime among computer geeks in the 1970s to the dominant force in cinematic entertainment the world over. The sheer command that VFX has over what we see—and increasingly, how we *interpret* what we see—is, pure and simple, a triumph in computer graphics research.

Visual effects that serve science

At Clemson, such research has for years stood as one of the School of Computing's most robust components. The school's Visual Computing Division, led by seven researchers, is a training ground for students seeking Ph.D-level research careers in computer graphics, visualization, animation, and related computer-based techniques, all of which are primarily aimed toward a central goal: rendering what we see in nature into bits and bytes of digital information that can be more easily studied, understood, and used by scientists and engineers.

Most of the Visual Computing Division's research is tied to what's going on in the school's Digital Production Arts program, says Robert Geist, professor of computing at Clemson since 1984. Even though the DPA program isn't specifically geared to research (its top degree is a master's in fine arts), Geist calls the program "the catalyst for most, perhaps all, of the computer graphics research at Clemson." Geist cofounded the DPA program in 1998 with Clemson art professor Sam Wang, now retired.

In truth, the DPA program and the school's doctorate-track research programs are joined at the hip, Geist said. For one thing, almost all the research in computer graphics at the school is funded by external grants (the National Science Foundation being the largest source), and most of these projects come with assistantships that are tailor-made for students with the kind of skills demanded by the DPA program. Students routinely get opportunities to work closely with Clemson researchers on a variety of projects, and are paid for it, Geist says.

As just one example, Geist cites a $3 million, NSF-funded project, led by his colleague Jason Hallstrom, that includes Geist and Jerry Tessendorf as coinvestigators. The project's goal is to develop a tool that scientists can use to model the behavior of river basins. (See related story, page 9.) In nature, river basins are vastly complicated ecosystems that are constantly changing thanks to such variables as rainfall, forest fires, and human demands on water supplies. DPA students and doctoral students work on the model.

Tools of the trade

Then there's all the coursework—at times it's hard to tell doctoral from master's students, Geist says. "We have lots of overlap between the coursework required for our doctoral program and that for the DPA. It's therefore not uncommon for some of our DPA graduates to realize that research is what they really love, and they choose to pursue a doctorate here."

A big step forward for Clemson's national profile in computer graphics research occurred in August 2010. The Santa Clara, California-based company NVIDIA, a world leader in visual and high-performance computing, designated the university as a center for conducting highly specialized research into what is known as CUDA technology. The work focuses on building tools that render a host of natural phenomena from the growth of plants and animals to the flow of air and water in real time.

The application of such tools reaches far beyond Hollywood, of course. Already they're revolutionizing the medical field, for example. The real-time simulation of blood flow is seen as a major weapon in the fight against heart disease. Meanwhile, a rapidly developing field known as nanoscale molecular dynamics, which depends almost entirely on real-time computer graphics, shows increasing promise for advances in biomedicine.

"The applications are endless," Geist says.

–Frank Stephenson

Rolling on the river

This idyllic, if synthetic, river scene was drawn by computer graphics specialist Jay Steele, a recent graduate of Clemson's computer graphics doctoral program. The image developed from Steele's help on an NSF-funded project aimed at designing tools to model river basins. Steele now works as a senior software engineer at Walt Disney Animation Studios in Burbank, California.

Patients Programmed for Trouble

Anna Simon

Simulated reality prepares nurses for the toughest of cases.

by Anna Simon

Nursing students check the condition of a simulated accident victim in the emergency room of the Clinical Research and Learning Center.

THE PACE IN THE EMERGENCY ROOM IS FRENETIC.

A young diabetic in a coma deteriorates rapidly. A doctor barks terse commands at the attending nurse.

An accident victim moans as a nurse injects a painkiller. It doesn't seem to help. A hovering, hawk-eyed family member unnerves the nurse, who draws a deep breath to regain her composure as she rummages through a cabinet for more medication.

A young woman diagnosed with a sexually transmitted disease has an emotional meltdown. She's engaged to marry the man who gave her the disease.

A prostitute in short skirt, fishnet stockings, and bright lipstick flirts with every passing male until she unexpectedly learns she is pregnant—and HIV positive. Rather than wait for a referral, she stomps out of the emergency room as a bewildered nurse helplessly watches.

It seems like the patients are *trying* to be difficult. Actually, they are.

Two of the patients are actors. Two are mannequins. They are in a mock emergency room in the School of Nursing's Clinical Research and Learning Center, a simulation lab on the second floor of Edwards Hall. The nurses are seniors one month away from graduation.

The diabetic and the accident victim are the mannequins, with pulse, heartbeats, and soft skin that can be pierced with needles for injections and intravenous medications. Instructors control the patients' responses with computers and digital tablets.

Performing-arts students play the roles of the prostitute and the distraught young engaged woman, and have creative license to challenge the nurses' patience and skills.

Only the diabetic is in imminent danger of death, but all four patients have demanding needs. Prioritizing is one challenge for the nurses. Their medical skills, communication skills, and leadership skills also are put to the test.

"The adrenaline is flowing," says Jacqueline Dickens, one of the nursing students. "The pressure is high. Everything's happening at once. You don't know what's happening next.

"It's very realistic," she continues. "We've had sixteen months of experiences from just getting patients out of bed to this." The simulation lab is part of the curriculum for nursing students in their junior and senior years. This final lab is the "most intense experience so far," Dickens says.

A crisis well planned

While the nursing students struggle with life-threatening situations and unruly patients in the mock emergency room, a second group of student nurses, in another room, administer CPR and oxygen to an unresponsive patient in a critical care unit. Tubes seem to sprout from every possible place on the mannequin's body. Lines connect the mannequin's neck, nose, arms, and bladder to a respirator and other lifesaving equipment. Suddenly, the patient stops breathing. There is no heartbeat. It's part of a scenario planned by faculty to require nurses to perform CPR and pull out the "crash cart," packed with emergency drugs and equipment.

The crisis that befalls the patient is planned. The outcome is up to the student nurses. "With the right kind of critical thinking and intervention the patient will improve. If not, the patient will die," says Tracy Fasolino, an assistant professor of nursing and the driving force behind the simulation lab. On this particular morning, the patient survives.

In a third room, more nursing students care for patients in a surgical unit. Like in the simulated emergency room, nurses are challenged by mannequins and actors portraying various conditions in lifelike scenarios.

Two more rooms in the simulation lab are equipped with big-screen monitors, and other students watch their peers in the simulated hospital settings and discuss what they see.

The scenarios play out, then there's a debriefing. Faculty, students who took part in the simulation, and peers who watched in the viewing rooms get real about went well, what didn't, and how the nurses performed under the intentionally extreme pressure.

Students are "under a nurse's wing" during their clinical experience in actual hospitals and other health-care facilities, but the simulation lab "gives you an idea of how fast things are going to go in the hospital," says Will Clegg, a nursing student. "In this you're more on your own. It's pretty intimidating at first." Clegg says this after a confrontation with a psychotic patient in the simulated critical care unit.

The simulation lab allows nursing faculty to "reinvent reality in a controlled environment," Fasolino says.

Critical patients, critical thinking

Each mannequin has a name, an identity, and a diagnosis. As student nurses give injections or put in a catheter or feeding tube, they must also incorporate "the critical thinking element" and make decisions based on the situation with that particular patient, Fasolino says. Some scenarios require the students to take action to prevent further decline. If correct actions aren't taken, the mannequin may "die."

