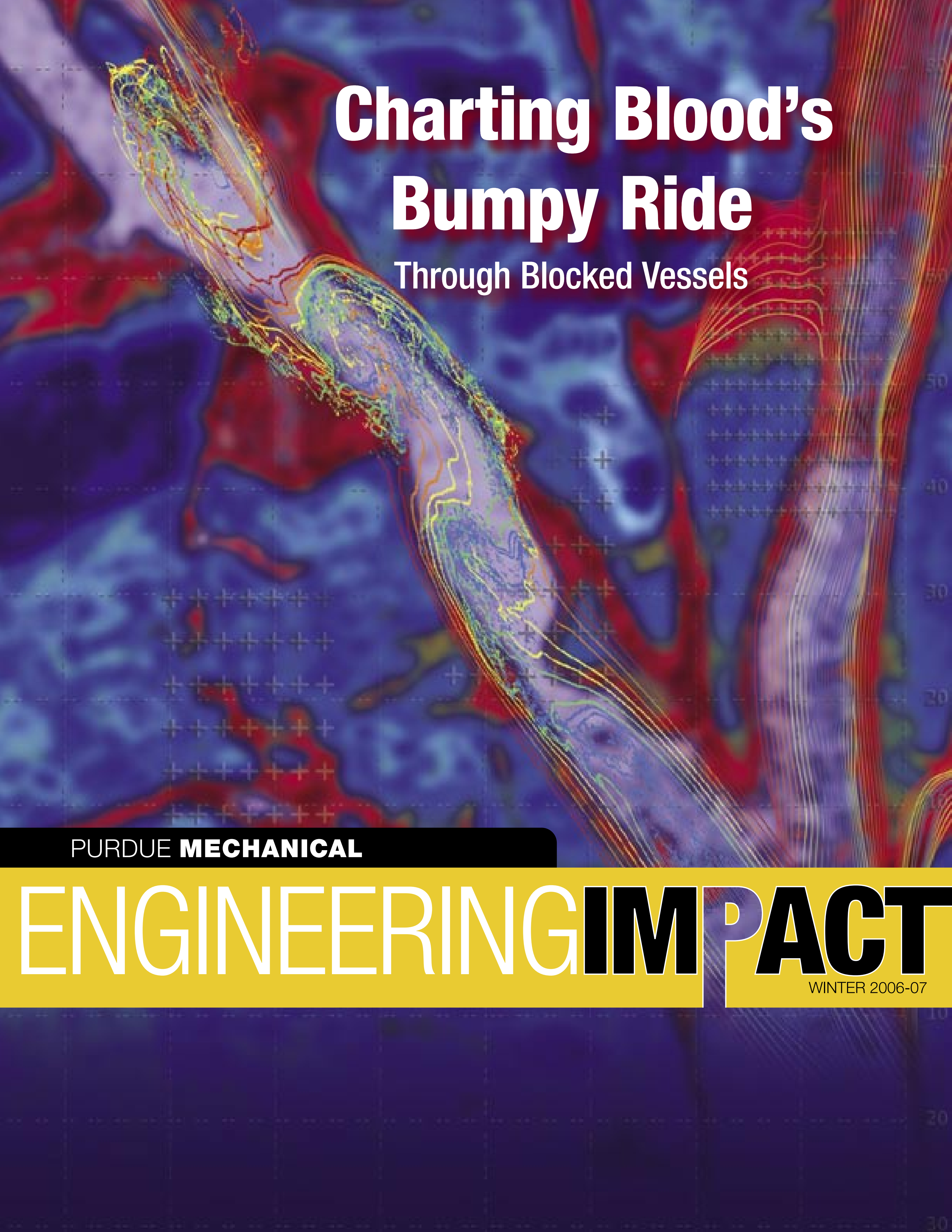


Charting Blood's Bumpy Ride

Through Blocked Vessels

PURDUE **MECHANICAL**

ENGINEERING**IMPACT**

WINTER 2006-07


Arline Meehan

Turn to page 15 for scenes from Homecoming.

From Dan's Desk

Just as the computer made the slide rule obsolete, transformations in the work we do and the ways we do it are making the traditional narrow image of the mechanical engineer obsolete. Mechanical engineers are using fundamental tools to solve problems in ever-widening fields.

As you'll read in the following pages, which take up the theme of healthcare, Purdue mechanical engineers are applying their expertise to cardiovascular disease, to the mechanics of voice production, glaucoma, and orthopedic implants—even to the study of soccer headers.

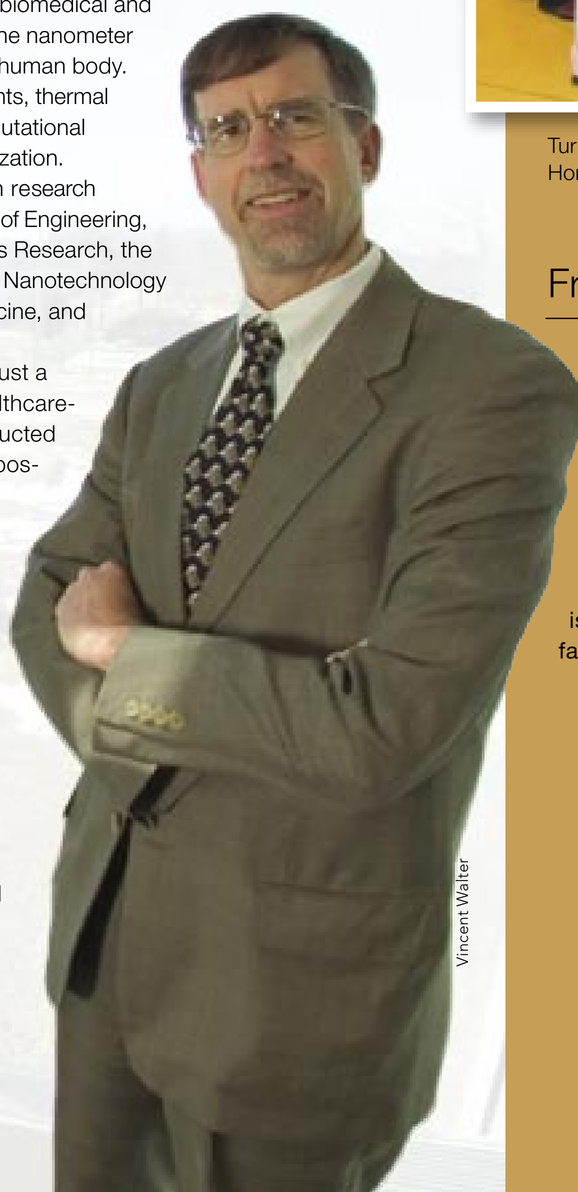
Within ME and our Herrick and Zucrow Labs, we have a range of equipment and expertise for biomedical and human-health-related activities from the nanometer scale to the level of mechanics of the human body. We perform physiological measurements, thermal imaging, cell and tissue culture, computational modeling, and biomaterials characterization.

ME faculty and students work with research groups across and beyond the College of Engineering, including Purdue's Center for Paralysis Research, the Bindley Biosciences Center, the Birck Nanotechnology Center, the School of Veterinary Medicine, and the IU School of Medicine.

In the following pages we present just a few examples of the multitude of healthcare-related research projects being conducted by mechanical engineers and made possible because of the generous support of alumni, friends, and industry partners. With your continued support, these activities mark only the beginning of Purdue ME's work to solve grand challenges in healthcare. I trust you'll be impressed and even gratified.

Dan

E. Dan Hirleman
William E. and Florence E. Perry Head
School of Mechanical Engineering


Vincent Walter

From the Editor

As you can see, your alumni magazine has assumed a revised identity: *Engineering Impact*. To learn more about this name change, please flip this publication to the college side and check the inside front cover. What are your thoughts about our new name or about the stories you find in this issue? Write to us (see address on facing page) and let us know!

