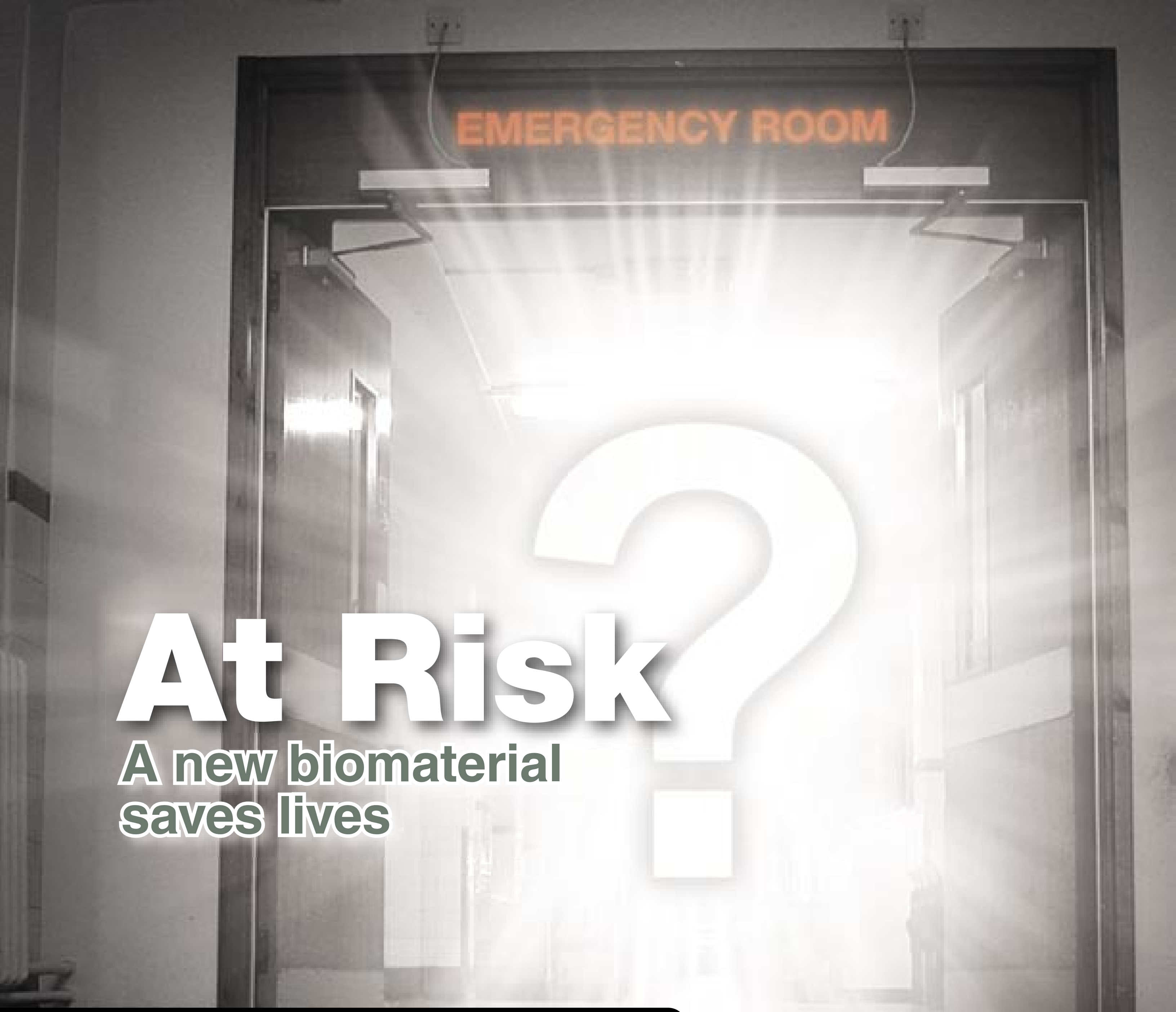

At Risk

A new biomaterial saves lives

PURDUE **MATERIALS**

ENGINEERING**IMPACT**

WINTER 2006-07

A Legacy Continues
Materials Engineering matriarch

SURF's Up
Materials students' new twist on the summer job


John Underwood

On My Mind

Materials contribute to our livelihood in remarkable ways, and my son has recently provided me with a handful of instructive examples. About a year ago, while riding a racing bicycle on the streets of West Lafayette, he had a collision with a car. All in the course of a split second, his life became entirely dependent on the performance of an odd collection of materials, many of which have only become available during my career. As far as we can tell, his head struck the car's windscreen, which did not break into shards, but failed "gracefully" by shattering into tiny rounded pieces that were held together by a thin, tough layer of polymer—saving both him and the driver from serious injury. He was further protected by a lightweight helmet that absorbed the impact by fracturing, thereby protecting his skull from doing the same. The aluminum alloy frame of his bicycle was seriously bent, and his tibia was broken, revealing two different modes of absorbing energy. My son's broken leg was eventually repaired with the assistance of a stainless steel plate that held the two parts of the bone together while they mended. You can be sure that a number of other materials were involved in his treatment in the emergency room and the operating room, too.

Biomedical technologies continue to make great strides in protecting us from disease and injury. The unofficial slogan of the School of Materials Engineering is perhaps more pointedly true here than in all the other arenas in which it applies: *You can't make it without materials.*

Alex King
Head, School of Materials Engineering

* See the college side (p.24) for Alex King's feature, "An Ounce of Prevention."

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Vincent Walter

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around mse

Emerging Research Areas

Multiscale modeling of materials based on first principles.

Predictive multiscale, multi-physics modeling of materials is another emerging area of science and engineering with an enormous potential for societal impact. Assistant professor Alejandro Strachan and his students are focusing on developing and validating new methods to predict the behavior of materials from first principles and on their application to technologically relevant problems. A hierarchy of methods is employed to capture the disparate time and length scales that govern the behavior and performance of materials and devices (shown in Figure A). Areas of interest include:

- Nanoscale materials for electronic and electro-mechanical systems.
- Active materials (ferroelectrics and shape memory alloys).
- Thermo-mechanical properties of metals.
- Molecular materials as well as energetic materials.