This kind of simulation is the core of Fasolino's research in applying technology to a nursing curriculum. She was one of three principal investigators in a 2012 Medline Discoveries grant titled "Evaluating Nurses Surveillance during Rapid Deterioration Scenarios Using 3-D Virtual Environments."

In the lab, simulations expose nursing students to uncommon situations that may or may not occur during their clinical experience, Fasolino says. They must be able to think on their feet as they use the skills they've learned and make life-and-death decisions. Only in the lab can they experience the conditions of a hospital setting without the risk of harming or killing a real person.

The pressure of performance in the lab adds another dimension to nursing students' training. The ultimate goal is to improve patient safety and outcomes for the health-care consumer, Fasolino says.

"It's as close to real life as we can make it," says nursing instructor Sheri Webster, who dove into an impromptu role as a security officer during the simulation and returned the angry prostitute to the charge nurse in the emergency room.

All of the one hundred to one hundred and fifty students awarded undergraduate nursing degrees at Clemson each year now have this experience. A pilot project will give graduate nursing students simulation lab exposure beginning the spring 2014 semester.

Serving the Navy Reserve

The U.S. Navy Reserve Medical Unit also taps into Clemson's simulation lab as a training ground. Fasolino is Clemson's lead facilitator in developing a five-hour scenario to give Navy Reserve corpsmen and women a realistic, hands-on experience that includes a traumatic amputation and a cardiac event.

Use of simulation to highlight ethnic differences and address cultural differences is a critical element of Fasolino's research. She has created scenarios involving Amish, Hindu, and Mexican-American patients and their families in order to expose students to a diversity of possible experiences and to help them dispel cultural biases or mistaken assumptions.

What goes on in the lab doesn't stay in the lab. Student performance enables faculty to enhance the curriculum, says John Whitcomb, an assistant professor in Clemson's School of Nursing and a fellow of critical care nursing. Whitcomb plays the part of the doctor in the mock critical care unit and observes the student nurses' reactions to the unexpected deterioration of the simulated patient's condition. Last year students struggled, but this year student performance was "marvelous," he says, and, "This is the payoff."

Tracy Fasolino is an assistant professor in the School of Nursing, College of Health, Education, and Human Development. Anna Simon is a freelance writer based near Pendleton, South Carolina.

YOUR STORY FOR A MUG

Benjamin Hines

Patricia Fancher and Brent Pafford in the Acorn Gallery, with their handiwork.

by Neil Caudle

Would you swap a story for a mug? So far, several hundred people have taken the deal. What happens next is anybody's guess, which is sort of the point.

Patricia Fancher, a Ph.D. candidate in rhetorics, communication, and information design, got together with Brent Pafford, a potter and master's candidate in fine arts, to test the notion that a mug can hold more than your coffee, hot tea, or a motley bouquet of pencils and pens. A mug, they thought, could also hold meaning. We grow attached to our mugs and include them in our everyday rituals, at work and at home. If we share a mug, or borrow one, or spill our secrets while we cling to one, the mug is also a conduit between people, Fancher says. So the mugs become, as Fancher and Pafford put it, "potent objects."

"With use and time they gather significance," Fancher says. "Everybody who touches them makes them different."

Four hundred takers

The Potent Objects Project, which debuted at the end of January with an opening at the Acorn Gallery in Lee Hall, involves trading a handcrafted mug to anyone willing to pony up a story. Fancher estimates four hundred takers. And the project is already out of control because Fancher and Pafford planned it that way.

"We want to expand the notion of what it is to be an author," Fancher says. "Authorship is not always about one individual controlling the work. Rhetoric and art are both inherently social. With this project, we are deliberately choosing to give up our authorial intent to four hundred participants. Which makes it far more interesting, I think, because it's so massive."

So the mugs go out, the stories come in, and Fancher and Pafford explore the connections. They are recording the stories as audio, to play in a gallery, and are using a website to follow the fate of their mugs. Each mug has been tattooed, on its bottom, with a QR code, which a smart phone can use to open the Potent Objects Project website. On the site, participants can log their locations, post photos, add stories, and describe what the mug has been up to lately. Fancher and Pafford hope that each participant will bond with a mug for a couple of weeks and then pass it along, to gather more stories and steep new connections. The mugs, they say, could go global.

Babysitting five hundred mugs

All of this sounds a lot simpler than it was. For one thing, the team didn't just go out and buy a few crates of cheap mugs. Fancher and Pafford supposed that a mug made by hand, by a potter with artistic intention, might conceivably elevate the potency of a potent object. Pafford isn't making any philosophical pronouncements on that point, but his basic design for the mugs is meant to suggest human touch and to stir up personal associations. He began with a basic mug form and added a slight bell

Benjamin Hines

Over the holidays, one good turn deserved another. And another...

Facing page: the Potent Objects Project debuted with a reception in the Acorn Gallery in Lee Hall. **Right and below:** Over his holiday break, Pafford throws another mug on the potter's wheel as ranks of unfired vessels wait for handles.

Jessica Hilvitz

Jessica Hilvitz

curve to the top, to hold heat. "We made them fairly thick," he says, "like the mugs from a diner, and heavy, so you can feel some weight in your hand."

Handcrafted potency came at a price. First, the team had to mix the four ingredients of white porcelain clay, eight hundred pounds of it in fifty- to seventy-five pound batches. They used a pug, a heavy-duty mixer of sorts, to extract air and align the particles. After the clay rested for a week, Pafford spent several days throwing mugs on the wheel. He "pinched off" the mugs to shape them and leave his fingerprints in the clay. When they were firm enough, he put the mugs back on the wheel, one by one, upside down, and trimmed the bottoms. Throughout, he had to keep checking each mug for dampness, to keep it from cracking.

"It was like babysitting five hundred little mugs," Pafford laughs, "which is wonderful, and a disaster at the same time." The endless repetition didn't bother him, he says, because "I became aware of each detail and what it could mean to someone else."

Are we there yet?

Fancher helped him attach the handles. "The worst day we had was the day we put handles on everything," she says. "That took about thirteen hours. We call it The Day We Shall Not Mention. The clay was cold, so our hands got cold and dry, and it was the same repetitive motion, over and over. It was like a long car trip that's fun at first, because you're laughing and talking about bands you like, and that kind of thing. But then it gets tiring, and you're saying, 'Are we *there* yet?'"

As any potter can tell you, not every mug survives the kiln. For the initial firing, the team loaded mugs into all five of the art department's electric bisque kilns. Thirty-six hours later, they opened the kilns and found what the firing had wrought. "We made five hundred mugs, and in the process we lost about a hundred," Fancher says. "They cracked or fell off the shelf."

The losses were especially poignant because of what Fancher and Pafford had invested to create the mugs. "We spent our Christmas break," Fancher says. "We gave our participants our Christmas break."

They unloaded the kilns and applied a clear glaze to the interiors and lips of each of the four hundred intact mugs. They left most of the exterior surfaces unglazed, not only to let the mugs acquire a natural patina but also to allow users to write messages directly on the porcelain. To prompt such writing, the team laboriously inscribed, by hand, three blank lines on the side of each mug.

The team's debut at the Acorn included fifty stories and one hundred mugs reserved for the event. The culminating exhibit, planned for April 22 to May 2, will make use of digital media in the recently renovated Edgar Brown Digital Resources Laboratory, part of Clemson University Libraries.

How good are the stories, so far? Fancher laughs about a crazy party where a mug made a storied appearance. But as of this writing, her favorite story is the one she received first, from Greg Shelnutt, chair of the Department of Art. Here, with his permission, is what he wrote:

One of the most potent objects I own is an image. It is an image of an apple. It is a photograph made by my father. He made it the summer I became ill with a nerve virus that kept me from being able to walk for the entire summer. He had come early home from a large-format camera workshop with Ansel Adams to make sure I was all right.