Lisa Hunt Tally

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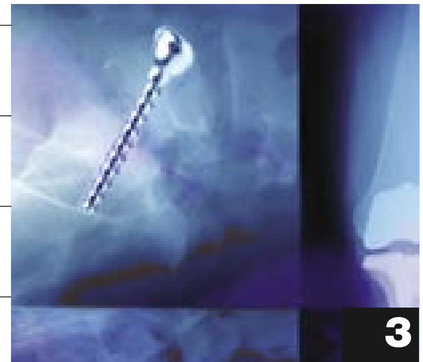

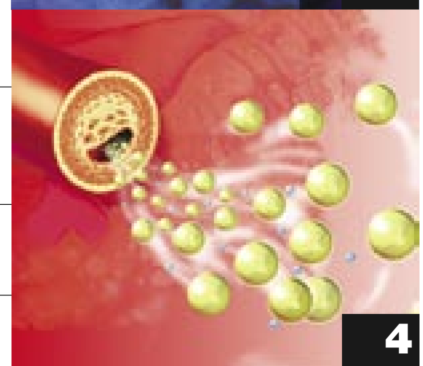

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UNS staff photo

Douglas Adams, right, and research engineer Ronald Evans, left, with doctoral student Harold Kess, who's using a "modal impact hammer" to tap the hub portion of a Stryker wheel assembly.

Stryker Force

Purdue joins with the Army to improve the maintenance of the newest ground combat vehicle deployed in Iraq.

Purdue mechanical engineers have teamed up with the U.S. Army to design a new portable test system ensuring the safety and readiness of the eight-wheel "Stryker" vehicle, the newest ground combat vehicle deployed in Iraq. The system uses sound waves to detect damage to a key component in the vehicles' wheel assemblies.

"Excess dynamic forces can cause cracks to form in a critical component of each wheel assembly called the spindle, which supports the wheel," says Douglas Adams, an associate professor of mechanical engineering. "The cracks can grow large enough to cause the spindles to break apart. As with any wheeled vehicle, if the supporting spindle fails, the wheel might fall off. The inspection system looks for these cracks so that damaged wheels can be replaced."

The Army has worked with Purdue to develop a proactive approach to manage the health of spindles in the field, Adams continues. "This is an opportunity to keep vehicles in service and reduce the costs of operating a tremendously important asset in the Army's arsenal."

Strykers are used in a variety of roles, including infantry carrier, commanders' vehicles, medical evacuation, reconnaissance, anti-tank guided missile delivery, fire support, and mortar carrier.

"To develop our software algorithm for the test kit, we had eight assemblies that were cracked, plus a bunch of other assemblies that weren't cracked," says Adams, whose research is based at Purdue's Ray W. Herrick Laboratories. "We tested all of the assemblies, cracked and not cracked, and used those results to develop our algorithm. Then we tested our algorithm on assemblies in which we did not know cracks existed."

The "fault-detection method" developed at Purdue uses a sensor called an accelerometer to detect acoustic energy, or sound waves, passing through the spindle. Data collected with the sensor are fed to a computer, where software interprets the information to analyze a part's performance.

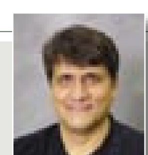
An Army technician or mechanic must first remove the wheel and attach the accelerometer to the spindle. Then a "modal impact hammer" is used to tap the hub on the outside of the wheel assembly, sending sound waves through the spindle. Sound flows through the metal differently depending on whether the spindle is cracked. The sound waves reveal not only the presence of cracks but also how large they are.

Eighteen kits were deployed to Iraq and elsewhere around the world this past May.

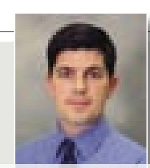
Emil Venere

Welcome to New Faculty

Jason Clark



Steve Son



Greg Shaver

Masa Rao

- **Jason Clark** is an assistant professor whose research interests include the design, modeling, simulation, and verification of complex engineered systems. The overarching goal: to develop the next generation of system-level computer-aided engineering and metrology tools to foster and accelerate advances in tiny technologies for solving societal-scale problems. Application areas include robotics, health, safety, ecology, transportation, communication, and commerce.
- Associate professor **Steve Son** is an internationally known scholar and researcher in nanoscale composite energetic materials and multiphase combustion. His expertise complements the activities of Purdue's Energy Center/Coal Transformation Lab, the NSF Engineering Research Center for Compact and Efficient Fluid Power, and the Rolls-Royce High-Mach Propulsion University Technology Center.
- **Greg Shaver** is an assistant professor whose expertise in the modeling, design, and control of advanced powertrains complements ongoing research in Herrick Labs and the Energy Center aimed at developing engines and related control strategies that can efficiently and cleanly use coal-derived fuels and biofuels.
- Assistant professor **Masa Rao** researches novel micro- and nanofabrication methods and materials for MEMS, MOEMS, RF MEMS, bioMEMS, and biomedical microdevices, working in Purdue's Birck Nanotechnology Center and with the Center for Advanced Manufacturing.

Orthopedic Implants

What's on the horizon?

altered istock

Mechanical engineering is a fertile breeding ground for interdisciplinary endeavors, and no other school embodies Purdue's vision of achieving preeminent interdisciplinary partnerships more than Mechanical Engineering. It should not be a surprise that many mechanical engineers have chosen to work on solving medical problems, such as the degeneration of bones and joints, restoring the flow of the circulatory system, or finding better ways to deliver radiation treatment to people who need it.

Today, total joint replacement surgery enjoys wide acceptance around the world. We all know someone who has had a hip or knee replaced. The cost-benefit ratio of total hip replacement surgery consistently outranks other surgical procedures such as kidney transplant, heart valve replacement, and pacemakers when considering the resulting increase in a patient's quality and length of life. While orthopedic implant technology may have reached a plateau, these metal and plastic devices are the foundation for the next generation of advancements. Biotechnology, nanotechnology, and robotics have started to reshape the world of orthopedic implants.

Biotechnology can improve the function of orthopedic implants through a better understanding of cellular function and by putting biological molecules, such as DNA and proteins, to work, resulting in the integration of pharmaceutical agents, biological compounds, and medical devices. Drug-device combinations that can accelerate the integration of implants into their surrounding tissues, reducing the chance for rejection, can now be realized.

Robotics, with emphasis on sensing, telemetry, artificial intelligence, virtual reality, and haptic interfaces, has revolutionized the manner in which surgeons can deliver orthopedic devices into the patient's body. The ability of the surgeon to better sense and visualize the anatomic implantation site and deliver the implant through minimally invasive means with high precision will result in faster healing times, less discomfort for the patient, and, ultimately, reduced surgical time and complications, which can be translated into savings for the entire healthcare system.

The advent of nanotechnology will allow us to better understand how orthopedic implants interact with their environment at the microscopic level. Nano-engineered materials that self-monitor and adapt will enable the development of self-healing implants that can overcome cracks or defects they might develop over time. When sensory and control capabilities are fully realized at this minute scale, the possibility of intelligent orthopedic implants will be a reality. Imagine devices capable of sensing changes of their environment and either predict—or confirm—imminent failure while still implanted in a patient. This data could be stored, be relayed to a central monitoring station for a physician's review, activate a simple alert signal, or trigger a response of the implant itself in order to prevent catastrophic failure.

