

*Office of the Senior  
Vice President for Research*

**Annual Report of  
Research Activity**

**FISCAL YEAR 2009**

PENNS<sup>T</sup>ATE



## Welcome

**P**ENN STATE ENTERS THE SECOND DECADE of the twenty-first century standing on a platform of remarkable growth and accomplishment. Since 2000, the University's research expenditures have grown 74 percent, with the total for this past year reaching \$765 million. In aggregate, these numbers are reflective of a faculty that is competitive at the highest levels, and of an elite cadre of students and postdocs who join these talented professors in conducting exceptional research and scholarship.

The Penn State intellectual climate embraces interdisciplinarity, an approach that has fostered the development of many creative initiatives. In this report you will read about a new imaging facility designed to explore cognition and behavior, a result of collaboration among life and social scientists and engineers. You will also learn of a partnership between the College of Medicine and faculty in the Department of Physics who are using network science to tackle the molecular biology of cancer.

Among the University's major research trajectories is a multipronged effort in energy-related science. Articles follow that describe a major Department of Energy-funded Energy Frontier Research Center in cellulosic biofuels and the translation of a long-term initiative to develop microbial fuel cells into practice in a pilot plant in the Napa Valley.

Penn State is a top-tier research university as measured by our research expenditures, but what truly distinguishes the University is the heterogeneity of its strengths. It is the breadth of quality research and scholarship—in sciences, social sciences, and the arts—and the way we bring these divergent fields together that create the character of this great institution.



*EDITOR'S NOTE: In January 2010, Eva J. Pell left Penn State after thirty-seven years of service to take the position of Undersecretary of Science at the Smithsonian Institution. Her successor as Vice President for Research and Dean of the Graduate School is Henry C. Foley.*

A handwritten signature in blue ink that reads "Eva J. Pell". The signature is fluid and cursive, with the first name "Eva" being the most prominent.

### Eva J. Pell,

Senior Vice President for Research and  
Dean of the Graduate School

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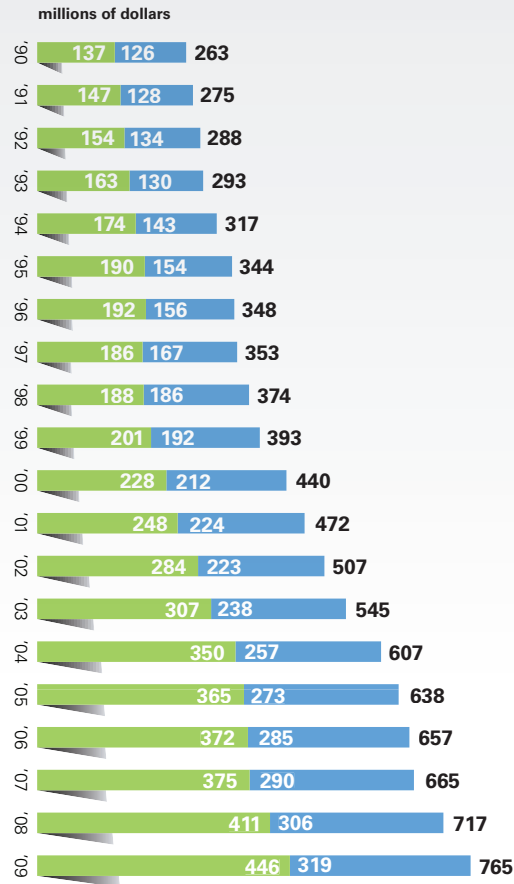
*Cover: Root system of a maize plant forty days after germination, showing the metabolic cost of root maintenance (in units of g carbon per day, with warmer colors representing greater cost) as visualized by the computer simulation model SimRoot. Research of Johannes Postma, Department of Horticulture, Penn State. For more on root biology, see page 11.*