My recovery was a slow process, and in addition to listening to Monty Python albums, we spent a lot of time talking and just being. My father was still in the mindset of Adams' concept of "making" a photograph and giving the viewer the "equivalent" of what he felt. Thusly, one day he pulled a Granny Smith apple out of the refrigerator and put it on the dining room table to photograph. He ducked under the cloth hood, studying the light as it changed, watching the moisture condense, form droplets, and roll down its shiny surface, finally clicking the shutter at the appropriate moment.

He then sat down and contemplated the changing light through the dining room window, waiting for it to change in a way that might reveal another aspect of the apple. When he judged that the light seemed just right, he ducked under the hood again.

To his consternation, the apple was gone. He began to search the room, but to no avail...Until he looked down, and in his hand (I don't recall which one), there was the apple core. The consumed apple was thus the subject of only the singular image, the singular moment.

My father died of cancer on January 7, 2003. At his eulogy, I talked about that apple, that moment, and that photograph, and how I wished that I knew where it was, since I did not have a copy.

On November 5, a package arrived from a longtime friend of the family, John Baskin, Jr. In that package was a framed copy of the photograph of the apple. When I called John to thank him for the meaningful gift, he was saddened to learn of my father's passing; in my grief, I had failed to inform him. My father's birthday was November 5.

In exchanging this story for Brent's mug, I knew from the start that I wanted to pass the mug along to my daughter, Emily. It was both a chance to share this story with her again, and an opportunity to ask her what objects, stories, what moments are important to her. I have no expectations about what she will say, or to whom she will give the mug.

I am, however, thankful to The Potent Object Project for sparking this dialogue and future exchange. Ultimately, it made me think of a favorite quote from Claes Oldenburg: "I am for an art that imitates the human, that is comic, if necessary, or violent, or whatever is necessary. I am for an art that takes its form from the lines of life itself, that twists and extends and accumulates and spits and drips, and is heavy and coarse and blunt and sweet and stupid as life itself."

(Story by Greg Shelnutt)

Craig Mahaffey

The LIT ROOM changes to evoke the book being read. The idea is to cultivate literacy in a space that is both physical and digital. The project's test site is the Richland County Public Library of Columbia, South Carolina.

VITAL ROBOTICS

with people in mind

by Jemma Everyhope-Roser

Keith Evan Green

The Assistive, Robotic Table is the hybrid of a typical nightstand and the over-the-bed table found in hospital rooms; it features a plug-in robotic surface that supports rehabilitation and can interact with human users.

IMAGINE—

When you go to work in the morning, your car selects the optimal route, accounting for accidents and ambulances, communicating silently with buses and trains, so that everyone reaches the correct destination safely and punctually. At your office, your desk configures itself around you to accommodate the morning's tasks. You can reprogram it if you like. When you return home, you step into an environment that adapts to your whims, altering its lighting and temperature and form. Your very furniture shifts and physically expands so that you can stretch out and relax in the evening.

In this vision, the biological and computational worlds have merged on every level, the physical world of humanity joined to digital reality, and artificial intelligence is embodied in the hardware around you.

In this strange realm Keith Green dreams and dwells.

Green works in the field of architectural robotics, trying to bridge the digital and the real within a cyber-physical environment. He started out as a psychology undergrad but branched out into architecture. His Ph.D. focused on designing built environments that exhibited qualities of the animate and inanimate. "Under certain conditions," Green says, "we might ascribe to inanimate things characteristics that are seemingly vital."

Green wanted the chance to apply what he'd learned in a practical way. And at Clemson, he got it.

About ten years ago, Green realized he worked well with Ian Walker when they were advising a mutual student in Green's master's of architecture studio. Green suggested they write a proposal to the National Science Foundation. They were ecstatic when the proposal was approved on the first attempt and immediately went to work on their first joint project: the Animated Work Environment.

"We're frequently a duo," Green says. Currently, they share two labs joined by two doors that tend to be open. Following the success of the Animated Work Environment, they've gone on to work together on the Assistive Robotic Table and the LIT Room, again with support from the National Science Foundation.

Green and Walker's projects—the Animated Work Environment, the Assistive Robotic Table, and the LIT Room—have something else in common: They help people help themselves. The Animated Work Environment is a desk-and-wall structure that physically alters its shape to support professional needs. Embedded with infrared sensors and computer screens, the Animated Work Environment can respond to gesture to fine-tune and store a variety of "activity configurations." Similarly, the Assistive Robotic Table is a hybrid of homey nightstands and over-the-bed hospital tables. Designed to work with people who are aging or who need rehabilitation, the Assistive Robotic Table allows people with changing capabilities to remain in their homes for as long as possible. At public library read-alouds, the LIT Room engages children by providing a programmable environment that gives form to children's own imagination. When the environment doesn't hold true to what the child imagines is in the book, the child can reprogram it. Green describes it as "an evocative environment."

From the ground up

Although a lot of researchers buy a robot to elaborate on, working with a platform that's already there, Green's team is unique in that it actually builds artifacts from "nuts, bolts, and whatever else we can find around," he says. It can be a struggle, sometimes, to work with a steel fabricator to produce the necessary parts, to get the pieces right so that they fit together. But Green states he's got a lot of local resources to draw on. The South Carolina Upstate, home to a thriving automotive industry, supports many high-tech companies.

Sometimes the team has to repurpose what's around. Green says that when they want to buy a linear actuator, which is more or less a rod that pushes up to lift part of the structure, they first must find one that works within what they've already envisioned.

Although you might think that the processing power required for complex movement might be an issue, Green states, "The capacity of a computer is not a problem, as digital tools are becoming so powerful and accessible. The real challenge is batteries. What happens if someone needs it and the battery is running out?"

Another challenge involves the movement itself—the object has to shift and turn with a person, so that its movement feels comfortable. Walker specializes in this aspect of design, combining the disciplines of kinematics and motion planning, Green says. "We have to be choreographers to make sure the dance between the users and the environment is clear, apparent, easy, and hopefully inviting."

So far, Green says, the participants have been intrigued by his projects. The environments assist physical therapists, teachers, and office workers in accomplishing what they're already doing with greater ease, productivity, and possibilities. "For people who are already kind of geeky and are working collaboratively, the Animated Work Environment is a thrill," he says. "Kids love the LIT

Room, and the teachers love its educational applications." And while hospital staff tend to regard new technologies with caution, Green says, "the staff at Greenville Hospital System are curious and willing to help us" with the Assistive Robotic Table.

"These are platforms for people to collaborate on location, beyond us being networked around the globe," Green adds, "because so many human activities demand hands-on participation in one site, localized."

Empowered, not imprisoned

Currently, Green is writing a book with the help of Mark Gross, a colleague at Carnegie Mellon. The manuscript, tentatively called *Architectural Robotics*, is under contract with MIT Press. In the book, Green tries to establish a typology for his developing field, describing the varieties of architectural robotics at physical scales ranging from smart furnishings to the metropolis.

"We still have a ton of work to do in getting these things up and running in a robust way," Green says. Green faces another challenge: selecting and locating the sensors and writing the algorithms that would best support people. He adds, "If a person is recovering from a stroke, how can the Assistive Robotic Table determine how little or how much assistance the person requires to enable that person to regain command of her life?"