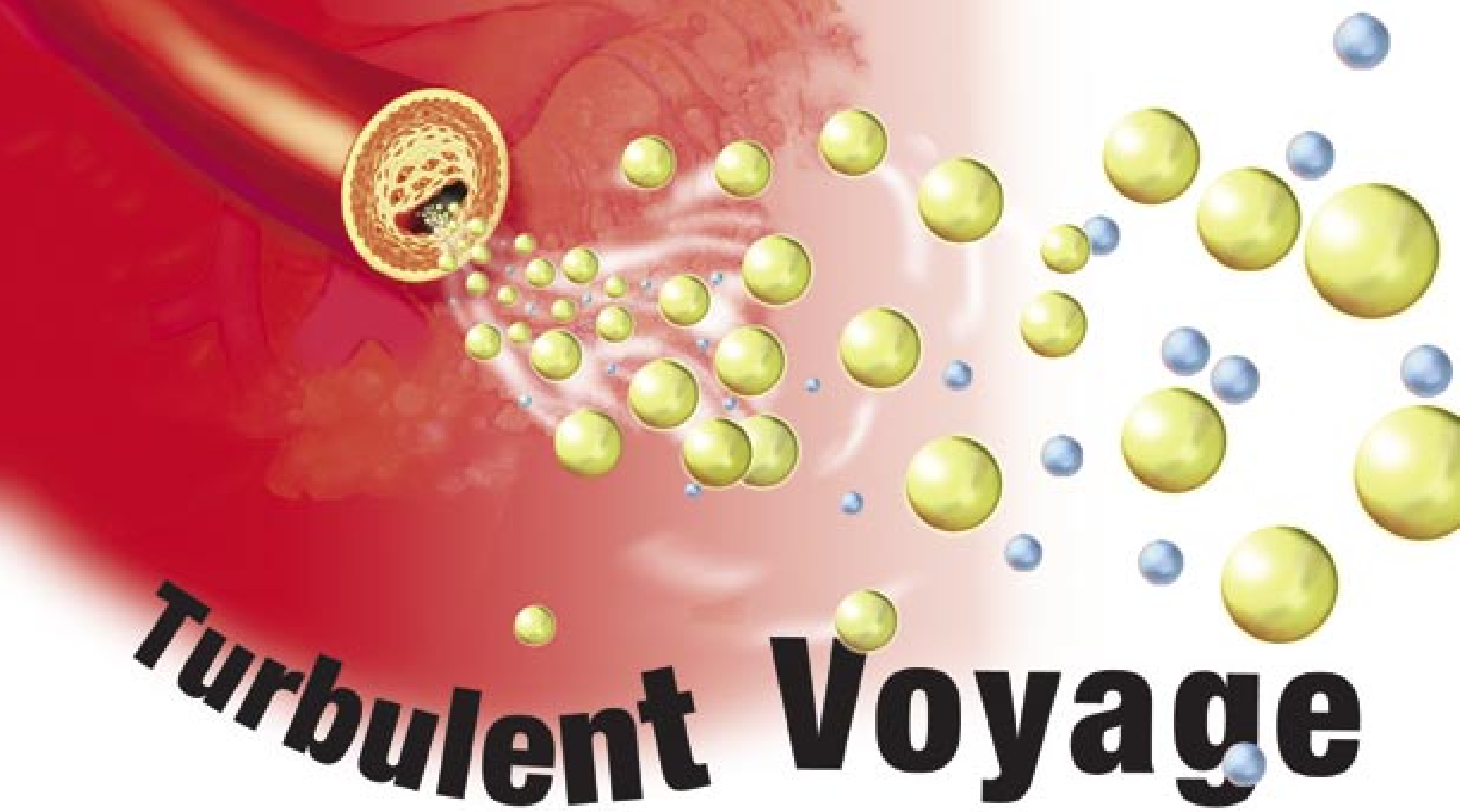
One of many potential applications for intelligent implants is infection. Ultimately requiring a revision surgery if not controlled, a deep infection has a biological origin and multiple symptoms. An intelligent orthopedic device would be able to detect and characterize the cause of the infection. This could be done by either directly identifying the bacterial strain causing the infection or measuring a rise in temperature, since infections result in swelling, which generates heat. The next logical step would be for such an implant to be equipped with an active, therapeutic module pre-implanted with the artificial joint that could be automatically activated to release antibiotic compounds to eradicate the infection, thus preventing the need for a re-operation and hospitalization. As you can imagine, the patient's discomfort and the cost of treatment for an infection are an order of magnitude higher than any discomfort or costs incurred by the original surgery.

The ultimate goal should be to develop orthopedic implants equipped with the capability to continuously sense their own function and environment and control the deployment of a therapeutic component in order to prevent failure. Being able to integrate our knowledge of electronics, mechanics, chemistry, biology, physiology, medicine, and scale is the key to a successful "intelligent implant." Working effectively at the interface of these disciplines will prove the tool that is most beneficial to the patient and most useful to the physician—and you can bet that Purdue mechanical engineers will continue to lead this revolution!

■ **Jorge Ochoa**

Jorge Ochoa (MSME '87, PhD '91) is vice president for research and development and chief technology officer of Archus Orthopedics Inc., a development-stage medical device company.

provided by Jorge Ochoa



Turbulent Voyage

Mechanical engineering professor Steve Frankel uses computational fluid dynamics to help predict and better understand the violent loops, eddies, and swirls in atherosclerotic arteries.

Combine *athero* ("porridge-like") with *sclerosis* ("hardening"), and you've got one of the deadlier processes within human physiology: the buildup of cholesterol, fatty substances, calcium, clotting material, and cellular waste into a wax-like plaque that sticks to the inner lining of the arteries. Atherosclerosis causes coronary heart disease, the single leading cause of death in the U.S. today, according to the American Heart Association, and it has traditionally been treated through bypass surgery, which reroutes the vessels around blocked or narrowed paths to prevent heart attack and stroke.

Despite its prevalence, atherosclerosis isn't fully understood. In Purdue's School of Mechanical Engineering, Professor Steve Frankel's research group is studying the fluid dynamics of stenotic—that is, blocked or partially blocked—blood vessels to further illuminate the causes and effects of the condition and, ultimately, provide practical help to the medical field.

"What does the presence of that stenosis do to the blood flow downstream?" Frankel asks. "How does the stenosis lead to further irregular flow? How are conditions right for the addition of further plaque? If we knew more about the precise nature of turbulent, irregular blood flow, we could gain a better understanding of how cells are damaged and how they respond."

Normally, blood travels through the blood vessels under laminar, or unidirectional, flow conditions. Atherosclerosis tends to occur where the blood vessels curve or bifurcate. "Those locations are prone to secondary flow," says Frankel. "Primary flow is blood streaming in the main direction of flow. Secondary flow is anything contrary to that: looping, swirling, recirculating flow structures."

Those structures create pockets of low flow, where toxic or damaging substances like LDL cholesterol can accumulate. "In the presence of the blood vessel wall," says Frankel, "this kind of flow can trigger a biological reaction in which the wall thinks it's under attack, and this may lead to further plaque buildup."

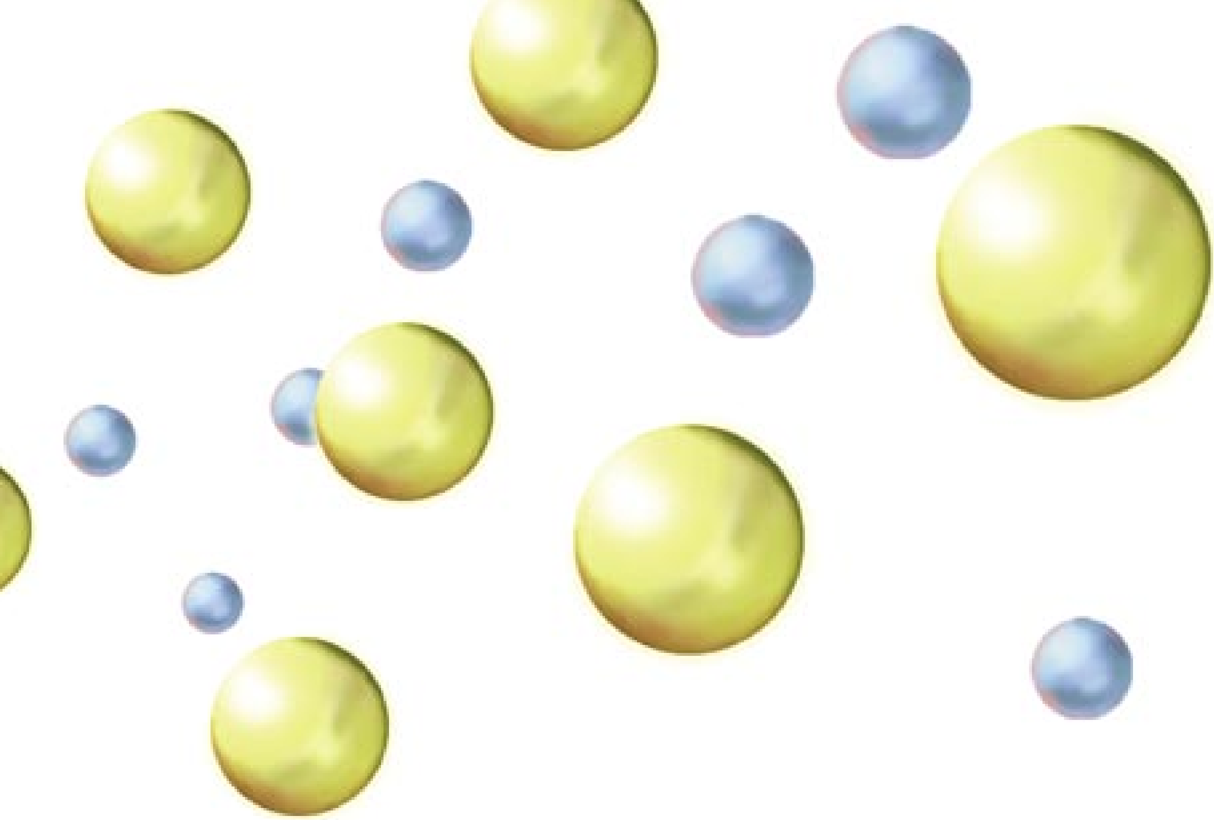
The buildup of plaque means the beginning of a blockage, which creates further irregular flow. "It's like putting a little ramp into the artery's wall," Frankel continues. "The blood has to go over it. It starts going too fast and doesn't flow smoothly, and introduces recirculation and quiet flow in the wake of this bump—which may lead to further buildup of plaque." And more blockages.