CREDIT: JONATHAN LYNCH/JOHANNES POSTMA

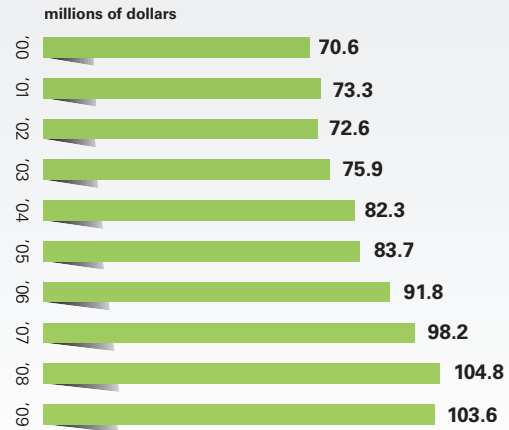
## Statistical Snapshot

### Total Research Expenditures, 1990–2009

Federal Non-federal



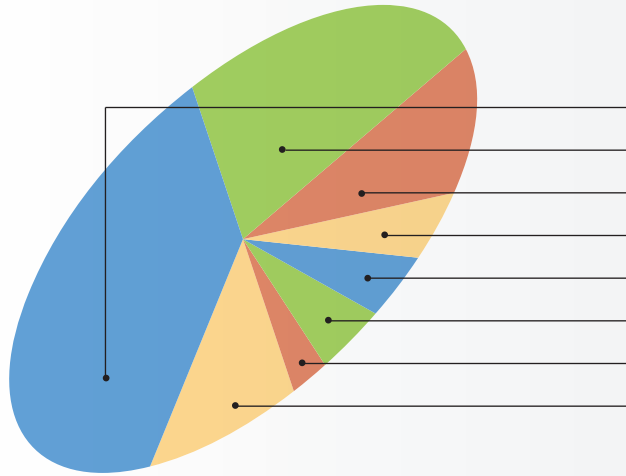
### Industry-Sponsored Research, 2000–2009



Penn State's research expenditures in fiscal 2009 reached a record \$765 million, a 6.7 percent increase over the previous year and a 74 percent increase since fiscal 2000.

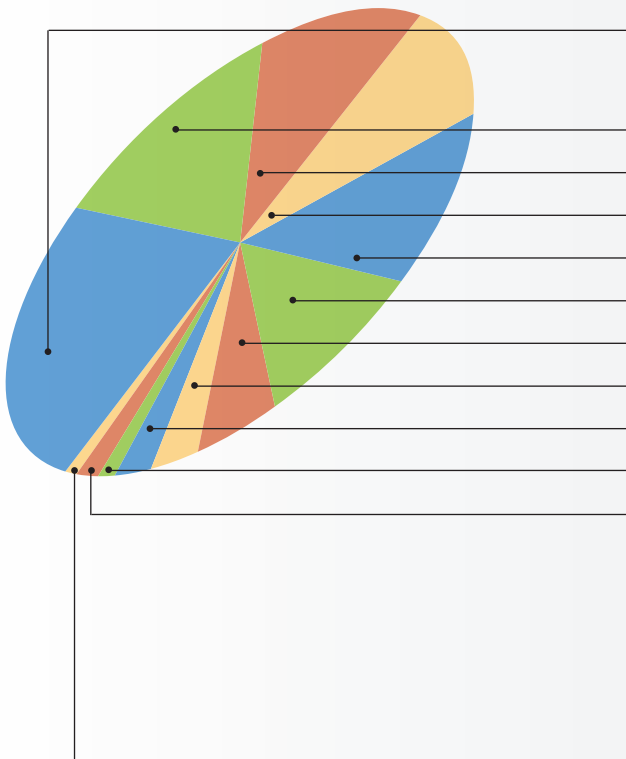
Funding from federal agencies accounts for \$445 million, and has grown 95 percent since fiscal 2000. Federal dollars came from a wide variety of agencies, including the Department of Defense, Department of Health and Human Services, and National Science Foundation.

Despite a small reduction in industry-sponsored research over the last year attributable to the economic downturn, Penn State continues to rank third nationally in this important category.