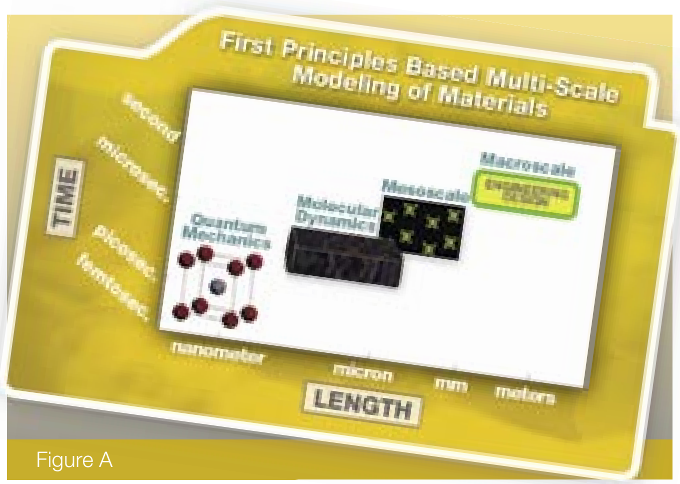


Figure A

The Interplay of Art and Engineering

A materials professor leads Purdue's nanotechnology future.

Whether it's his children's oil paintings, blueprints for the now-opened Birck Nanotechnology Center, or graphics in a presentation, Tim Sands has an artful eye. In fact, the Basil S. Turner Professor of Engineering in the schools of Materials Engineering and Electrical and Computer Engineering considered graphic design for a career. But he loved engineering and science more.

"I still have the art bug," he says. "But there's a lot of art involved in science, so I feel that part of me is taken care of."

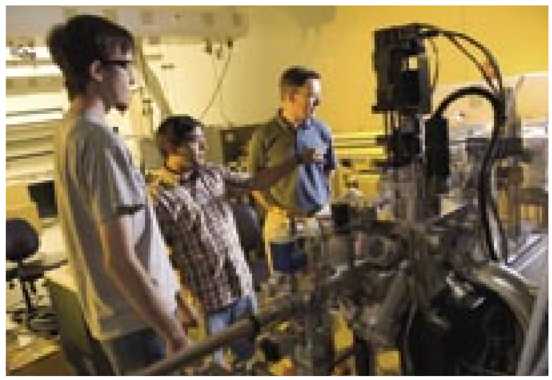
His look at drawings for the Birck Center—and the possibility of the collaborations that could occur there—drew Sands to Purdue in 2002. He brought along a bachelor's, master's, and PhD from the University of California, Berkeley, and 18 years of industry and academic experience.

Today, he and his 10 graduate students are focused on nanostructured materials for energy-conversion devices and electronics, and what he was able to foresee has come to pass.

"It's worked exactly the way I thought it would. I moved my group over to Birck and they immediately began working with other groups in other areas," he says. "When you share space, pretty soon boundaries fall away. These are fantastic facilities. It's a great environment."

On the first day of November, Sands became the director of Birck—overseeing a $58 million, 187,000-square-foot center that houses more than 300 faculty, staff, and graduate students from 36 schools and departments across the university.

"Our work in Birck and with nanotechnology will impact healthcare, energy, computer technology, homeland security, food safety, and so many other areas," says Sands.



A Winding Path

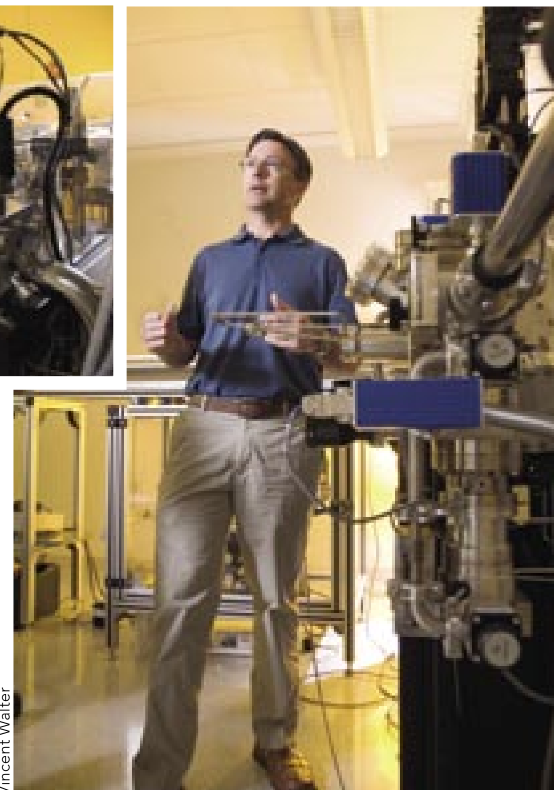
His path to Birck was a winding one. "I often wonder where materials engineering came from. It was almost an accident."

As a California kid, he was "into things nerdy"—bug and butterfly collecting, bird watching, meteorology. "I loved science and I loved art. I was the school poster person, the tee-shirt person. Then I thought, 'What am I going to major in that will bring me some money? How about engineering?'"

He started out in civil, soon finding engineering physics and then solar energy. "It captivated me," he says. But there were materials problems, which clinched his choice for graduate degrees in materials engineering.

When energy-saving interests waned in the 1980s, Sands switched to semiconductors, spending several years in research at Bellcore in New Jersey. When his alma mater called in 1993, "I guess I gotta go," he decided. At UC Berkeley, he worked on thin-film materials integration for functionally enhanced microsystems and spent six months as a visiting professor in Belgium.

Then energy became a hot topic again. And he learned about Purdue's Discovery Park research complex, of which Birck is a part. "Wow," he told himself. "I could be around risk takers and all those other disciplines."