Although the rise of artificial intelligence and citywide networks may not happen tomorrow, we do have drones flying today. Green says that we should thoroughly investigate the consequences such technologies could bring us. "The adoption of new technology always comes with issues of how we conduct our lives—how we want to live," he says.

Building robots on a large scale also brings up safety concerns. If someone were to hack into an intelligent transportation network, the potential for disaster could be huge. If a transportation network couldn't perform during an emergency, then people could be hurt when it failed.

"One of the unique challenges is the safety dimension for moving mass." Green is talking about the physical mass of the object he's created. Take the Animated Work Environment: Because it weighs a lot, Green had to mount it in a heavy concrete block and attach a safety cable before he could get approval for people to test it out. "Since these large-scale robotic artifacts could be dangerous, we have to do a lot of testing and evaluation to make sure that these systems not only support human activities in ways we discerned from study, but are also safe."

Other concerns Green is careful to address involve job security. Green says that when people think about robotics they're wondering what it will mean for their business a decade or two from now.

"This is inevitable," Green says. "We are working hard to be sensitive to how this technology might be adopted, and we want it to be very supportive of the way we live our everyday lives. We want it to be pleasing aesthetically, function well, and we want people to be empowered, not imprisoned, by the technology."

In an increasingly digital society, where we carry the Internet around in our pockets, we still live in a hard-wired and physical world. "We really celebrate the world that we live in," Green says. "The scale we work in promotes a physical world with digital things in it, as opposed to living a virtual life more exclusively. At least that's my theory."

Keith Evan Green is a professor of architecture in the College of Architecture, Arts, and Humanities and a professor of electrical and computer engineering in the College of Engineering and Science. Ian Walker is a professor of electrical and computer engineering in the College of Engineering and Science. Jemma Everyhope-Roser is the editorial assistant at Glimpse.

Craig Mahaffey

Keith Green (black shirt) and Ian Walker (left) meet with students in the lab.

SEEDING THE FUTURE

A bumper crop of genetic data will help boost yields and equip plants to cope with pests, diseases, and weather extremes.

by Peter Kent

CEFS, NC State University

HEAD TO HEAD

For now, corn is the go-to ingredient in animal feeds, but it's a pig compared to sorghum, whose highly efficient photosynthesis conserves water and nutrients.

Murphy-Brown has a food problem. Raising about 17 million market hogs a year takes a lot of feed.

The North Carolina-based company, a subsidiary of Smithfield Foods Inc., is the largest hog producer in the world. Its hogs could eat all the corn grown on the Eastern Seaboard in a month and half. Company officials met with geneticist and plant breeder Stephen Kresovich to see how Clemson could help.

Sorghum, in a word, is what Kresovich envisions—South Carolina farmers growing acres and acres of grain sorghum. Drought- and heat-tolerant, the hardy grass produces panicles—seed heads of grain—and can be genetically manipulated to optimize its yield for South Carolina's growing conditions.

Kresovich is one of many voices hailing this era as the "biological century." Decoding and reading life's ultimate instruction book—DNA—genomics and bioinformatics have the potential to revolutionize ways we manage agriculture, practice medicine, cope with climate change, and develop innovative technologies based on natural design.

Last year, Kresovich evaluated two varieties of sorghum. One research plot had plants reaching fifteen feet tall. Across the way, sorghum grew three feet high.

"Manipulating four genes, we could change the genetic instructions for how tall the plants grow," Kresovich says. "Tall plants put out a lot of leaves and stalks, which can be used as biofuel or silage—stover. The shorter variety puts more energy into growing panicles to produce grain that can be processed into palletized livestock feed. Sorghum is very versatile. It uses less fertilizer and other chemicals, and requires less water."

A plant that can take the heat

Thought to have been first cultivated about 2000 BCE, sorghum is adapted to hot, dry conditions. In drought, the plant goes dormant and resumes growing when moisture returns. In heat, the leaves wilt rolling up, making less surface area for evaporation. The waxy leaves and stalks also protect the plant from drying out.

Bred from its wild ancestors in Africa, sorghum (sorghum bicolor) made its way to America in the 1800s. Midwestern farmers who could not grow corn raised grain sorghum—called "milo"—as cattle fodder, while southern farmers found sweet sorghum, juicier and higher in sugar content, a homegrown substitute for white sugar. Many cultures worldwide use sorghum as a food crop, fuel, and building material.

Corn is a pig compared to sorghum, gobbling up costly nitrogen and pesticides, growing best under irrigation. Dryland corn is a gamble for growers, but corn prices make it worth the risk and the expense.

Corn is often a main ingredient in animal feeds. Cattle eat it, and so do pigs, poultry, and dairy cows, along with pen-raised catfish and salmon. Corn also feeds us, industrially shape-shifting from kernels to high fructose corn syrup and other less recognizable ingredients. It's used as feedstock for chemical compounds and biofuels.

A commodity that much in demand can get costly and hard to come by. Price fluctuations and market competition are part of the problem. Add in the cost of Midwest corn and shipping it, and the unpredictability of crop yields because of the weather, and it's easy to see why Murphy-Brown is interested. Sorghum could be regionally grown as a grain crop, a cost-effective alternative to corn.

What would Kresovich and Clemson have to do to make sorghum a menu item at the hog trough?

The to-do list involves genetics, plant breeding, ag economics, and precision-farming methods to grow sorghum—all areas that Clemson does well and is expanding.

In July 2013 Kresovich became director of Clemson's Advanced Plant Technology initiative. He left the University of South Carolina, where he was vice president for research and graduate education.

"I missed the land-grant connection, doing research where you can follow its path from lab bench to research plot to farm field," Kresovich says. Before USC, he had worked at another land-grant institution, as director of Cornell University's Institute for Biotechnology and Life Science Technologies, in the Institute for Genomic Diversity. Kresovich got soil under his nails working on a master's in agronomy at Texas A&M and a doctorate in crop science at Ohio State University.

The Advanced Plant Technology initiative—APT for short—is based at the Pee Dee Research and Education Center in Florence, South Carolina. The relationship Kresovich and Murphy Brown are creating exemplifies the mission of the initiative: Use basic science to leverage economic growth.

Kresovich thumb-taps his fingers as he lists what the program looks to accomplish—identify genes to improve foods and feeds, evaluate alternative crops to grow, find ways to use everything off the field, preserve wild plant varieties, and develop ways to grow crops to cope with climate changes—particularly heat, drought, salinity, and plant disease and pests on the move to more hospitable regions.

The mission dovetails with the state's ambitious goal of increasing the South Carolina agribusiness economic impact from $34 billion annually to $50 billion, boosting the number of ag-related jobs from 200,000 to 290,000. The due date is 2020.

State legislators see APT as an investment in meeting the goal. During the past two years, they have approved $8 million to hire more researchers—plant breeders and scientists—and upgrade the Pee Dee Research and Education Center (REC). The $3 million used to renovate the building—which was built in the 1980s—will improve lab space and add equipment, but the biggest change will be amping up computer power via a digital pipeline to campus to handle the vast amounts of information in plant-genetics databases.

Mapping the pathways with math

"Genetics today involves more mathematics than ever before," Kresovich says. "It's impossible to identify and follow the interactions of genes, modules, networks, proteins, amino acids, the bonds, and the pathways without using probabilities and algorithms."

Revealing and putting the pieces together has created the *-ics* revolution—bioinformatics, genomics, proteomics, metablomics—a growing number of disciplines, involving computer science and mathematics, that explore and map how life works at the cellular and molecular levels.