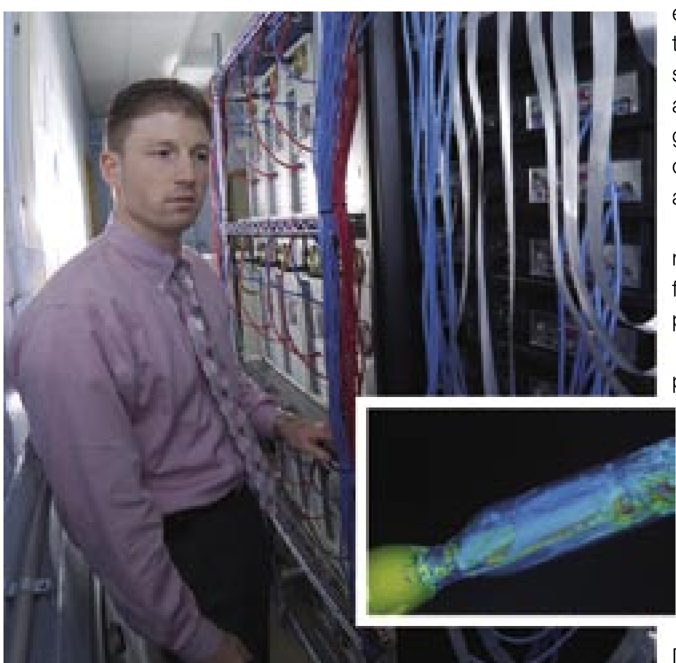
Even if the blood vessel isn't fully blocked, the likelihood of a fatal outcome remains high because of the presence of vulnerable plaque: soft, fibrous-capped formations that are prone to rupture from the pounding blood flow and to produce deadly clots.

Number Cruncher

Frankel employs computational fluid dynamics (CFD), a form of computer simulation, to gain insight into turbulent blood flows.

"To simulate pure laminar flow, the equations that need to be solved are very well understood and can be numerically solved accurately," he says. "But for blood flow through stenotic arteries, the question is much more difficult. That's due to the possible presence of transitional or turbulent flow, which is irregular and appears random. To use the same equations [as for laminar flow], you need much finer numerical resolution."





Vincent Walter

“If we knew more about the precise nature of turbulent, irregular blood flow,” Frankel says, “we could gain a better understanding of how cells are damaged and how they respond.”

Frankel puts the required equations through a process called discretization, which converts partial differential equations—calculus—into algebraic equations, which computers can solve. “We employ a grid, or mesh, of points within the space representing the interior of the blood vessels,” he says. “We’re able to predict the velocity of the blood flow only at those discrete points. If those points are close enough together, and if we march along at small enough time steps, we can possibly resolve the wide range of length and time scales associated with unsteady turbulent flow.”

Of the tools available for computational fluid dynamics, the next-generation technology *direct numerical simulation* uses a fine enough mesh to resolve all of a problem’s spatial and temporal scales. “It’s the ultimate experiment,” Frankel says.

Other tools include a quicker (and thus less expensive) approach that attempts to predict average data rather than actually simulating a random signal varying wildly in space and time, as with DNS. “That brings in what’s called *turbulence modeling*,” Frankel says. “Anybody who takes a commercial CFD code and applies it to a turbulence problem has to select a turbulence model as a menu option in the package. The accuracy of the prediction depends critically on the accuracy of the turbulence modeling.”

One other tool—between the averaged approach and DNS—is *large-eddy simulation*, a technique developed for weather forecasting that uses a grid fine enough to capture big eddies but not small ones.

Using data from some landmark in vitro stenotic flow experiments conducted in the late 1970s and early 1980s, Frankel set out to determine whether existing commercial turbulence models actually predicted turbulent blood flows that agreed with the experimental data: “We started out by using existing tur-

continued on next page

bulence models and the averaged approach and then comparing our results to the experimental data, and we found that agreement was not good. Then we moved on to the DNS approach and, interestingly enough, also did not find good agreement."

The 5 Percent Solution

Frankel's group introduced a shift in the simulated stenosis, offsetting the symmetrically placed blockage by 5 percent. Working with Argonne National Laboratory's Paul Fischer on IBM's Blue Gene parallel-processing supercomputer, the team computed data for some 2.3 million discrete flow points in time and in space—and found "an unbelievably rich, beautiful turbulent flow," says Frankel. "This case is interesting," he adds, "because in a biological case, you'd never get a symmetric stenosis in your body."

The research has yielded a gold-standard data set that can be used for researchers conducting future studies. It's also yielded the finding that turbulent blood flow caused by atherosclerosis results in a 30-fold increase in damaging shear stress on the walls of the blood vessels immediately downstream of the blockages.

"The endothelial cells—the cells that make up the blood vessel walls—are like shingles on the roof of your house," says Frankel, "and the frictional force of the turbulent flow can rip those shingles off. If the irregular flow hits the endothelial cells on a regular basis, you're going to have further progression of plaque buildup."

DNS has been useful for gaining insight into turbulent blood flow and for providing a computational database for comparison to predictions from existing commercial models. Despite its accuracy, though, DNS is not useful at this point for everyday engineers or scientists to employ to make predictions about the cardiovascular system, because time is always pressing. "When a physician wants to potentially use a computer model to understand a patient's case," Frankel notes, "you can't wait weeks to get the result." He is continuing his research with Fischer at Argonne, using large-eddy simulation.

As he works to lay the foundation for accurate blood-turbulence models, Frankel foresees the day when so-called computational surgery will be the norm. "When you have models that are able to predict how blood will flow through stenotic arteries, then a surgeon could use that information and prepare before an operation by asking, 'If I reroute this vessel over here, how's that going to change the flow picture everywhere else?' Or, using a computer in the operating room, the surgeon could drop and drag representations of the patient's arteries in a real-time 'what if' exercise, reacting on the fly to unexpected developments on the operating table."

The possibilities are intriguing. For now, though, says Frankel, "there's an urgent need for more accurate models to predict these complex flows. That's the message."

■ **Lisa Hunt Tally**

As Small as Life

Contributing to Purdue Mechanical Engineering's research into stenotic blood vessels, professors Mike Plesniak and Steven Wereley, with doctoral student Sean Peterson, have conducted experimental studies using a glass-and-Plexiglas physical model of a section of a large artery containing a stenosis, or blockage, along with actual bovine endothelial cells, to investigate blood flow and its effect on those cells. The purpose is twofold: to discover what the flow patterns around the cells are at the microscopic scale, and to provide benchmark data for computer modeling.

Whereas other researchers looking at stenotic blood flow conduct studies at larger-than-life scales without live cells, Plesniak's niche is in using the real-life-sized arterial models. "Live endothelial cells can't be scaled up," notes the researcher, who was appointed to the Eugene Kleiner Chair for Innovation in Mechanical Engineering at Brooklyn's Polytechnic University just this fall.

Wereley provides expertise in new experimental techniques called micro particle image velocimetry that can make measurements at small scales. Mimicking the heart's pumping action, the researchers work with a pulsing flow, performing complex, realistic experiments to determine the forcing on cells. Colleagues in Biomedical Engineering examine the cells' biochemical and genetic responses to this hemodynamic forcing in the same facility.

Looking down the road, Plesniak says, "We need to develop models that take information from short-time-scale experiments and predict outcomes over the long term." The ultimate goals: to work with medical scientists to develop pharmaceuticals that inhibit plaque formation, and to be able to perform faithful computations using patient-specific images of diseased arteries, for use by physicians for planning surgery.

■ **L.H.T.**

GLAUCOMA'S ANATOMY

Eric Nauman is applying structural mechanics to the understanding and eventual treatment of the disease dubbed the "silent thief of sight."