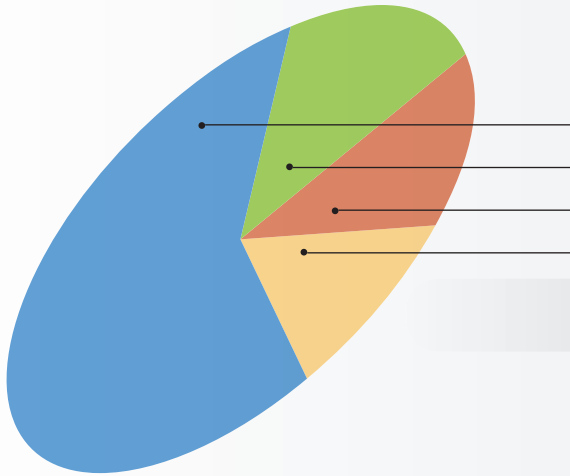
**Expenditures from Federal Agencies**

Department of Defense . . . . .	<b>\$178,939,000</b>
Department of Health and Human Services . . . . .	<b>105,508,000</b>
National Science Foundation . . . . .	<b>52,604,000</b>
USDA . . . . .	<b>19,419,000</b>
NASA . . . . .	<b>18,220,000</b>
DOE . . . . .	<b>16,586,000</b>
Education . . . . .	<b>10,562,000</b>
Other . . . . .	<b>43,423,000</b>
<i>Transportation</i> . . . . .	7,140,000
<i>Interior</i> . . . . .	1,706,000
<i>Commerce</i> . . . . .	1,254,000
<i>EPA</i> . . . . .	796,000
<i>Other Federal</i> . . . . .	\$32,527,000
<b>Total . . . . .</b>	<b>\$445,261,000</b>



**Expenditures by Performing Unit**

Defense Related Research Units . . . . .	<b>\$186,594,000</b>
<i>Applied Research Lab</i> . . . . .	154,931,000
<i>Electro-Optics Center</i> . . . . .	31,663,000
Engineering . . . . .	<b>104,929,000</b>
Agricultural Sciences . . . . .	<b>96,828,000</b>
Eberly College of Science . . . . .	<b>91,660,000</b>
Medicine . . . . .	<b>91,552,000</b>
Earth and Mineral Sciences . . . . .	<b>73,409,000</b>
Health and Human Development . . . . .	<b>40,273,000</b>
Liberal Arts . . . . .	<b>25,250,000</b>
Education . . . . .	<b>22,431,000</b>
Information Sciences and Technology . . . . .	<b>10,323,000</b>
Other . . . . .	<b>14,457,000</b>
<i>Altoona College</i> . . . . .	801,000
<i>Behrend College</i> . . . . .	4,362,000
<i>Berks College</i> . . . . .	202,000
<i>Capital College</i> . . . . .	4,056,000
<i>Great Valley</i> . . . . .	187,000
<i>Penn College</i> . . . . .	1,622,000
<i>Other Commonwealth Campuses</i> . . . . .	3,227,000
Other Schools and Colleges . . . . .	<b>7,331,000</b>
<i>Arts and Architecture</i> . . . . .	900,000
<i>Communications</i> . . . . .	155,000
<i>Dickinson School of Law</i> . . . . .	470,000
<i>School of Nursing</i> . . . . .	674,000
<i>Smeal College of Business</i> . . . . .	5,132,000
<b>Total . . . . .</b>	<b>\$765,037,000</b>