In April 2003—just eleven years ago—the Human Genome Project was completed. A genome is an organism's complete DNA, including all of its genes. A complete copy of the genome containing all the information needed to build and maintain that organism is kept in every cell with a nucleus. It took hundreds of scientists worldwide thirteen years at cost of roughly $3 billion to build the human genome with its three billion chemical base pairs and 22,000 or so genes.

But the cost and time required for producing a genome have been falling. "Now we are closing in on a 'thousand-dollar genome sequence' done by a technician in less than a day, using machines that cost less than one hundred thousand dollars," Kresovich says.

Molecular mother lode

The steady decline in costs, time, and staff has spurred scientists to go DNA exploring. Hundreds of thousands of DNA sequences are stored in databases available to anyone with an Internet connection. The U.S. National Center for Biotechnology Information, and its sister groups in Europe and Japan, stockpile gene sequences in a database called GenBank. There are other databases as well.

Sorghum has about 30,000 genes. Why does a plant have 18,000 more genes than a human?

Plants are sessile—literally rooted in their environment, while humans and most other animals can move if conditions are bad. Plants need genes and gene networks that can send chemical signals to cope with conditions, turning on or off activities to survive. Every eventuality has to be preprogrammed—drought, insects, disease, temperature, salinity, nutrition, and soil quality.

The proliferation of genes offers plant geneticists a mother lode of molecular opportunities. Genes can be identified and manipulated to control activities. "This is the value of bioinformatics," Kresovich says. "Computers and DNA-sequencing equipment have advanced so much in the past few years that we can now mine DNA to find the gold nuggets."

Much of Kresovich's research focuses on food and fuel characteristics in sorghum and sugar cane, both relatives of corn. These are C-4 plants, overachievers in photosynthesis, but to understand what a C-4 plant does we have to go back to the basics.

Carbon is the structural building block of the cells and organic chemicals. Carbon atoms are in the air and can be claimed one way—via photosynthesis. During photosynthesis, most plants extract three carbon atoms, so the plants are called C-3. C-4 plants have a distinct advantage, obtaining four carbon atoms in each photosynthesis exchange. That extra carbon atom boosts their efficiency. Their stomata open fewer times, which conserves another life-sustaining molecule: water. Each time a stoma opens, water vapor escapes. C-4 plants do better in dry, hot places.

Figuring out how to create plants that use C-4 photosynthesis would not only produce plants capable of more mass but also able to withstand heat and drought. "There's long way to go from identifying the right genes to having something farmers could grow," Kresovich says. "All the advances offer tremendous new avenues to explore, but the roads still lead to the research plots. That's the proving ground for our ideas."

It may be the proving ground, but it is also a bottleneck. Plant breeders must grow generation after generation of plants to get a desired trait to appear consistently—"pure lines" of seeds that growers can rely on.

It takes six generations to establish a pure line. Plant breeders can accelerate the process—fast crop breeding—getting a second season each year by sending the seeds to farms in warmer places. Kresovich sends seed to winter in Mexico.

"It still takes six to ten years to have something to sell," Kresovich says, adding that the timeline is getting shorter because of better tools and techniques.

Research and breeding with sorghum are also being done with peanut, cotton, and soybean crops. Hired last year to work at the Pee Dee REC, Ben Fallen works with soybean and Shyam Tallury with peanuts, important crops in the state.

In 2012, South Carolina growers planted 380,000 acres in soybean, 340,000 acres of cotton, and 110,000 acres in peanuts, according to the USDA National Agricultural Statistics Service.

The work of Fallen and Tallury will help in the search for plant oils to replace hydrogenated oils with unhealthy trans fats, which are being phased out of foods.

The timing is right for the APT program. Last fall, China for the first time purchased U.S. grain sorghum. The reasons were economic: Chinese corn was expensive. Tariff quotas prevented more corn imports. U.S. sorghum was a good buy.

The U.S. Grains Council estimates that U.S. sorghum exports will double in one year, from 75 million bushels in 2012-2013 to 150 million bushels in 2013-2014. Much of this increase will result from higher demand from China, the council says.

China doesn't have to be half a world a way to buy sorghum. Smithfield Foods Inc., parent company of hog producer Murphy-Brown Smithfield, made headlines last fall when it was purchased for $7 billion by Chinese food producer Shuanghui International.

Sorghum may well offer southern farmers far more than syrup for biscuits.

Stephen Kresovich is the Robert and Lois Coker Trustees Chair of Genetics and SmartState Chair of Genomics, Department of Genetics and Biochemistry, College of Agriculture, Forestry, and Life Sciences. Peter Kent is a news editor and writer in Clemson's Public Affairs Activities.

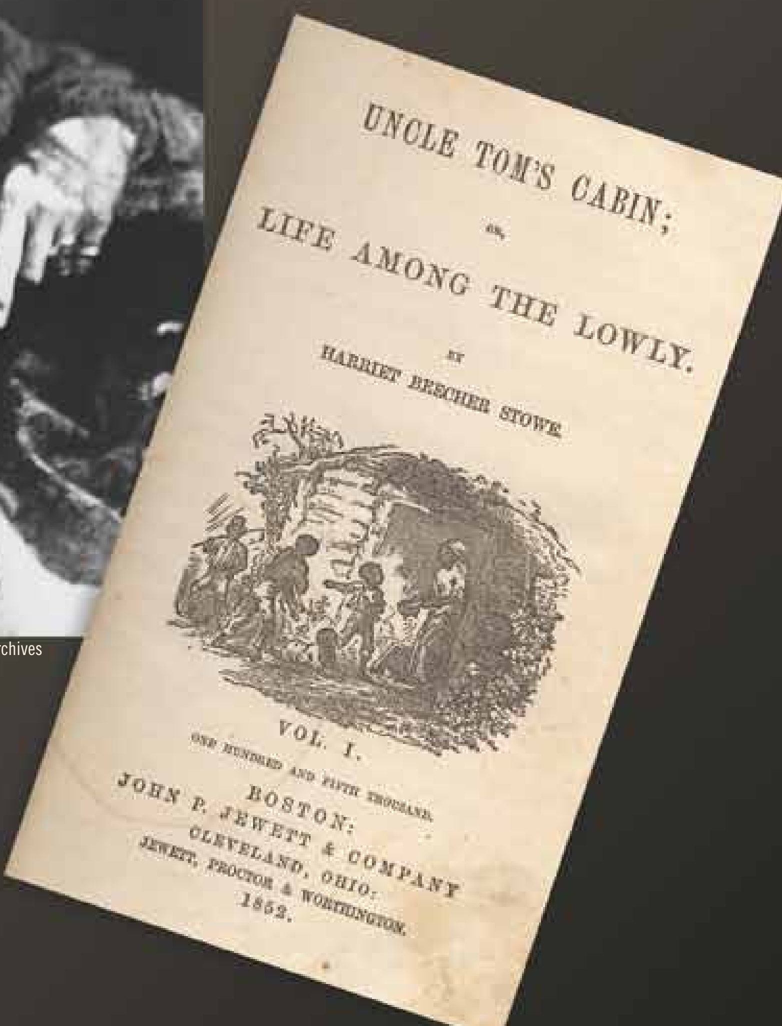
Harriet Beecher Stowe

AND THE FUGITIVE

SHE SHELTERED A RUNAWAY SLAVE. DID HE HELP INSPIRE A NOVEL THAT SHOOK THE WORLD?

BY JEFF WORLEY

National Archives



HARRIET BEECHER STOWE AND VOLUME I OF HER NOVEL.