Vincent Walter

Tim Sands at work in the Birck Nanotechnology Center.

Four kids, their art supplies, and his wife—nursing professor Laura Sands—in tow, the family soon became Boilermakers.

Berkeley to West Lafayette was just another jaunt for the well-traveled family that likes Lake Tahoe, Martha's Vineyard, Hilton Head Island, Oregon, Europe, and Ireland, as well as playing lots of tennis and golf. ■ **Kathy Mayer**

Seasonal Work

Purdue's SURF program gives materials students a new twist on the summer job.

Most materials engineering undergrads enter the summer by closing their books and putting on landscaping gloves or a Starbucks apron. But materials engineering students Karen Lynch and Jonathon Vernon took advantage of Purdue's Summer Undergraduate Research Fellowship (SURF) program and sported lab coats this past summer.

As summer jobs go, participating in SURF is among the best opportunities available. Students receive a stipend of $1,000 per month and get research experience under the guidance of a faculty member. There are also opportunities to socialize and network with other faculty members, staff, and students at Purdue.

"SURF gives students experiences that enhance classroom learning, involve them in solving real problems, and open doors to 'aha' moments of their own to excite them about science and engineering," says founder Jay Gore, associate dean and Vincent P. Reilly Professor of Mechanical Engineering.

For Lynch, the decision to participate in SURF was supported by her interest to eventually attend graduate school. "Undergraduate research can help you figure out if you want to go on to graduate school," she says. "It can help you find out which aspects of your discipline you are most interested in."

Lynch spent the summer months learning how to use computer modeling to simulate failure in the molecular structure of nickel-aluminum alloy exposed to compressive shockwaves. Her faculty advisor, Alejandro Strachan, assistant professor of materials engineering, selected this project for Lynch and taught her how to use computer modeling. "The simulations Karen performed provide a complete, atomic-level description of the process that leads to failure," Strachan says. "I think her project and the experience she gained reinforced her decision and confidence to enter a graduate program."

As for Vernon, he spent his summer experimenting with ways to machine high-temperature ceramics into complex shapes. Unlike metals, ceramics do not lend themselves to this type of shaping. His findings will assist his faculty advisor, Rodney W. Trice, associate professor of materials engineering, in compiling a research proposal. Trice says that by collecting basic information, students get experience in research methodology and also perform tasks that are tremendously valuable for the faculty members.

Had Vernon not entered the SURF program, he would have spent the time taking classes to lighten his senior year course load, but he does not regret his choice. "Undergraduate research teaches students self-reliance and provides hands-on experience," he says. "The undergraduate research program confirmed my decision to attend graduate school, proving it would be enjoyable."

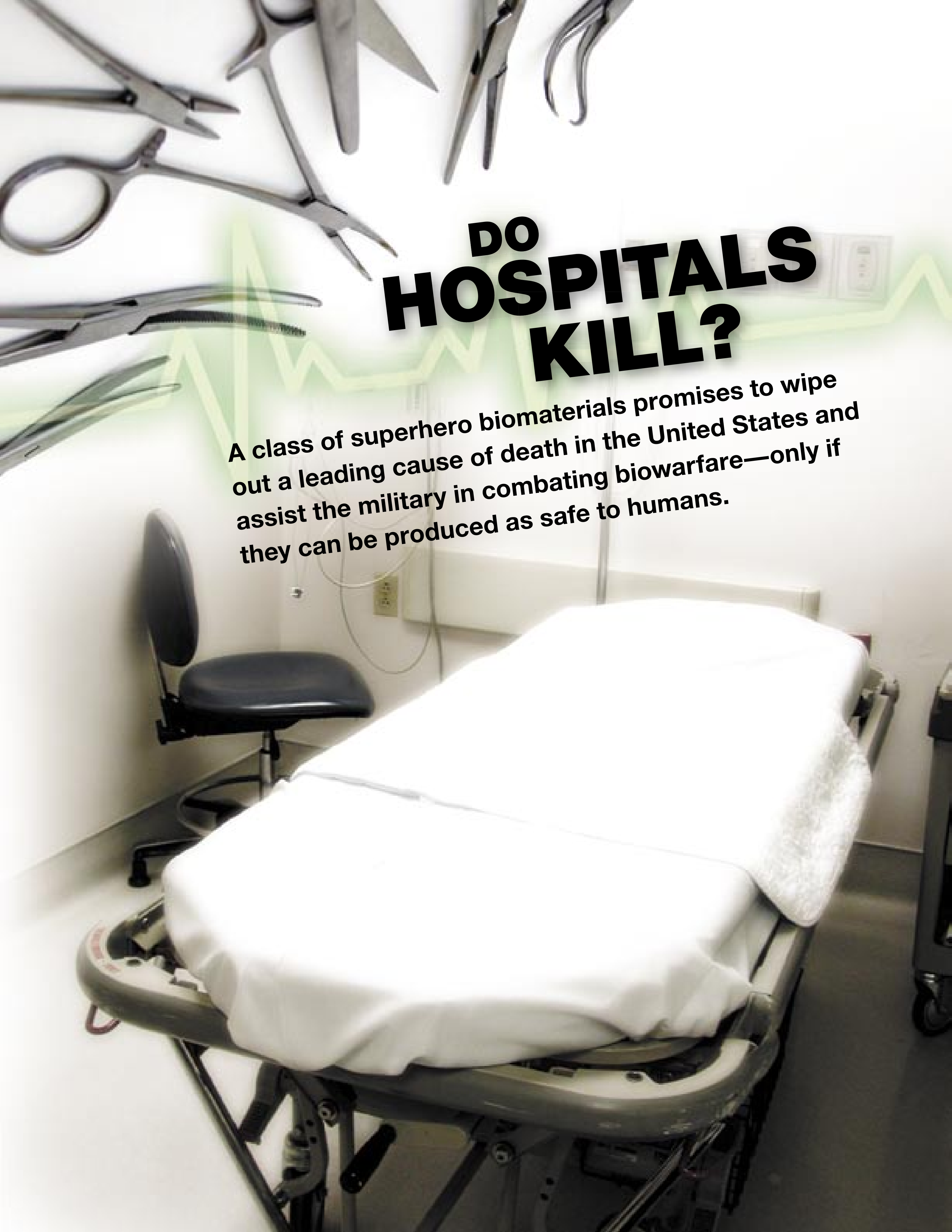
■ **William Peck**

Vincent Walter

Materials SURF students Karen Lynch and Jonathon Vernon.