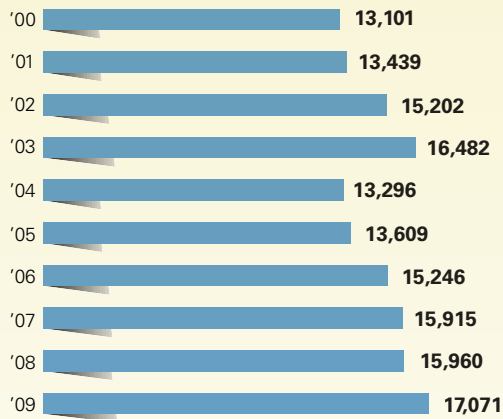


Sources of Research Funding

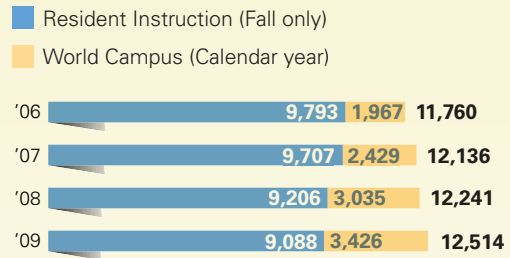
Federal .....	\$445,261,000
University .....	130,710,000
Industry and other .....	105,301,000
Commonwealth of Pennsylvania .....	83,765,000
<b>Total. ....</b>	<b>\$765,037,000</b>

The Graduate School

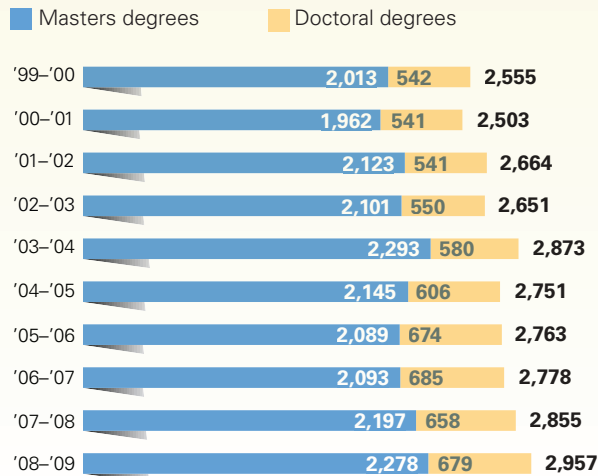
Applications, ten-year history, 2000–2009



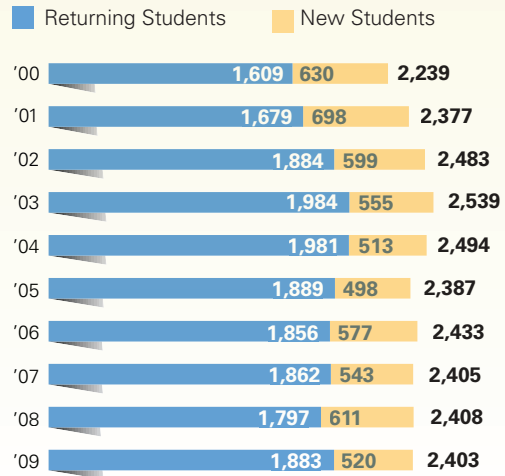
Total Enrollment, 2009



Degrees Conferred, ten-year history, 2000–2009



International Students, ten-year history, 2000–2009



## Secrets of Cellulose

**Stimulus funding from the American Recovery and Reinvestment Act of 2009 (ARRA) is meant to advance scientific research that will make a meaningful difference in the nation's future, particularly in the area of renewable energy.**

A perfect example is the Department of Energy's award of \$21 million over five years to Penn State to fund the new Center for Lignocellulose Structure and Formation.

One of forty-six Energy Frontier Research Centers (EFRC) established nationwide, Penn State's center (which will collaborate with North Carolina State University and Virginia Polytechnic Institute and State University) is part of a major effort to accelerate the scientific breakthroughs required to create a new twenty-first-century energy economy.

Says Daniel J. Cosgrove, professor of biology and the center's director, the Penn State center will use cutting-edge approaches and an interdisciplinary team—including physicists, material scientists, computational modelers, and engineers—to study the molecular biology of cellulose.