ONE COLD NIGHT IN BRUNSWICK, MAINE, in late 1850, Harriet Beecher Stowe hid a fugitive slave in her house. She and her children listened with great interest to his stories and songs, and sympathized with him when he told her how much he missed his wife and daughter back in South Carolina. Stowe even inspected his back, which was covered with scars from numerous whippings. The man left early the next morning and, with help from the Underground Railroad, made it safely to the town of Saint John in New Brunswick, Canada.

"He was not the first fugitive she had ever met, but he was the first—and only—runaway slave that Stowe harbored in her own home," says Susanna Ashton, whose special research interest is nineteenth-century American literature. "She willingly did this despite the draconian penalties imposed for such behavior by the Fugitive Slave Act of eighteen-fifty, which had been passed only a few weeks earlier." This law declared that all runaway slaves were, upon capture, to be returned to their masters, and that any person aiding a runaway by providing food or shelter was subject to six months' imprisonment and a $1,000 fine.

"This man made a great impression upon Stowe and her family," Ashton says. "He was, as Stowe wrote in a letter to her sister, 'a genuine article from the Ole Carling State.'"

While it is tempting to speculate about what the fugitive might have told Stowe on the one night that he spent under her roof, we can never ultimately know, Ashton says, adding that the historical impact of the incident stemmed from in its "domestic presence."

"Stowe, like her husband, had long been an outspoken abolitionist, but taking this man into her house upped the stakes considerably," Ashton says. "A man fleeing for his life was not an abstraction or an inspiration but someone who brought the stark reality of slavery into her living room. In meeting him, the corridor opened between Stowe's intellect and her heart, and in talking with him—she was a devout Christian—she very likely would have also felt the hand of divine providence at work."

A few months later, in early March 1851, Stowe was sitting in the family's church pew in the First Parish Church in Brunswick when she had a vision of a man being whipped to death, a vision that she said compelled her to write *Uncle Tom's Cabin.* Her novel became a best-selling book of the nineteenth century, second only to the Bible, and significantly helped energize the most consequential social revolution in American history.

"This vision drew upon a lifetime of Stowe's impressions, research, knowledge, and experiences. Adding this man to that assortment of influences is important, because the fact that he was 'the genuine article,' and the fact that he was sent to her for protection in a strange town, may have been part of the final push toward the writing of her great novel," Ashton says.

So who was this influential man?

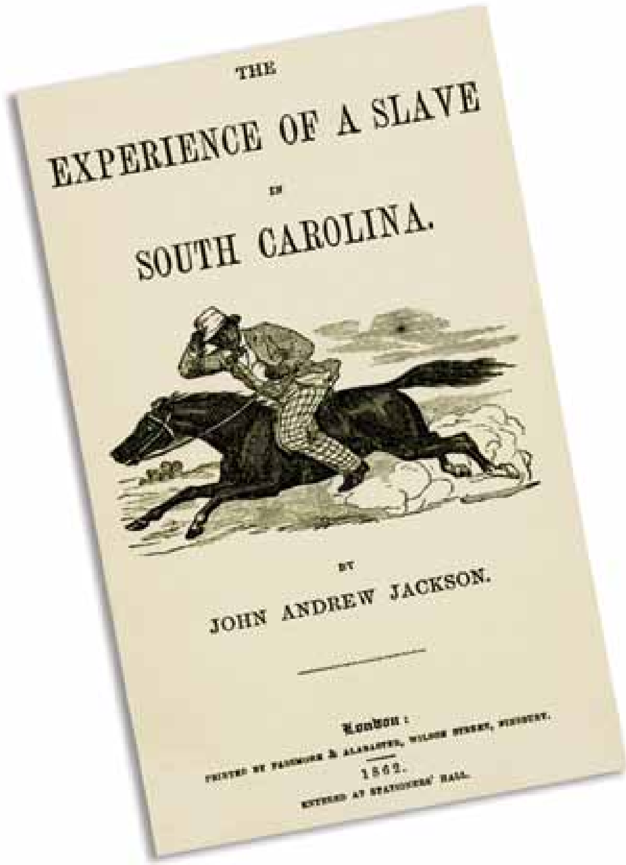
Harriet Beecher Stowe never named this fugitive who was fleeing to Canada and, Ashton explains, Stowe had good reasons to not disclose his identity.

"It's entirely possible that she didn't know his name," says Ashton, "because the Underground Railroad made a point of anonymity. But even if she did, to write or speak in specifics about the night he stayed with the Stowes would have been an admission that she violated the Fugitive Slave Act, and she might have suffered severe consequences."

It would be another twelve years before the man's identity was revealed—by the man himself. After a few years in the city of Saint John, John Andrew Jackson went overseas to England on the abolitionist lecture circuit and, while there, wrote and published a complex and powerful memoir of his time in bondage, *The Experience of a Slave in South Carolina* (1862). In this book he mentions Stowe by name and recounts the night he spent in her house:

> Just as I was beginning to be settled at Salem [Massachusetts], that most atrocious of all laws, the Fugitive Slave Law, was passed, and I was compelled to flee in disguise from a comfortable home, a comfortable situation, and good wages, to take refuge in Canada. I may mention that during my flight from Salem to Canada, I met with a very sincere friend and helper, who gave me a refuge during the night, and set me on my way. Her name was Mrs. Beecher Stowe. She took me in and fed me, and gave me some clothes and five dollars. She also inspected my back, which is covered with scars which I shall carry with me

UNC Documenting the American South



Jackson's memoir includes an account of Stowe hiding him.

to the grave. She listened with great interest to my story, and sympathized with me when I told her how long I had been parted from my wife Louisa and my daughter Jenny, perhaps for ever.

Although there has never been a strong reason to doubt Jackson's claim that Stowe hid him overnight, some scholars of this historical period have been frustrated that it remained unverifiable. Important, too, is the timing of his overnight stay at the Stowe house. Was Jackson the trigger Stowe needed to put pen to paper and begin her history-making novel?

Literary detective work

Three years ago Ashton started an investigation that she hoped would lead to a fuller understanding of the night in question. She had already edited Jackson's memoir for her book, *I Belong to South Carolina: South Carolina Slave Narratives*, and she wrote a further study of Jackson for her second book, published last February, which focuses on the South Carolina roots of African American thought. Still troubled by what seemed to be an incomplete sense of his life and of who he was, Ashton realized that the complexities of Jackson's life might merit a full biography.

"As I started working through his life story, using as my primary document, of course, his eighteen-sixty-two memoir, I suddenly realized that the passage where he talks about Stowe hiding him was quite early—immediately after the Fugitive Slave Act of eighteen-fifty," Ashton says. She tried to trace any connection between Stowe and Jackson, but Ashton found no particular mention of Jackson in any of the Stowe biographies and papers.

"I reached out then to colleagues and scholars around the country who had expertise in Stowe, and one suggested that the research staff at the Harriet Beecher Stowe Center in Hartford, Connecticut, might have an idea about overlooked sources. I contacted a reference librarian there who had never heard of Jackson but did direct me to one of Stowe's little-known letters held at Yale University, in which she mentions hiding an unnamed fugitive slave in November or December of eighteen-fifty." Ashton found this letter, on microfilm, and was thrilled to read Stowe's account of a fugitive she hid, a fugitive who seemed to match what is known about John Andrew Jackson.