DO HOSPITALS KILL?

A class of superhero biomaterials promises to wipe out a leading cause of death in the United States and assist the military in combating biowarfare—only if they can be produced as safe to humans.



Leading Causes of Death in the U.S.

- Heart disease
- Cancer
- Stroke
- Chronic lower respiratory diseases
- Accidents (unintentional injuries)
- Diabetes
- Alzheimer's disease
- Influenza/pneumonia
- Naphritis, nephorotic syndrome, and nephrosis
- **Septicemia**

Source: 2004 Preliminary and final data from the National Vital Statistics System, National Center for Health Statistics.

For Jeff Youngblood, assistant professor of materials engineering, wiping out the incidence of infections in hospitals and the threat of bioterrorism in the United States is a major concern. A novel class of bacteria-destroying polymers is his focus. "We're working on a general class of materials that are plastics that kill bacteria and pathogens in general," he says.

Youngblood explains, "Things in nature are negatively charged. The material I'm working with is positively charged—it is attracted to the cell wall of pathogens. A chain of this material inserts into the cell wall of bacteria and kills it.

"The problem is that as a class, these materials are not biocompatible, which is very important. People are looking for a coating for a table, hospital walls, or for instruments used in the hospital and on patients."

The question is, can you keep the antibacterial activity and make the material biocompatible? "If you can keep activity, all of a sudden you have something you can coat on a catheter, needle, or even use as a cleaning solution," says Youngblood.

Hospitals Kill?

According to Centers for Disease Control and Prevention estimates, nosocomial infections—infections that are a result of treatment in a hospital-like setting—affect one in ten patients (around 2 million) each year. In 1995, the annual costs were estimated at $4.5 billion. Today, these infections could cost the U.S. up to $11 billion. And those infections are deadly. Nosocomial infections often lead to septicemia in patients—the tenth leading cause of death in the U.S. "The medical industry wants to kill infections," says Youngblood. "Infections are why you don't want to be in the hospital."

The most common hospital-acquired infections seen in patients are Catheter-associated Urinary Tract Infections (CAUTI), comprising more than 40% of all hospital infections and killing thousands of patients each year. With more than 5 million patients receiving urinary catheters every year (and an added cost of $1,000 to each hospitalization when a catheter becomes infected), the infection rate and its costs are astounding.

Infected catheters are covered by a thick biofilm composed of microorganisms attached to a protein. Commonly used anti-infective and silver-hydrogel catheter coatings have proven effective, but not against drug-resistant bacteria. "What the medical profession is doing—placing antimicrobial stuff into a plastic—that'll work, unless the organism becomes resistant or the biocide is depleted," suggests Youngblood. "Bactericidal plastic never runs out, and it kills bacteria such as *E. coli* and *Staphylococcus,* which causes toxic shock syndrome in patients, as well as drug-resistant pathogens."

As hospitals house larger numbers of immunocompromised patients, and with the rise of drug-resistant bacteria in healthcare settings, Youngblood's research will play a critical role in mitigating the risk of open infections such as burn wounds and bloodstream infections caused by unclean instruments.

continued on next page

On the Warfront

Youngblood's bacteria-killing material could also be used to clean up after biowarfare agents such as anthrax. "When you talk about bacteria used in warfare, they're really hard to clean up. The problem is that most methods that kill these 'nasties' aren't too good for you and me," Youngblood says. "With a bactericidal polymer, you could decontaminate an affected area and be nontoxic to humans."

Think back to the anthrax attacks—also known as "Amerithrax" from their FBI code name—made by mail at the Brentwood, New Jersey, postal facility and the Hart Senate Office Building in 2001. Because of the likely resistance of anthrax to most environments, the remediation of contaminated environments is critical, and a team of experts has to clean and then determine when the area is safe enough for people to return. What if the anthrax wasn't contained to a single envelope, but dispersed within a wide area?

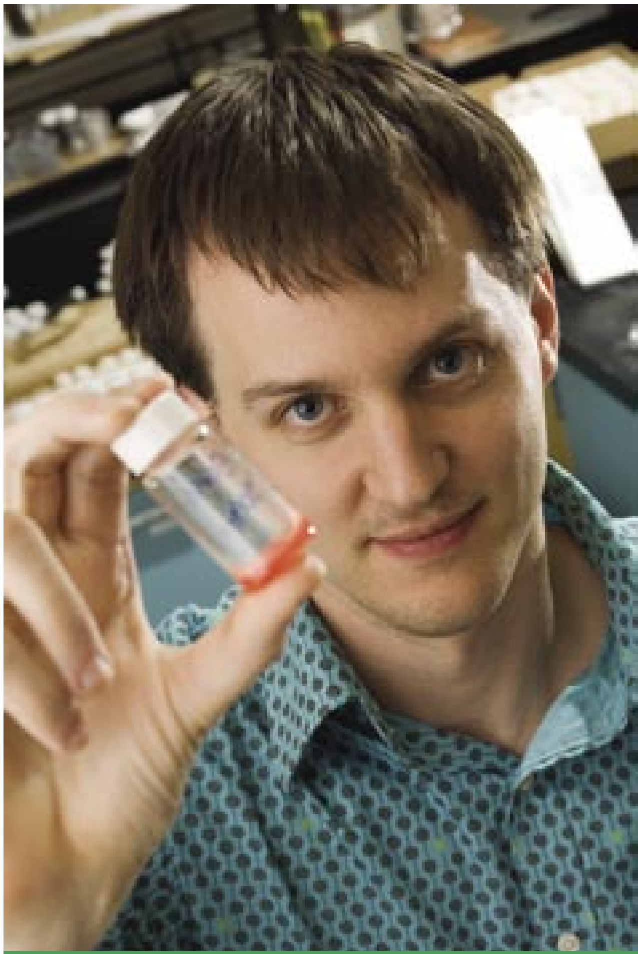
The question Youngblood raises is, "How do you keep these responders alive and from contaminating other areas?" He continues, "If the affected area is a large field, you can load an aqueous solution of these polymers on a tanker plane and spray the area like a forest fire so no one has to enter the contaminated area."