Vincent Walter

Glaucoma strikes without fanfare. Half its victims won't realize they have the disease—the second leading cause of blindness worldwide, after cataracts—until permanent damage to the eye has occurred. The U.S. alone counts more than 4 million glaucoma sufferers, 120,000 of whom have gone irreversibly blind.

At Purdue, in research funded by the National Institutes of Health, mechanical engineering professor Eric Nauman and his research group are studying the eye's structure in order to determine precisely what the root cause of glaucoma is. The disease—actually a class of disorders that damage the optic nerve, which carries visual information to the brain—is poorly understood, and only in the past six years has the medical community begun collaborating with structural mechanics experts.

"The eye is one of the more complicated structures in the body," says Nauman, a self-described "mechanics guy." "With glaucoma, we're trying to figure out what's happening from a mechanics perspective, and we're trying to develop a stem-cell-based treatment to repair the nerves and the support cells."

The eye is a pressure vessel, and the optic nerve—a bundle of nerve fibers, or axons, that also contain blood vessels—must pass through a hole at the back of the eye in order to reach the brain. "Any time you have a hole in your pressure vessel, that's a problem," Nauman says. "That's where it wants to fail." The sieve-like lamina cribrosa forms the exit for the nerve fibers.

Most glaucoma sufferers have abnormally high eye pressure, and as that pressure tries to expand the eye, Nauman says, "the lamina cribrosa has to hold it all together in the back. So under high pressure, the axons at that site start to die." No one is exactly sure why they die, but a loss of peripheral vision, and in some cases, all sight, is the result.

Applying beam theory ("all that stuff our students get in their 'Mechanics of Materials' class," Nauman says), the research group has investigated whether the stresses in the compromised axons were too high—and found that they weren't.

"What we think is happening is that as the axons stretch out, you bend them, and the blood stops flowing, so the nerves start to die," he says.

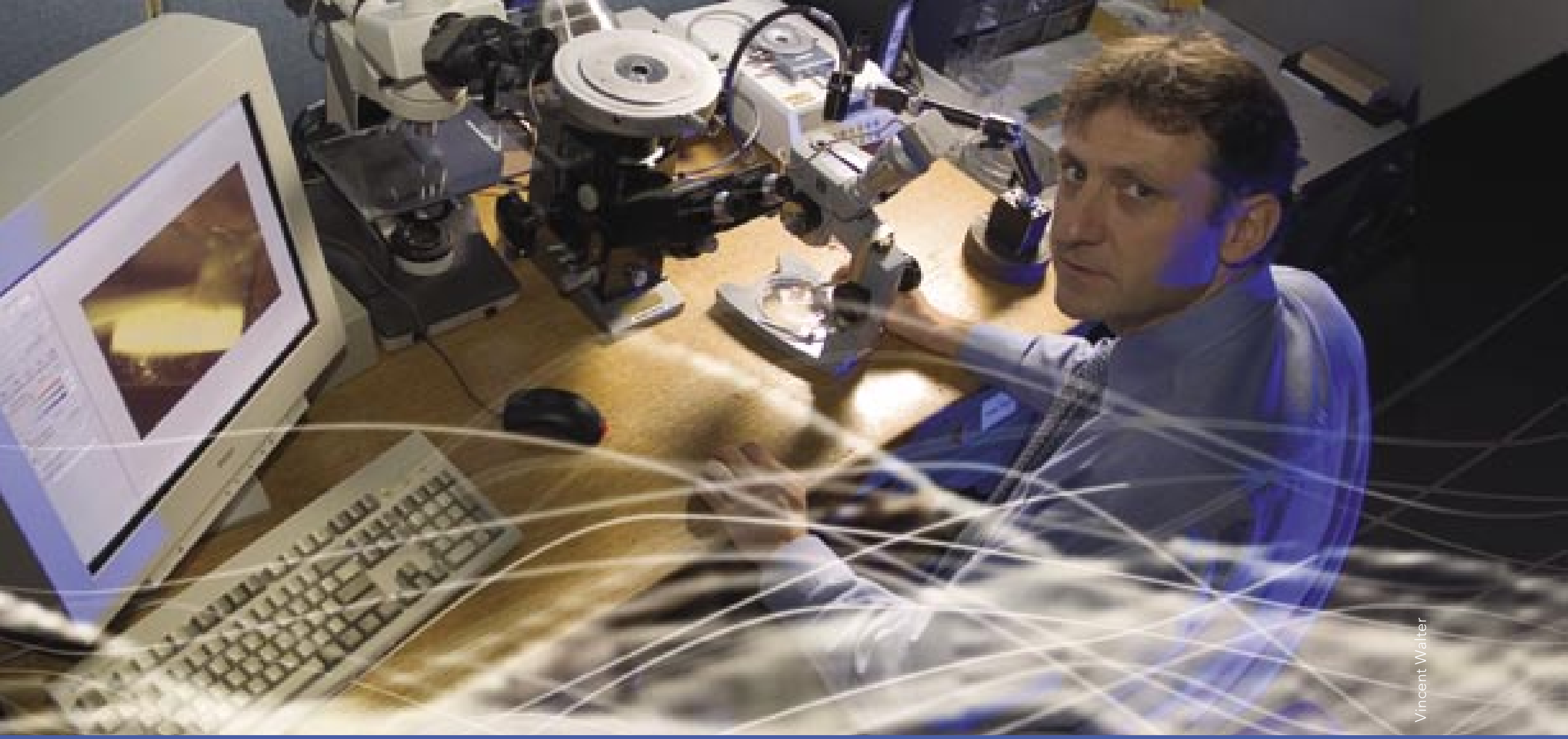
The researchers are working on an approach for rebuilding the axons, using adult stem cells and porous scaffolding with the long-term view of regenerating tissue and replacing the interface—the lamina cribrosa—and reconnecting the axons across it. In the shorter term, the group will be reporting findings in the *Journal of Biomechanical Engineering* that characterize the levels of stress and strain at the optic nerve head through microstructural computer modeling of the lamina cribrosa.

"If we can detect glaucoma earlier, and discover how to provide regeneration," Nauman says, "it can really open up a lot more possibilities in terms of treating patients."

■ **L.H.T.**

Arline Meehan

The lamina cribrosa forms the eye's exit for the optic nerve. Archetypal models of the lamina cribrosa enable Purdue researchers to calculate the mechanical properties and mass transport characteristics of the tissue.



Vincent Walter

VISUALIZING THE VOICE BOX

For Thomas Siegmund, mechanical engineering is the window into a better understanding of the human vocal folds.

Hold an air-filled balloon and release a rush of air through its neck. Adjust the length and tension of the neck, and you change the sound produced. That familiar exercise represents just what mechanical engineering professor Thomas Siegmund is investigating through research on the human vocal cords, or vocal folds.

According to the National Institutes of Health, more than 7 million people in the United States have trouble using their voices. "We hope to accomplish an understanding of how the length, thickness, elasticity, and viscosity of the vocal folds create differences in pitch," Siegmund says. Understanding the biomechanics involved and describing the behavior of the vocal fold is fundamental to the ultimate goal: enabling reconstructive surgery for patients that provides the best acoustic match to the original voice, whatever the age or gender of the patient.

Damage to the voice box can result from cancer, vocal-fold paralysis, or trauma, including intubation. Researchers are looking to understand how these conditions affect voice and speech and to search for custom-tailored replacement materials for patients who've suffered such damage.

In speech production, the vocal folds vibrate to produce sound when air expelled from the lungs flows past. Funded jointly with Siegmund by the National Institutes of Health, colleague Dr. Roger Chan of the University of Texas Southwestern Medical Center uses human tissue samples to measure mechanical properties directly, and Siegmund, together with doctoral student Kai Zhang, develops constitutive models of tissue viscoelastic ("stretchiness") behavior.

In their models, these researchers account for the fact that vocal folds are actually multilayered tissue structures. "It's rare data," Siegmund says, referring to the vocal-fold samples, "compared with bone, for which there are thousands of data points.

"The models describe the highly nonlinear and dissipative relationship between an applied stretch and the resulting stress and their changes over time," he continues.

Top view of the vocal folds

Given that view, Siegmund has been able to quantify, for example, the biomechanics governing how men's voices rise in pitch after age 40 while women's remain rather constant.

The researcher intends to expand the complexity of his computer models in order to describe vocal-fold behavior in more complete ways. "It's gratifying," he says, "to apply engineering knowledge to help people."