"Even with her husband almost certainly away— as well as her teenage twin girls, who were then visiting relatives—Stowe took the unnamed fugitive in and marveled at how well her three young children [Henry, age 12, Frederick, 10, and Georgiana, 7] interacted with the charismatic man," Ashton says. She reads from Stowe's letter:

> Now our beds were all full & before this law passed I might have tried to send him somewhere else. As it was all hands in the house united in making him up a bed in our waste room & Henry & Freddy & Georgy seemed to think they could not do too much for him—There hasn't any body in our house got waited on so abundantly & willingly for ever so long—these negroes posses some mysterious power of pleasing children for they hung around him & seemed never tired of hearing him talk & sing. He was a genuine article from the 'Ole Carling State.

When she came across this letter, Ashton realized that she had two incredible documents that told a remarkable story.

"Not only had I almost certainly verified Jackson's story, I had also provided information about a historical incident which surely informed, if not inspired, Stowe's composition of *Uncle Tom's Cabin*. Also, in terms of verifying an actual event on the Underground Railway, this was tremendous too, since there are very few accounts of the railway that are documented from two perspectives—that of the freedom seeker and that of the contact who helped him along the way."

The letter that opened doors

The night he spent in the Stowe house was not to be the only contact Jackson ever had with Stowe. Having learned to read and write after settling into Saint John, Jackson surely read *Uncle Tom's Cabin* after its publication and, says Ashton, had to be surprised and impressed.

"I can imagine him saying to himself, 'Wow, that's the lady who hid me in Maine!'" Ashton says, laughing. "It was the best-selling novel in the world—he couldn't have missed it by then."

After a few years in Saint John, Jackson decided to go to England to speak on an abolitionist lecture circuit, recounting his experiences as a slave in the American South. He knew that a letter of introduction from Stowe would greatly increase his chances of doing this successfully, that it would be a form of currency, so he got a letter from her. Did he visit Stowe a second time to get her endorsement?

"Saint John isn't all that far from Brunswick, so geographically it wouldn't have been all that difficult for Jackson to come and see her, but because of the Fugitive Slave Act this would have been extremely risky for him," Ashton says. "So this was much more likely just a letter exchange or was obtained through the help of sympathetic intermediaries."

From 1856 until the end of the Civil War, Jackson lectured at churches and for social organizations in England and Scotland, and in 1862 published his book, *The Experience of a Slave in South Carolina*. After the Civil War, he settled in Massachusetts, shuttling back and forth to South Carolina and making a living for the rest of his life as a teacher and lecturer.

John Andrew Jackson, author

When Ashton's discovery was widely publicized by the Associated Press—with considerable help, she says, from the media office at Clemson—Ashton got dozens of emails from Stowe scholars and others excited about this new perspective that had been added to the writing of *Uncle Tom's Cabin*. These responses have been focused almost entirely on Stowe.

"The truth is," Ashton says, "Harriet Beecher Stowe doesn't interest me that much. Lots of scholars are out there to tell her rich and complex story. More compelling to me is that Jackson, who came from nothing, a field hand degraded and abused brutally, and not even literate at the time he was sheltered by Stowe, *claimed his life* by his daring act of 'self-theft,' as it was sometimes called, by running away. What's more important to me is, how does somebody like Jackson come to believe his life story is worth telling, worth writing about? How did that encounter help lead him to believe that his testimony on paper mattered?"

Then Ashton brings this question home. "How do we enable people to believe their truth, their expression with words, is important and valuable? That's our challenge today in South Carolina—how do we get students and others to believe that their stories can change the world?"

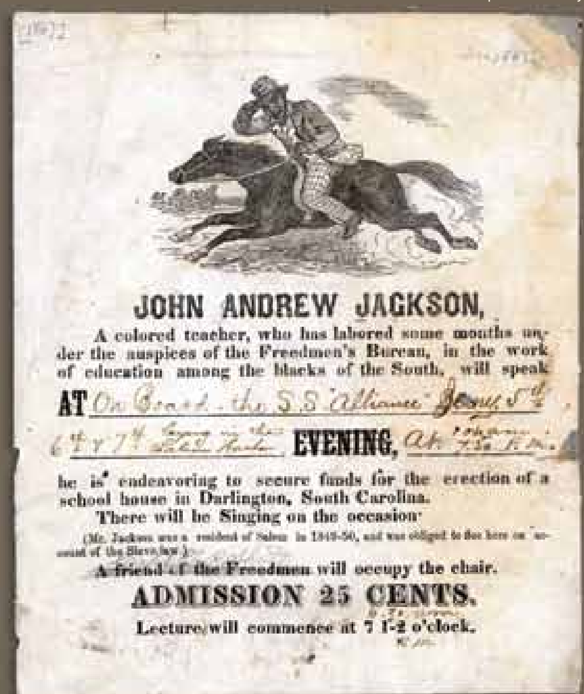
Susanna Ashton is an associate professor of English in the College of Architecture, Arts, and Humanities. Jeff Worley is a freelance writer and poet who lives in Lexington, Kentucky.

Susanna Ashton found a little-known letter, on microfilm, and was thrilled to read Stowe's account of a fugitive who seemed to match what was known about John Andrew Jackson.

Craig Mahaffey

John Andrew Jackson's Great Escape

American Antiquarian Society



Above: poster designed to advertise an 1862 speech by Jackson in order to raise funds for a freedmen's school.
Below: illustration, from *The Experience of a Slave in South Carolina,* of the gimlet Jackson used to bore air holes in the ship's deck.

UNC Documenting the American South

John Andrew Jackson was born into a brutal life of labor and abuse in what is present-day Lynchburg, South Carolina. Even as a boy, he was whipped or beaten—for praying, not obeying fast enough, or for no reason at all. Most horribly, he saw his sister whipped to death at the instruction of the plantation owner's daughter.

He found some brief happiness with Louisa, a young woman who lived on a nearby plantation. He married her, but when she and their daughter, Jenny, were sold to a plantation owner in Georgia, Jackson's devastation knew no bounds, and he resolved to use the rapidly degrading sanity of plantation owner Robert English to his advantage. With his owner collapsing into dementia, oversight and discipline on the plantation were lax. Jackson began to hatch a plan for escape. If he couldn't join Jenny and Louisa, he would escape slavery entirely and perhaps someday, somehow, be reunited with them.

Jackson traded some chickens for a pony that a neighboring slave had somehow obtained. He hid the pony deep in the woods. On Christmas Day, he took advantage of the customary three-day holiday and fled on horseback for Charleston. He had often been to Charleston to drive his master's cattle to market and knew the route well. Unlike many fugitives forced to brave unknown terrain, Jackson's flight to Charleston was through familiar turf. From Charleston, he hoped to head north, for permanent freedom.

Where did he belong?