A benefit of Youngblood's material is that it is a polymer and is generally a sticky substance. Well-made bioweapons linger in the air. "Because this material is sticky, it'll keep dust down and it won't migrate, similar to how starch solutions are sprayed on desert helipads," says Youngblood.

Promising Results

Funded by Purdue's Showalter Research Trust, Youngblood and his team of student researchers are working to take his polymer to the next stage. "We're not to a product, but we have some interesting results. We're trying to get to that mix where we kill bacteria but not humans," Youngblood says.

"We envision catheter coatings, needle coatings, burn wound gels, and biowarfare mitigation." ■ **Lee Lamb**



John Underwood

Jeff Youngblood holds his potentially life-saving biomaterial.

A graduate student's research leads to better testing for implantable devices.

Orthopedic device manufacturer Zimmer is hoping for a better biomechanical testing material and is banking on materials graduate student Kayla Calvert-Doyle and Professor Kevin Trumble to deliver. "The idea behind my research is the testing of a device before it goes into the body—to test the initial stabilization," says Calvert-Doyle.

It's a research project she started as an intern at Zimmer, after finishing her undergraduate degree in 2004. The project specifically targets trabecular bone—found at the ends of long bones—to find a way to accurately model and mimic the human bone. Calvert-Doyle says, "When you can do that, you can test the material and know if it's going to fail before you implant it into a human."

The current testing standard is to use polyurethane closed-cell foam, but this material doesn't represent human bone. "The bone has varying properties across the surface, which makes it inhomogenous, while polyurethane foam is homogeneous in its structure and mechanical properites," says Calvert-Doyle. "Another problem is polyurethane tends to melt when you drill into it."

Using a total of 40 tibias, Calvert-Doyle employed a surgeon's method to remove the top of the tibia at the knee,

Solving the Parkinson Puzzle

Electron microscopes—instruments that use a beam of highly energetic electrons to examine objects on a very fine scale—are tools that were initially developed to meet the needs of materials scientists and were much later adapted by bioscientists for gaining insight into the structure of biological molecules to find cures for diseases. But for assistant professor Lia Stanciu, electron microscopy is the key to unlocking the mysteries of neurological disorders such as Alzheimer's and Parkinson's diseases.

"When I was a graduate student in materials engineering, I studied electron microscopy and learned all the techniques," she says. "The question I wanted to answer was how could you use these techniques, traditionally used to image metals and ceramics, to study more delicate, organic and biological materials?" In answering this question, Stanciu became an expert and filled a critical niche in materials science.

After completing a post-doctorate in structural biology, she came to Purdue and instantly began collaborating with medicinal chemistry and pharmacology assistant professor Chris Rochet, whose goal is to understand how protein aggregation, or clumping, contributes to Parkinson's and Alzheimer's diseases.

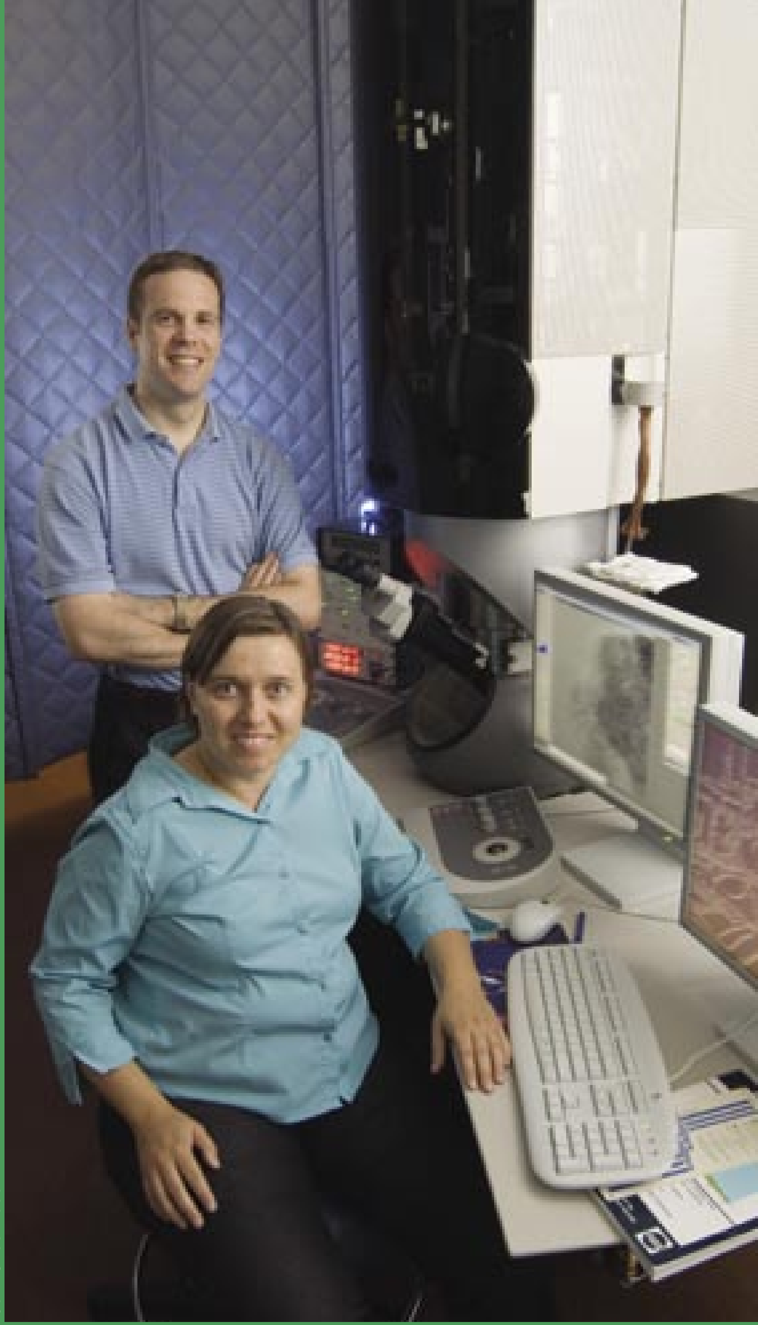
Rochet says, "By collaborating with Lia, we are in a unique position to combine the functional information from studies in my laboratory with structural insights obtained using her cutting-edge electron microscopy methods."