Cellulose, says Cosgrove, is vital to future fuels. "The biggest solar collectors on Earth are plants that use sunlight to convert atmospheric carbon dioxide into complex structural materials like cellulose and lignin," he explains. "These make up wood, paper, cotton, and many other everyday materials; globally, they represent a huge untapped reserve of biorenewable energy. Our new center will try to pry loose the secrets of how these molecules interact to form these substances that have so many practical uses as an energy source."

Cosgrove and colleagues—including Jeffrey Catchmark, associate professor of agricultural and biological engineering in Penn State's College of Agricultural Sciences and co-director of the new center—are working to understand the structure and formation of plant cell walls, or lignocellulose. Such information will be important for transforming cellulose into a more affordable and sustainable feedstock for ethanol production.

The main limitation in existing biomass-to-biofuel production is the high cost of dissolving the tough fibrous plant material, such as corn stover, switchgrass, and fast-growing trees. Currently, the best treatment is to soak the fibers in enzymes, adding 30 to 50 cents per gallon to the cost of the ethanol fuel produced.

"Even after decades of research, cellulose synthesis is not very well understood," Catchmark notes. "We don't know how the cells assemble this chemical barrier to weather, insects, and other organisms. The cell wall is very difficult to degrade."

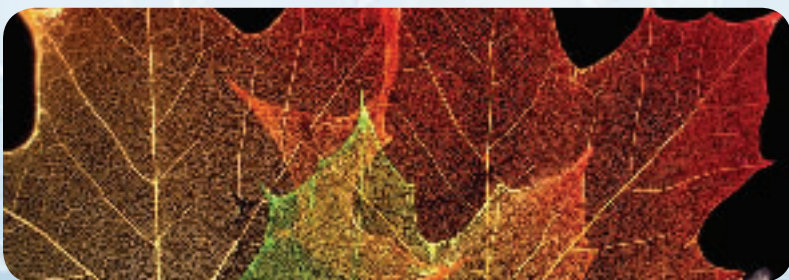
A decade ago, the Cosgrove lab discovered a new group of proteins, dubbed "expansins" for their role in allowing plant cell walls to expand as the plant grows. These "wall-loosening" proteins show promise in speeding the breakdown of cellulose material into sugars. The expansins strip off surface polymers so the cellulose layers can be pulled apart to allow the enzymes to act on all of the layers of material at once, explains Cosgrove. The hope? That expansins will help transform the industrial process for making cellulosic biofuels into a cost-competitive, cleaner, renewable energy source.

"This is the most abundant biomass on the planet," says Cosgrove. "This is the material in which most of the organic carbon on Earth is found and that the DOE wants to convert back into simple sugars and then into ethanol."

Virendra Puri, Distinguished Professor of Agricultural Engineering and one of the Penn State researchers involved in the center, comments, "Once we unlock the mystery of how the materials go together—how they are intertwined—and learn to take them apart, the possibilities are vast."

Penn State's center is moving forward with energy and a shared vision to help the United States—with its vast agricultural and forest-based resources—unlock the full potential of its lignocellulosic materials.

TO LEARN MORE, SEE: [www.lignocellulose.org](http://www.lignocellulose.org)



**Cellulose, found in the cell walls of plants, provides the rigidity and support that gives leaves their shape. Its synthesis is not well understood.**

## The Critical Zone

**Nestled in a quiet hollow in the Stone Valley experimental forest south of State College lies a twenty-acre tract that's been studied by Penn State researchers since the 1970s.** Now the so-called Shale Hills watershed is part of a growing global network of sites that are boosting understanding of the Critical Zone, that life-sustaining region of Earth's surface from the top of vegetation to the bottom of groundwater.

"I like to say it's where rock meets life," says Susan Brantley, professor of geosciences and director of the Penn State Earth and Environmental Systems Institute. "It includes soil, water, plants—everything we see at the surface of the Earth."