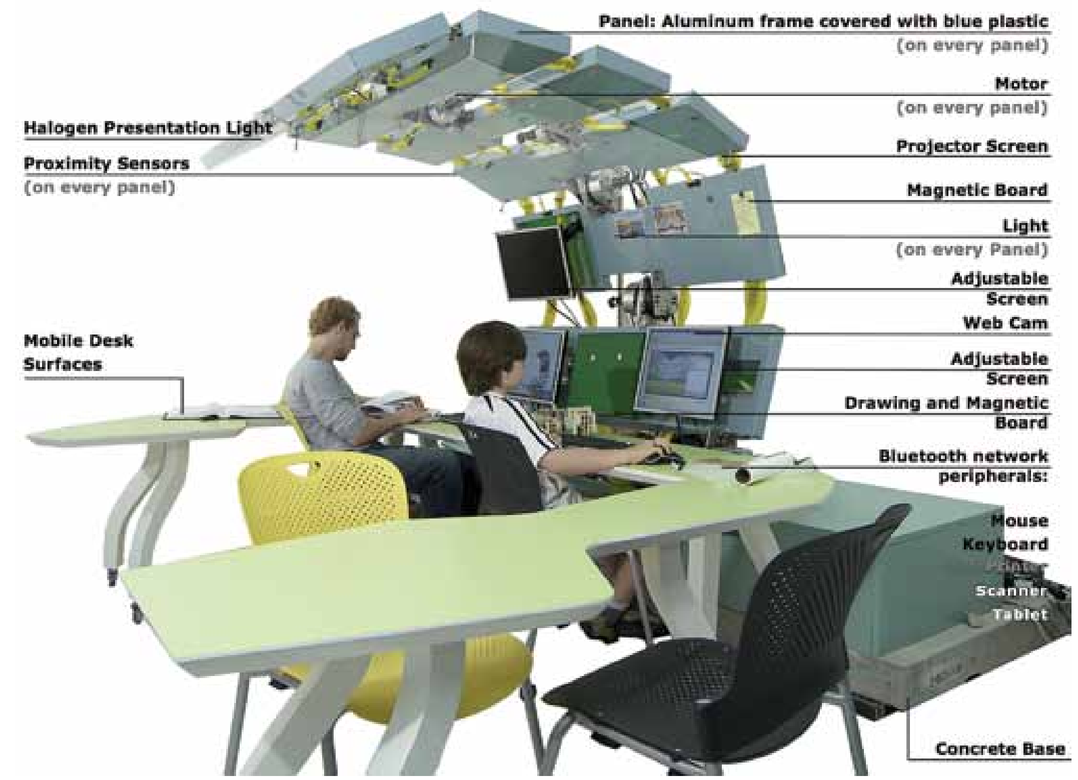
In Charleston, Jackson had a tense encounter that could have led him back to the plantation. As he was walking past the docked boats, several dockworkers asked him bluntly if he was a fugitive slave and asked to whom he "belonged." Since he couldn't plausibly pass as a Charleston slave and certainly didn't want to admit to being a fugitive, Jackson said he "belonged to South Carolina." His clever and unexpected response may have perplexed his interrogators—and they let him be.

When Jackson found a ship heading to Boston, he tried to board, but the crewmen refused to let him. That night, when he was sure no one was on the ship, he hid in a five-by-three foot box on a lower level of the vessel. Eventually, on the high seas, the crewmen found him and threatened to unload him on the next ship. There never was another ship, and Jackson made it to Boston safely.

From Boston, he went on to settle in Salem, Massachusetts. Rather than live underground, Jackson chose to keep his name and live openly. He worked to raise funds with Northern abolitionists who were willing to help him negotiate freedom for the wife and baby daughter he had left behind.

But this plan was doomed to failure. Before he was able to raise sufficient funds to purchase his family's freedom, the passage of the 1850 Fugitive Slave Act effectively forced him to flee again, this time north to Canada with the help of the increasingly organized Underground Railroad. Brunswick, Maine, and his fateful night with Harriet Beecher Stowe, was perhaps his last stop before he made it to Canada and, finally, to freedom.

Keith Green



Your next desk could be AWEsome

The Information Age is transforming the work of architects and designers, expanding collaboration, and changing the tools of the trade. Keith Evan Green and his collaborators and students set out to build a new kind of work environment to support the next generation of digital design and human interaction. The Animated Work Environment (AWE) is a robotic work environment users program to accommodate work styles and materials new and old, digital and analog.

AWE is composed of eight hinged panels that change the spatial characteristics of the work environment. Users select one of six configurations and fine-tune the selection by hand gestures detected by sensors. Embedded with touch-screens, touch-pads, and virtual keyboards, AWE's three horizontal work-surfaces of different forms can be moved, rotated, and re-joined to create a variety of work surfaces.

"For people who are already kind of geeky and are working collaboratively, the Animated Work Environment is a thrill," Green says. Read more about vital robotics on page 56.

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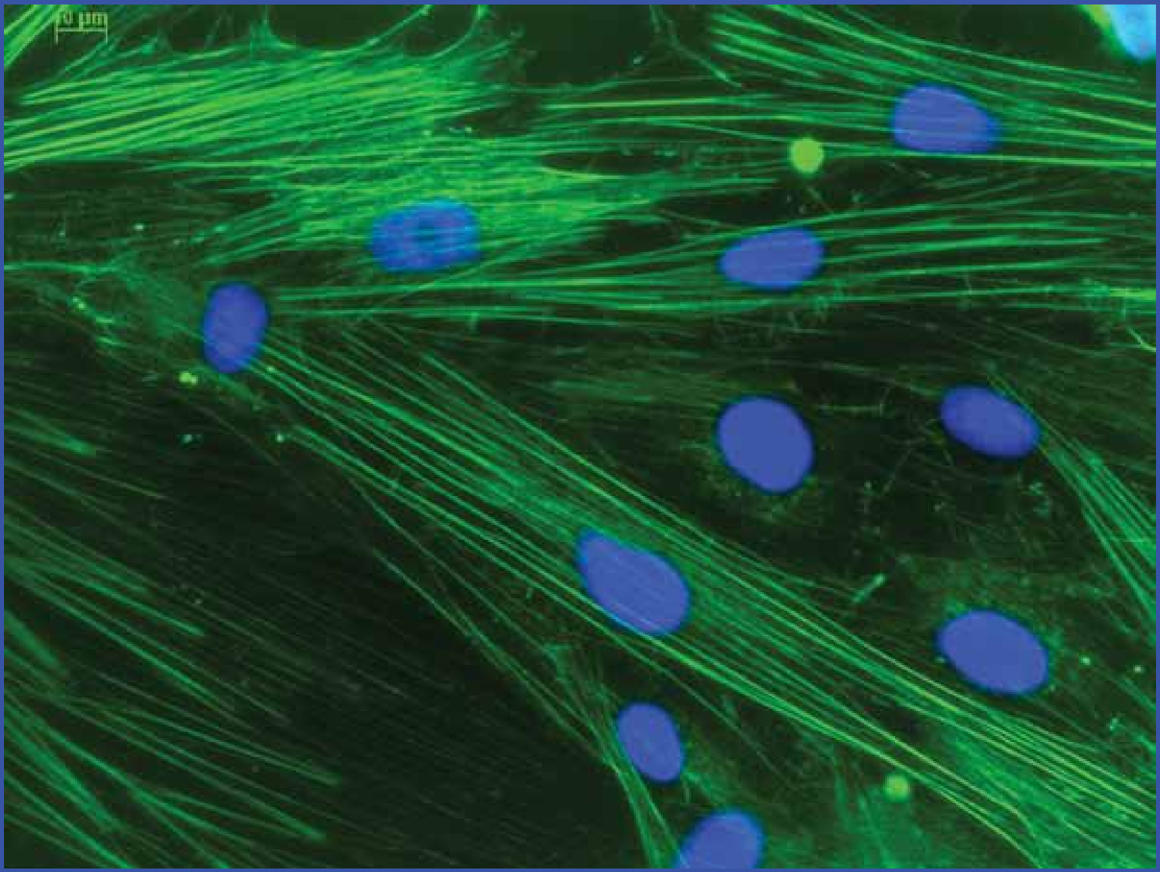
Simionescu lab



Stem cells up close and personal

Could stems cells extracted from our own belly fat help us repair our failing heart valves, blood vessels, or other parts? So far, the answer appears to be yes. This detail from the image on the front cover shows stem cells growing in petri dishes. The cells' nuclei are stained blue. The cells can help transform a matrix of collagen fibers into new, living tissue to replace failing body parts. Page 12.