"My job is to use these methods to figure out how the structure is changing," says Stanciu.

To explain Stanciu's contributions to his research, Rochet says, "One can consider different views of any of Purdue's red-brick buildings. A far-away view, analogous to what would be obtained using our previous methods, would allow us to realize that the building has a reddish color, whereas the more powerful, close-up view, similar to what is perceived by electron microscopy, would enable us to visualize the fine structure of the brick pattern."

Rochet's goal is to use Stanciu's method to examine how the structure of protein aggregates is influenced by oxidative damage, mutations, or the presence of other drugs.

With this collaboration, it's hoped that another piece of the Parkinson's puzzle (and other neurological diseases) will be solved. ■ **L.L.**


John Underwood

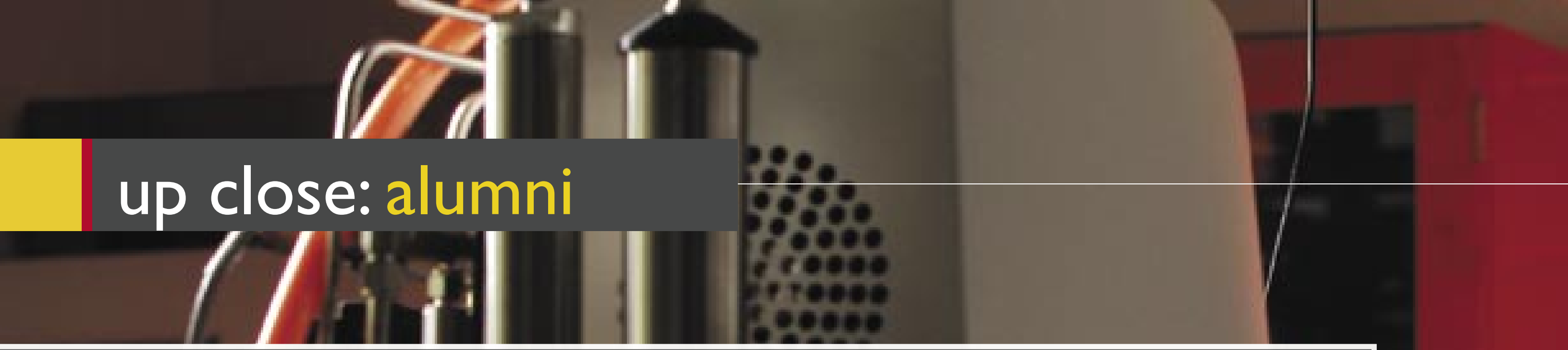
Lia Stanciu and Chris Rochet

leaving a flat plateau. Performing mechanical tests on cylinders from different regions of the plateau, she came up with a map of the bone's different regions and strongest areas. "We want to eventually have a material that represents the different properties across the plateau," says Calvert-Doyle. "Right now, I've completed the bone testing. I have an idea of how the properties vary across the plateau and how osteoporotic bone compares to regular bone." The key now will be to use this knowledge in developing a material with these properties.

"Once we've created a testing material that is representative of human bone," she says, "it will work for all knee implant designs." ■ **L.L.**


Vincent Walter

Kevin Trumble and Kayla Calvert-Doyle examine bone structure.



Vincent Walter

up close: alumni

Materials Engineering's Next Frontier

An alum examines the intersection of medicine and materials.

A Natural Decision

A self-professed "farm boy" from Bremen, Indiana, Ryan Roeder's (BSMSE '94, PhD '99) decision to attend Purdue was a no-brainer. "I grew up in a family with strong ties to Purdue," he says. "But, as a freshman, I had a hard time choosing between materials and mechanical engineering."

Given his enjoyment of chemistry and physics, he ultimately decided to go into materials engineering. "It made sense to me. Materials science is the physics and chemistry of engineering materials!" exclaims Roeder. "My backup plan, if materials didn't work, was mechanical engineering. But, I stuck with materials and never regretted it."

Roeder reflects on his nine years at Purdue with delight. "I formed so many incredible friendships at Purdue, which included meeting my wife and best friend, Lisa, while in graduate school," Roeder says. "Outside my studies, I have fond memories of participating in intramural sports, Christian fellowships, and rebuilding a 1988 Kawasaki jet ski that I bought with a friend. It still runs today."

After graduating from Purdue with a bachelor's and PhD in materials engineering and completing a postdoctorate fellowship in the Department of Orthopaedic Surgery at the Indiana University Medical Center, Roeder accepted a faculty position at the University of Notre Dame, where he's currently an assistant professor of aerospace and mechanical engineering, and is back in the area where most of his family still resides. "This is a big plus in raising kids," he says.