In 2007, Brantley and Chris Duffy, professor of civil engineering, with colleagues at the University of Colorado and University of California, went to the National Science Foundation with proposals to establish a number of observatories where interdisciplinary teams of scientists could exhaustively study geology, hydrology, and ecology, creating a coordinated picture of Critical Zone processes. Shale Hills was named one of three observatories, along with sites in the Sierra Nevada Mountains and the Rockies, and Brantley and Duffy were awarded a five-year, \$4.2 million NSF grant.

In the fall of 2008, Brantley reports, three more NSF observatories were established in the rainforest of Puerto Rico, a coastal watershed along the Delaware–Maryland border, and in the Sonoran desert of Arizona. And, she says, thanks in part to the activity of the Worldwide Universities Network (WUN), the Critical Zone concept is spreading to Europe and beyond.

The WUN is a partnership of fifteen research-intensive universities from Europe, North America,

Southeast Asia, Africa, and Australia whose goal is to develop collaborations in rapidly developing interdisciplinary areas of global significance. Penn State is a founding member of the alliance, which began in 2000.

"When we started talking about Critical Zone science a number of years ago," Brantley remembers, "some of our European colleagues heard about it and I was invited to do a WUN seminar on the subject." A series of workshops at some of the other WUN universities followed, along with student and faculty exchanges. Says Brantley, "I think all that activity slowly led to the point where four Critical Zone observatories are going to be established next year in Europe, along with one proposed in Australia. Our Chinese colleagues are talking about it as well."

In September of 2009, Penn State hosted a WUN workshop at University Park. Attendees from the United States, United Kingdom, Australia, and China visited the Shale Hills Observatory. By building a global network of field sites like Shale Hills, Brantley says, researchers hope to develop models to predict the impacts of human activities on Critical Zone processes and thereby determine how best to protect this vital region from threats including desertification, loss of soil fertility, and soil erosion.

"We are encouraging researchers to share data across sites so that we can begin to quantitatively predict how the Critical Zone is responding to natural and human perturbation," said Tim White, senior research associate at Penn State, who organized the meeting.

**TO LEARN MORE, SEE: [www.psiee.psu.edu/research/project\\_details/60TN](http://www.psiee.psu.edu/research/project_details/60TN)**



**BETH HERNDON** doesn't hesitate when asked what brought her to Penn State's Department of Geosciences. "It's one of the best programs in the country," she says.

Herndon was a senior at Washington University in St. Louis, Missouri, double majoring in earth and planetary sciences and biochemistry, when her adviser invited Susan Brantley to speak at a colloquium series. "That was my introduction to Penn State," she remembers.

Now, under Brantley's tutelage, Herndon is investigating manganese cycling in the Shale Hills watershed, "quantifying the amount of excess manganese and figuring out where it comes from, and how widespread anthropogenic manganese addition is to the soils." She recently spent a month in England at the University of Sheffield, one of Penn State's partners in the Worldwide Universities Network, learning techniques to mimic in the laboratory some of the mineral-weathering processes she has observed in the field.

Herndon is enrolled in the dual-title Ph.D. program in Geosciences and Biogeochemistry, which draws students from seven participating departments at Penn State. "I like being able to cross these boundaries and understand different perspectives and ways to approach a problem," she says. "In this program we have students not only talking across departments, but doing research together."

## Thin-film Fellow

**“A piezoelectric material,” Susan Trolier-McKinstry explains, “is one that has a coupling between electrical and mechanical energies.** If I take such a material and apply an electrical field to it, I can make it change shape. If I squeeze it—apply mechanical stress—I can generate an electrical field.

“We use these materials all the time without knowing it,” adds Trolier-McKinstry, professor of ceramic science and engineering at Penn State. “Medical ultrasound is a good example.” An ultrasound probe, she explains, contains piezoelectric crystals, which vibrate (i.e., change shape) when an electric current is applied. These vibrations produce sound waves that travel outward into the body until they reach the boundaries among fluid, soft tissue, and bone. Some of the sound waves are then bounced back to the probe, where the crystals emit an electrical current.