■ **L.H.T.**

Going With the Flow

Carl Wassgren's research may make pharmaceuticals an easier pill to swallow.

Taking a seat in the atrium of the Materials and Electrical Engineering Building, Carl Wassgren discusses particulate behavior against the background noise of students and the grinder of a little coffee stand. An associate professor of mechanical engineering, he studies the flow of particles and powders in particulate systems. It's not the most popular field in mechanical engineering, but it may be its best-kept secret. Pharmaceuticals, food products, chemicals, metallurgical products, building products, and many other products are typically, at one time or another, handled as particles, and it's what happens in this handling that fascinates Wassgren.

Wassgren (shown at right) concentrates primarily on pharmaceutical engineering. The pharmaceutical industry encounters problems with the application of tablet coatings, the granulation of small particles into larger particles, the flow from hoppers and bins, and the inevitable attrition, or chips and breakages, of tablets. The current method for these processes is primarily "trial and error," Wassgren says. He is working to make solid-dosage tablet production more efficient and predictable.

One of the methods that he employs is discrete element modeling, in which he designs computer simulations to replicate the dynamics of real particulate systems. "One of the big problems with experimentation in this field is, unlike liquids or gases, you can't see through the particles very easily, so you don't really know what's happening on the inside," he says. Wassgren's computer simulations, however, allow him to see whatever he wants in the particulate system and enable him to predict the behavior of powders and particles in the real world.

When Wassgren was a young graduate student, he recalls, he "didn't really have much of a clue that there was even an issue with the flow of particulate systems. What attracted me to the field was that it seemed to be kind of unique. It seemed like there was a lot that was still unknown."

Now the situation is reversed. "When I tell graduate students about this field, they all say, 'Is this brand new?'" However, despite the fact that few graduate students are aware of this research, there are growing opportunities at Purdue for the study of particulate systems, especially in relation to pharmaceutical engineering. Wassgren is member of a Purdue committee that is designing a pharmaceutical engineering graduate program that will offer a master of science, which is expected to be in place and accepting students by the fall of 2007. Purdue has "strong engineering and strong pharmacy programs," says Wassgren. "No other schools have that combination." That gives Purdue the unique ability to offer engineering students a strong career in pharmaceutical manufacturing.

Wassgren enjoys his research because it gives him the ability to sample so many fields, but particles always capture the majority of his attention. "Like the coffee grinding over there," he says as he motions to the coffee stand. "Those are coffee beans, and it's a milling process, which basically is a very common pharmaceutical process where you take big particles and you want to make them into small particles. So even there I kind of pick up on little things."

It's that ability that has made him such an apt researcher of particles. At this rate, he might help end the guesswork that plagues much of our pharmaceutical manufacturing.
■ **William Peck**

Vincent Walter

Operating a hopper.

Soccer Studies

Undergraduate Marc Cyr asks, "Do headers cause brain injury?"

When Purdue student Marc Cyr took a course in the kinetics of human motion last spring, he got to study the dynamics of a baseball pitcher's windup and pitch, of a weight-lifter's bicep curl, of a thrill-seeker riding a rollercoaster—even of a driver hurtling forward in a car crash.

Cyr enjoyed the course so much that he later sought out the professor, Eric Nauman (see page 7), and asked about research opportunities for the fall. He's now enrolled in a for-credit research course in which he'll study the kinetics of soccer's signature move: the header.

"I became interested in biomechanics almost as an afterthought," says Cyr, an Avon, Connecticut, native who set his sights on engineering as a high school student. He knew he was interested in mechanics, he says. When he interviewed with companies through Purdue's co-op program (now called the Office of Professional Practice), GE Healthcare hired him, launching him on a biomed path.

Working at GE Healthcare Technologies in Waukesha, Wisconsin, Cyr completed five rotations (alternating with on-campus academics at Purdue) that exposed him to development, testing, and quality functions related to medical imaging, specifically X-ray and CT (computed tomography) machines. Among his assignments: simulating the lifespan and performance of X-ray tubes to be used in a next-generation CT system. "The people I worked with would get very excited about how their newest product could revolutionize the market," Cyr recalls.

Now back on campus to finish up his bachelor's degree, Cyr has returned to the study of human-motion kinetics through his soccer-header project. The header is a player's use of his head to pass, receive, shoot, or redirect the ball. There are standard headers, diving headers, and glancing headers.

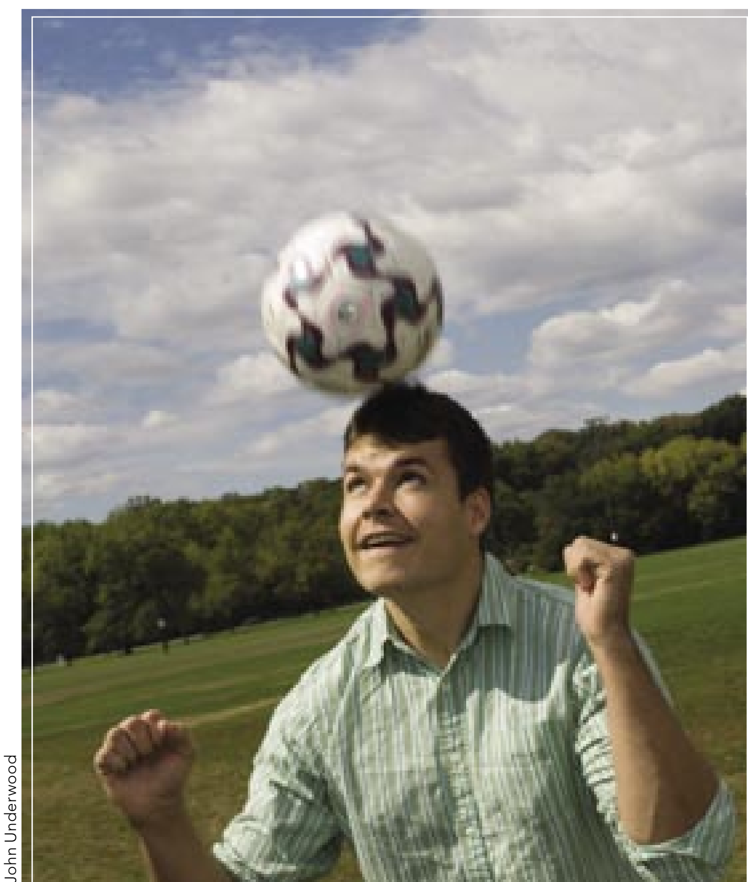
"I'll be using video analysis and numerical analysis to understand what a player experiences when he hits the ball with his head," Cyr says. "Currently, the research papers that are out there disagree over whether you get cognitive dysfunction from a career's worth of headers."

A soccer ball, typically weighing about a pound, can be kicked at more than 74 miles an hour—and deliver enough force to fracture a cheekbone. Whether players are experienced or inexperienced or are expecting the impact or taken by surprise affects what happens, kinetically, during a header. A professional soccer player performs thousands of headers during a career. Cyr himself, who played soccer from the age of 5 through high school, has executed hundreds.

"I'll be looking at video footage and using vector mechanics to quantify what the ball is doing just before and just after impact," says Cyr. "Then I'll be able to 'back out' how much force is experienced by the player."

Next, he'll relate that data to already existing data on what kinds of forces cause brain injury. Ultimately, he says, "we can think about what kinds of improvements can be made to soccer equipment, like thin helmets or headbands, and to techniques that players learn."

■ **Lisa Hunt Tally**



John Underwood

Mechanical Engineering's Mark Cyr, who played soccer from the age of 5 through high school, has executed hundreds of headers.

Taylor amid Facet medical products. Inset: a 3-D model of a next-generation finger-lancing system, which implements low-/no-pain blood-sampling technology.

Photos courtesy of William Taylor

The Quest for a Painless Needle Stick

William Taylor's mission: diabetes testing products.

For the estimated 21 million Americans who have diabetes, William Taylor is an angel of mercy. Taylor has been on a mission to develop a painless and minimally invasive needle stick since his undergraduate days in mechanical engineering at Purdue. Now at the helm of Facet Technologies, he runs a company that is a market leader in the global micro-sampling sharps market for diabetes testing products—and that's good news for all who must endure daily finger pricks as they monitor blood sugar levels.