"My studies at Purdue taught me to think critically and independently on open-ended problems," Roeder says. "Today, I find myself emulating much of the way I was taught by my undergraduate professors, including Keith Bowman and Kevin Trumble, and by Professor Elliott Slamovich, who guided me during my PhD research."

The Biology of Materials

Today, Roeder's research focuses on synthetic biomaterials and biological tissues, particularly those pertaining to orthopedics. "In much of my research, I'm looking for an improved understanding of structure-property relationships in biomaterials and human tissue in order to produce new materials that replace, augment, or interact with biological tissues," Roeder explains. "My overall goal is to see that basic scientific research is transferred into new biomedical devices or methods which improve human health."

One of Roeder's projects, funded by the National Institutes of Health, U.S. Army, and the Centers for Disease Control, looks into the development of a non-invasive technique for detecting microdamage in bone—a condition that can lead to stress fractures in active individuals and bone fragility in the elderly. "There is currently no non-invasive means to detect microdamage for either clinical or scientific purposes," Roeder explains. "My objective is to use micro-computed tomography to assess microdamage levels in bone. This could eventually translate into new clinical methods for evaluating bone quality and fracture risk."

In another project, Roeder is investigating the structure-property relationships in composites to identify and mimic the structure and biomechanical function of bone tissue. "We have tailored reinforced polymers to mimic the stiffness, strength, and directionality of bone," he explains. "The response of bone-forming cells in the body to these materials is also being investigated with my collaborators in biological science. My research program is interdisciplinary—intersecting materials science, mechanics, and biomedicine.

"It's my hope that the interdisciplinary nature of my research will cultivate in students a vision that transcends narrow preconceptions of materials engineering and even engineering as a whole."

Materials engineering's next modern transition, he says, will involve problems posed by the complexity of the human body. "In order to meet the challenges of the next century, new synthetic biomaterials must be developed that are able to interact synergistically with natural tissues and biological processes," he says. "One of the next frontiers for materials engineering is and will be the interaction of biology and materials." ■ **Lee Lamb**

Everyone's Favorite Aunt

Donna Bystrom holds Materials Engineering together.

Donna Bystrom: diplomat, supervisor, event planner.

To tell her story of serving Purdue's School of Materials Engineering (MSE) for over two decades, Donna Bystrom—their matriarch—points to the personal photos of faculty, students, and alumni covering the front wall of the MSE office. The pictures announcing a birth, marriage, or a big move show the history of a tightly knit family.

"Donna knows the names of most of our alumni, their spouses, children, and even their pets," say Alex King, professor and head of MSE. "She even knows who likes what kind of food!"

Over the years, Bystrom has seen students grow into their engineering careers, and she keeps tabs on them.

"When I was president of MSE's student organization, Donna mentored me on leadership and always donated extra time to help with our organization's events," says Dustin Ruh (BSMSE '03). "Now that I'm an alumnus, Donna takes the time to keep in touch with me and provides valuable insight during tough decisions."

Bystrom says, "The students aren't just numbers. We get to know them by name, and we're always glad to hear from them after they leave us."

"Donna is everyone's favorite aunt and has had a profound impact on two decades' worth of MSE alumni," says King. "She is the true 'head' of the school. Donna holds us all together."

Many in MSE describe Bystrom as a diplomat, supervisor, and event planner. A typical day might see her coordinating projects with faculty, scheduling meetings, organizing receptions, or working on documentation for faculty awards and promotions—all while dealing with interruptions from faculty, staff, and visitors. Bystrom is the center for all of MSE's administrative, clerical, and hosting activities.

"Donna organizes receptions and open houses. All from planning to set up to clean up, even at out-of-town alumni receptions and national technical meetings," explains King. "She has created a vibrant and effective alumni relations program on a volunteer basis and even sometimes over my own objections!" Recognizing her professional achievements and contributions, the College of Engineering awarded Bystrom its Leadership Award in 2005.

"Donna has contributed to the smooth functioning of our school for nearly three decades and has been described as the only staff member who can substitute for all office workers," says Mysore Dayananda, materials engineering professor and associate head.

Throughout her 35-year career at Purdue (28 of those years have been in MSE), Bystrom has seen the school evolve. In 1988, Bystrom coordinated the school's relocation from the CMET Building to its current location in the MSEE Building. And with the school moving once again next fall to the Neil Armstrong Hall of Engineering, Bystrom is overseeing many details—assessing space needs and allocation for faculty and staff.

The move to Armstrong signals many changes occurring within the school, and Bystrom lights up when she talks about the future. "The school is growing and is in good shape. There are more students. The curriculum is expanding, and some faculty members are getting the opportunity to move to the Birck Nanotechnology Center in Purdue's Discovery Park," Bystrom says. "We'll miss seeing those faculty members and students on a daily basis."

As excited as she is about MSE's advancements, Bystrom can't help but feel a little regret that it's becoming more difficult for her to cultivate those close relationships she's used to having with faculty members and students. "I don't have quite as much contact with students as I used to, due to changes in my responsibilities." Bystrom says.

continued on next page

"Donna is *everyone's* favorite 'aunt' and has had a profound impact on two decades' worth of Materials Engineering alumni."

No one seems to think that anyone else can fill Bystrom's shoes. It doesn't take much time spent in MSE to realize that everyone respects, admires, and depends on Bystrom.

"Her leadership comes from the genuine personal relationships she seems to have with virtually everyone who walks through our doors," says Kevin Trumble, professor of materials engineering.

Materials professor Elliott Slamovich adds, "Some day in the not too distant future, Donna will retire, leaving a giant hole in our school. Until then, we all look forward to working with her—few people have the commitment it takes to make contributions on the scale Donna has."

■ **William Peck**

What's in a Name?

Why we're called the School of Materials Engineering at Purdue.