Taylor (BSME '91) landed his specialization when he joined the School of Mechanical Engineering's Co-op Education Program (now operated out of the Office of Professional Practice) his freshman year. In the program, students alternate sessions of academic study with sessions of work with a qualified employer. Taylor, who had spent the summer before college as a draftsman for an Elkhart-area RV factory, enrolled without a particular focus. He interviewed for co-op positions with various companies, including McDonnell Douglas and the healthcare company Miles Inc. (now Bayer Corporation), and opted for the job with Miles, where he worked in the diagnostics division, focusing on making products to check blood sugar levels. By the time he graduated, he had served as co-inventor on several patents and had been project manager on a safety finger-lancing device for blood sampling.

With degree in hand, Taylor joined the Miles R&D department as lead mechanical engineer on various blood glucose meter projects. He moved to Gainor Medical in 1994; the company's name later changed to Facet Technologies, and it was purchased by Matria Healthcare Inc. in 1999.

Gainor grew rapidly. When Taylor started, the company had about 25 people and $15 million in revenue annually. Now, with 300 employees, the company's annual revenue totals $85 million. In late July 2006, Facet was sold to Water Street Capital Partners, a private equity firm focused on healthcare. Taylor is to become CEO of the new company, which will be independent rather than a subsidiary as it was under Matria. This will allow Facet to invest its profits back into itself. "This will spearhead a higher level of growth and allow us to expand our business in handheld medical devices for microsampling and specialty sharps," Taylor says.

Taylor's work may seem a long way from Purdue engineering classes. But he says it was part of a plan he devised in a senior engineering course called "Creativity in Engineering." The professor asked the students to form a mental picture of where they wanted to be in 10 years; Taylor said he would be manager of a medical device company. Dead on—in 2001, he was appointed president of Facet Technologies.

Facet, whose services include medical device design, development, and commercialization, is based in Marietta, Georgia. The fundamentals of mechanical engineering play an integral role in the design process, ensuring that the dynamics of the lancing system are precisely controlled, the manufacturing processes are tightly controlled, and the final product—billions of units—gives precise results. Potential areas for expansion include vascular suturing, biopsy, and other specialty surgical devices where precise manufacturing and innovation in product development is essential, according to Taylor.

As a guest lecturer in Purdue's ME 290 class ("Global Engineering Professional Seminar"), Taylor told undergraduates that having a passion for what you do is essential to a fulfilling and successful career.

And with an ME degree, he adds, "there are so many different directions you can take and have an impact on a company and its services. The possibilities are endless."

An estimated 41 million Americans have been identified by the Centers for Disease Control as pre-diabetic. With such staggering figures, the future for blood glucose testing devices seems well assured.

Or, as Taylor might say, the possibilities are endless.

■ **Linda Thomas Terhune**

Congratulations to Our 2006 Outstanding Mechanical Engineers

Honored at an October 26 ceremony, these seven distinguished alumni have made their marks in cutting-edge MEMS research, energy, higher education, transportation, real estate development, commercial spaceflight, and compressor manufacturing.

John Underwood

Purdue's 2006 Outstanding Mechanical Engineers (from left): Michael S. Kelly, John E. Grimmer, Roger B. Gatewood, Patricia J. Bishop, and James J. Allen (not pictured: John H. Atwood and J. Douglas Field).

James J. Allen
PhD '81
Distinguished Member of the Technical Staff
MEMS Device Technologies
Sandia National Laboratories
Albuquerque, New Mexico

"As a student I was very fascinated and focused on the attainment of science and engineering knowledge, which the mechanical engineering curriculum readily contains. However, through my experiences later in life provided by the military, teaching in academia, and as a researcher at a national laboratory, it is readily apparent that the impact on the world as a whole is much larger than mere science and engineering technology. The satisfactions and impacts range from the use of this knowledge in the defense of our country, the development of technology for the betterment of society, and the interactions with students who will carry this knowledge forward and produce future developments. An engineering degree allows a person to move into many different facets of our society and to make advances for the betterment of all."

John H. Atwood
BSME '51
Retired Chairman, CEO, and President
Atwood Oceanics, Inc.
Barker, Texas

"Graduating from high school in 1940, I attended the engineering school at the University of Wisconsin for one year, prior to the outbreak of World War II. After the war, I was fortunate to be able to have some conversations with the president of A. O. Smith in Milwaukee. He advised me that each year A. O. Smith always went first to Purdue University to interview and hire graduating engineers for their company. I enrolled at Purdue in the spring of 1946, and it has definitely turned out to be one of my smartest moves—and not one of the 'fall downs' in the motto of my life: Fall down seven times, get up eight."

Patricia J. Bishop
MSME '72, PhD '76
Vice Provost and Dean of Graduate Studies
University of Central Florida
Orlando, Florida

"Engineering and engineering education are experiencing significant transition. Technological, social, and political forces are placing a premium on efficiency, bringing multidisciplinary knowledge to bear to solve the most important problems of society. Energy, healthcare, transportation, and poverty will need technological, cultural, and social solutions. Faculty are updating the overpacked undergraduate curriculum, since engineers will need to be more adaptable, multilingual, and work in teams that are more diverse. Engineers will need to be more engaged in their own learning and committed to continuing education. Graduate education has also changed to accommodate the need for advanced education, offering graduate certificate programs and professional master's programs for working professionals. One of engineering's biggest challenges is to recruit the best and brightest into engineering careers. U.S. demographics are changing, and we will miss the best and brightest if we fail to convince our youngsters that engineering is a potential career."

J. Douglas Field
BSME '87
Chief Technology Officer
Vice President of Design and Engineering
Segway, LLC
Bedford, New Hampshire

"As it becomes possible to have a product designed as well as built offshore, the role of creativity in engineering becomes an ever more important competitive advantage. Creativity requires failure, it requires diversity in viewpoints instead of a single 'right' answer, it requires conflict, and it requires humility. New engineers must learn to embrace (and enjoy) this environment, which at first appears messy, unpredictable, and uncomfortable. At the end of the process, the sheer joy of seeing a mind's idea become real makes it all worthwhile."

Roger B. Gatewood
BSME '68
President
Westbay City Homes, LLC
St. Petersburg, Florida

"Science and technology proficiency, once again, is being hailed as the key to maintaining the United States' leadership position in the world as other countries enact programs that emphasize and incubate those skills. Purdue University's top-rated mechanical engineering program has always and will continue to provide students with an unsurpassed knowledge base of science and technology as well as other unique learning opportunities. With this background, I believe that graduates will pursue and excel at any chosen career in their field or area of interest and thus make significant contributions on future critical issues of importance to all of us."

John E. Grimmer
BSME '52
Founder and Chairman Emeritus
Grimmer Industries, Inc.
Franklin, Indiana

"A degree from Purdue led to 16 productive years at Cummins Engine Company. This Purdue/Cummins training gave me the courage to start my own business after developing a new product. I'm grateful to Purdue for launching my career and want to personally congratulate Purdue for rising to national prominence in many academic endeavors and for its leadership in Indiana's economic growth."

Michael S. Kelly
BSME '78, MSME '83
Vice President of Operations
X PRIZE Cup and X PRIZE Foundation
Santa Monica, California

"Engineering is the discipline that gives physical form to thought, in a predictable manner based on scientific knowledge of nature. It's the last part that distinguishes engineering from art, and establishes engineering as the source of all the practical fruits of human creativity. The engineer who originates and executes an idea shares the entire creative experience with the artist, and that is probably the most satisfying aspect of the field. Creating an idea that, when translated into reality, increases the material wealth of humanity is what motivates my life as an engineer. My experience at Purdue was invaluable in showing me how to meld creativity with sound science and engineering. It gave me the tools for fulfilling all aspects of my goals in life."

The Accidental Engineer

For alumnus Melvin Glimcher, educational opportunity is a jewel—
and he intends to share the treasure.

In the early 1940s, as America plunged deeper into World War II, a Massachusetts high school student named Melvin Glimcher had two things on his mind: how to participate "in this great war" and how to get to college. The United States Marines provided the answer, although not exactly in the manner he had hoped.

"The war was encompassing engineering problems [logistics, for example], and the Marines were looking for people who had a scientific background," says Glimcher. The classics-trained student, who had his heart set on medical school, took a special Marine Corps exam, signed on to join the Marines for an officer-training program—and found himself assigned by Uncle Sam to study mechanical engineering at Purdue. "I'd never been further from home [Boston] than Framingham, Massachusetts!" Glimcher says with a laugh.

Dick Myers-Walls

"I never would have gotten through [college] without support myself," says Glimcher.

Once on campus, this "accidental engineer" recalls, "I loved it. I was astounded by the quality of education at Purdue, and I got a very high level of education and teaching at Purdue." He studied high-pressure thermodynamics with renowned ME professors George Hawkins and Harry Solberg (then head of the School of Mechanical Engineering and later an associate dean of engineering) and took extra classes for the sheer intellectual pleasure of doing so. "I couldn't get enough," he says. "The experience was like entering a cave filled with diamonds, emeralds, and rubies, and I wanted to pick up everything that was there."

With a mechanical engineering degree in hand by 1946, followed by a Purdue science degree, Glimcher did eventually earn an MD, becoming one of the first two Purdue alumni to graduate from Harvard Medical School. He later joined the faculty of Harvard Medical School's Children's Hospital, where he currently holds the title of Harriet M. Peabody Professor of Orthopedic Surgery. An early pioneer in electron microscopy and electron diffraction, he helped launch the use of electron microscopy to study the mechanical and biological functions of bone and other calcified tissues, achieving breakthroughs in the field of the structure of bone. He's currently collaborating on quantum-mechanics research aimed at confirming which protein in bone prompts the calcification that makes bone hard.

"I greatly appreciate the values of engineering and science and research," he says, "and how important the teaching at Purdue was in inculcating a philosophy that was applicable to other research aspects, to medicine, and eventually to biomedical and bioengineering sciences."

In 1999, Glimcher funded merit scholarships in the School of Mechanical Engineering for students interested in a biomedical specialization. Why? "I never would have gotten through without support myself," he says, referring to the various educational funds he received from the U.S. government, Purdue University, and other sources. "My education turned me around, and I want to make that possible for students today."

ME sophomore Christine Kim, a 2006 scholarship recipient, appreciates that generosity. "I became interested in orthopedics and sports medicine after suffering a knee injury during a soccer game a few years ago," she says. "I'd like to work with surgeons on knee reconstruction surgeries that are less invasive than current methods. I also want to be involved in designing knee replacement systems. When I found out that I had received the scholarship [funded by Glimcher], I realized that I'm getting this scholarship from one of the most notable professionals in my field. That's pretty amazing."

The pleasure of sharing educational opportunity with young Purdue students brings a smile to Glimcher's face. And the impact that those engineers-in-the-making can have when they graduate? Priceless.

■ **Lisa Hunt Tally**

Homecoming on Wheels

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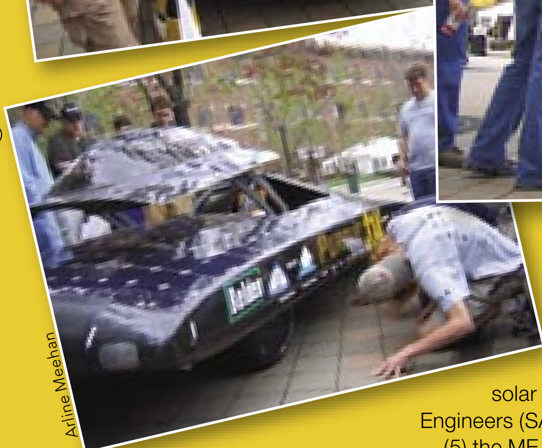
② 

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Arline Meehan

ME's Homecoming celebration revealed a bent toward machines on wheels. On the Purdue Mall, alumni and friends were treated to (1), (2) the ME student solar race car, (3) the Society of Automotive Engineers (SAE) Mini Baja car, (4) the SAE Formula car, and (5) the ME high school remote-controlled-robot project.

Calendar 2007

February	
19	Naples Annual Weekend (President's Council)
22	National Engineers Week: Distinguished Lecture by former secretary of state Colin Powell
23	National Engineers Week: Distinguished Engineering Alumni Convocation
24	Rube Goldberg Machine Contest (local)
March	
27	Silicon Valley Symposium: "Light Scattering for Rapid, Label-free Identification of Bacterial Colonies" by E. Daniel Hirleman, PhD
April	
14-15	Spring Fest/Gala Weekend
June	
30	Campaign Finale

Congratulations to these ME alums who solved our last issue's "Plumber Puzzle":

- Robert Osmon (BSME '71)
- George Hoke (BSME '50)
- Larry Cloud (BSME '65, MSME '66)
- Michael Dew (BSME '91)
- George Eckerly (BSME '49)
- Thomas McMillin (BSME '49)
- William DeBellis (BSME '62)
- Kenneth Simpson (BSME '63)

Look for a new puzzle in our next issue!

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.

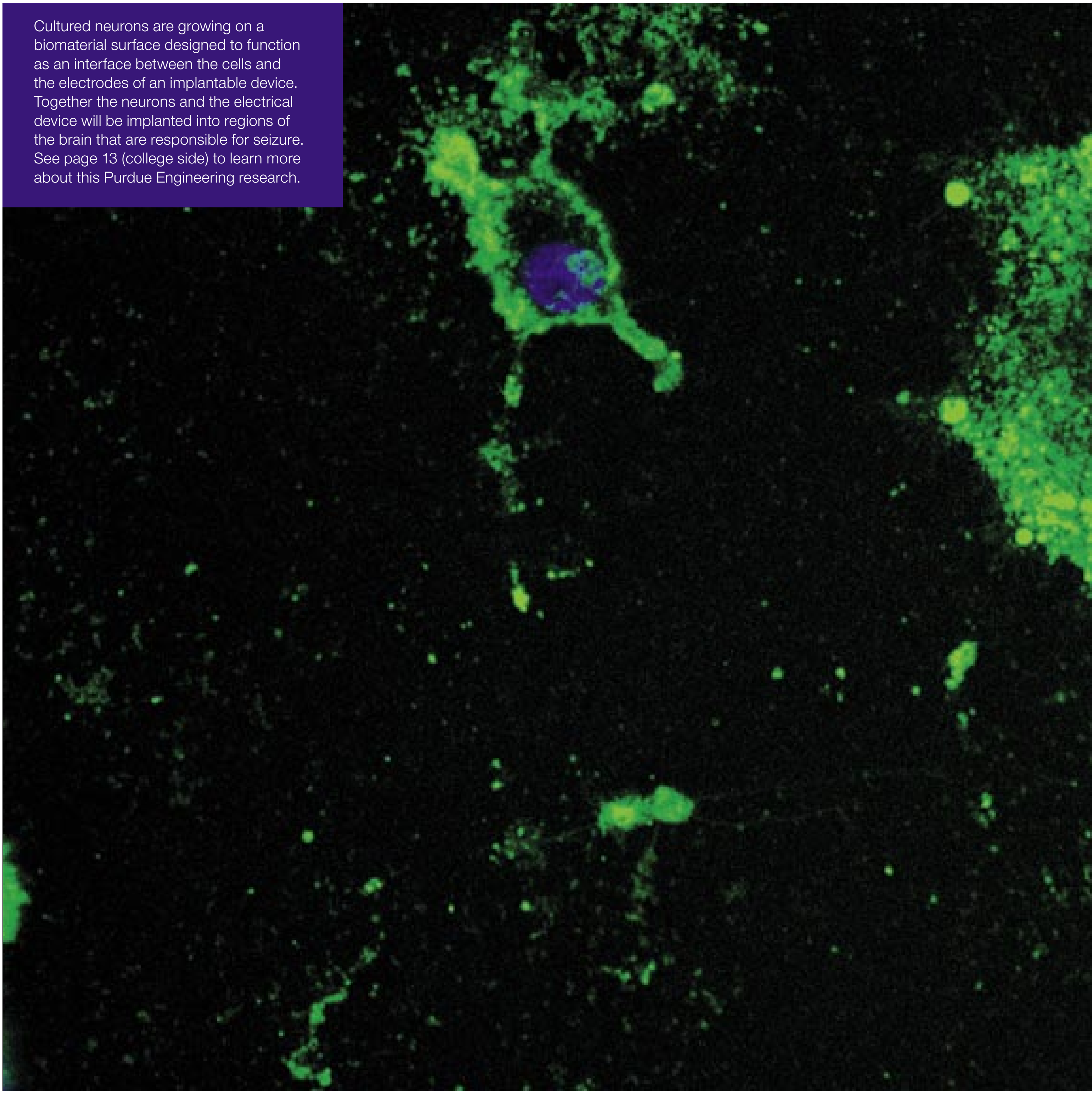

Image provided by Jenna Rickus