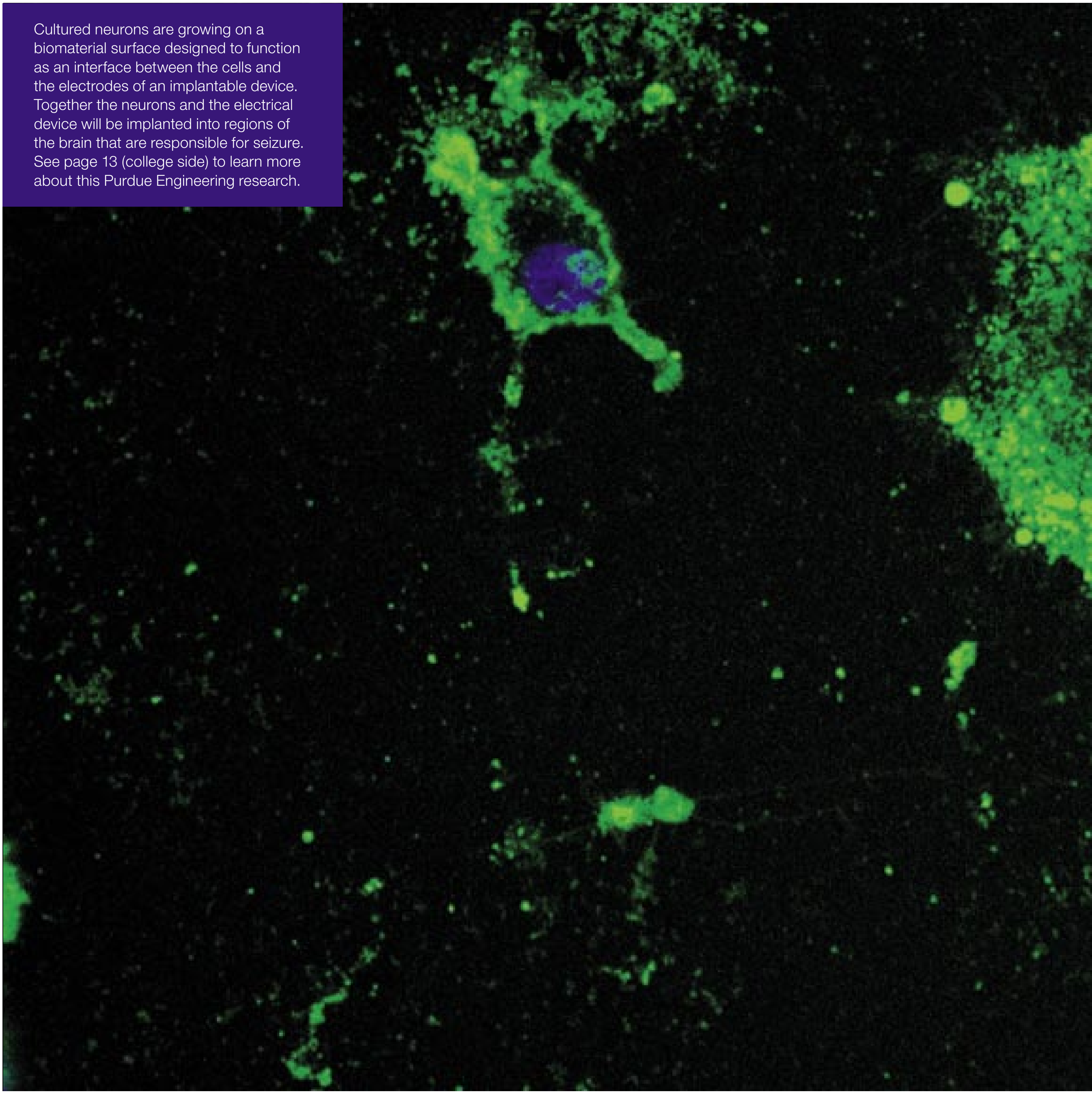
The history of a name.
At most other universities these days, materials are studied in a "Department of Materials Science and Engineering," a name that has gradually become standardized since it was first coined at Northwestern University in the 1960s. The predecessors of all these departments of Materials Science and Engineering were typically departments of Metallurgy, Metallurgical Engineering, Mining, Ceramics, and so on. And, yes, we were called the School of Metallurgical Engineering in 1959 (when it became independent from the School of Chemical Engineering), before the school adopted its present name in 1973.

So why are we a "school" instead of a "department?" And why don't we include "science" in our name?
It's partly a matter of tradition and partly a reflection of our particular style. Our undergraduate degree is a bachelor's in materials science and engineering, and this gives us our familiar three-letter campus code, or designator, "MSE." Even this is sometimes written as "MsE," acknowledging the difference between the school's name and that of the materials degree.

What's the difference between a school and a department at Purdue?
Academic units at Purdue may be schools or departments. Generally speaking, schools are larger, more independent, and more powerful units—operating much like colleges on many large university campuses. The right to award degrees is vested only in the schools. The School of Liberal Arts has departments such as English and Philosophy, and the School of Science has departments of Physics, Chemistry, Math, and Biology. But the College of Engineering comprises 11 schools and two departments. We take pride in our school designation, which reflects a certain independence of style. This is embodied in our unique approach to the teaching of materials.

Where's the science?
Well, we do teach a lot of science. Campus legend has it that there was once an objection to the already powerful Schools of Engineering venturing into the hallowed field of science but, in fact, the title reflects our approach to materials—that we study them because of their engineering utility, not their scientific beauty. This is not to say that we are above stopping and smelling the scientific "roses," and much of what we see in our microscopes is, indeed, truly beautiful. We just begin with the question, "How could you make that?" And then lead up to, "Why does it work?" The emphasis on engineering is not in opposition to science, it's just the fundamental reason for doing what we do, and it is appropriately reflected in our name.

■ **Alex King**



Cultured neurons are growing on a biomaterial surface designed to function as an interface between the cells and the electrodes of an implantable device. Together the neurons and the electrical device will be implanted into regions of the brain that are responsible for seizure. See page 13 (college side) to learn more about this Purdue Engineering research.