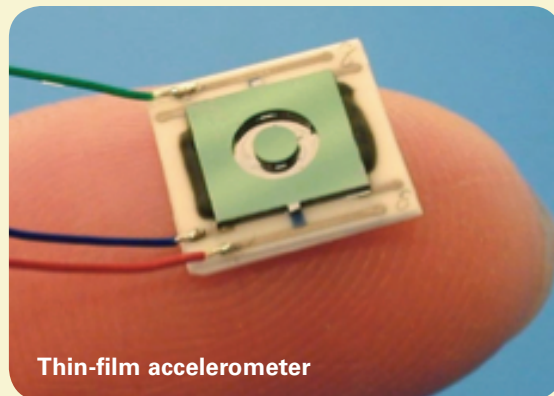
Most bulk piezoelectric devices, however, operate at fairly high voltages—often more than 60 volts. Says Trolier-McKinstry, “It would be really nice to make an actuator that you could drive with really low voltage, like that produced by a silicon chip.”

She recently received major support to do just that. Last fall, Trolier-McKinstry was selected as one of six distinguished researchers from U.S. universities to form the inaugural class of the Department of Defense’s new National Security Science and Engineering Faculty Fellows Program. The program provides long-term funding to scientists and engineers to pursue basic research of crucial importance to next-generation DOD technologies. The six Fellows will receive grants of up to \$3 million each over a five-year period.

Trolier-McKinstry’s proposal to the DOD contained three parts. Her first objective is to improve the piezoelectric response of the thin-film materials that are crucial to increasingly miniaturized devices. “I want to be able to create a big change of shape with just a little bit of voltage,” she says.

Next, Trolier-McKinstry is looking at ways to create usable structure on the surfaces of thin films without ruining them. “The materials we use are rather complicated in their chemistry,” she explains. “They usually contain at least four different types of atoms, and inevitably these don’t all etch at the same rate. So it’s often easy to induce damage when you etch into these materials. Instead, we’re trying to print the patterns we want directly, using a stamp. We’re the first group that has ever done this.”

Her third goal, she says, is to be more precise in applying the high temperatures necessary for crystallization of thin films. “We start out with a film that’s



Thin-film accelerometer

amorphous, like glass,” she says. “And it’s not piezoelectric until we crystallize it.” That usually requires 600 to 700 degrees Celsius, however—a heat much too intense for integrated circuits and other potential components to withstand. “So instead of heating up the whole film and everything it sits on, we’re using laser adsorption to target just the film.”

The materials she’s working to perfect have lots of potential applications, both defense-related and not. “DOD is very interested in switches for high-speed communications,” she says. “For radar applications, they need to be able to switch parts of the circuit in and out. This is hard to miniaturize.

“The same generic technology is useful in lots of sensors for condition-based maintenance,” she continues. “These allow you to tell when a bridge or a big industrial tool is in need of repair—before damage is being done.”

Trolier-McKinstry also envisions a thin-film version of an ultrasound system. “Our long-term goal would be to make something small enough that you could swallow it. So you could maybe replace the colonoscopy with a pill that just passes through.”

As director of the W. M. Keck Smart Materials Integration Laboratory and the Center of Excellence in Piezoelectric Materials and Devices at Penn State, she says the DOD fellowship “gives me a tremendous amount of flexibility to address the key science and engineering challenges in piezoelectrics for micro-electromechanical systems. This kind of sustained funding allows us to explore deeper, fundamental problems.

“What we’d really like to do is move beyond the incremental and make big improvements in the functionality of these materials.”

TO LEARN MORE, SEE: [www.matse.psu.edu/fac/profiles/mckinstry.htm](http://www.matse.psu.edu/fac/profiles/mckinstry.htm)

## Virtuosi Visit

**For a couple of hours on the evening of March 20, 2009, Penn State was arguably the epicenter of the classical music world.** Three of today's most renowned musicians—pianist Emanuel Ax, violinist Itzhak Perlman, and cellist Yo-Yo Ma—made their world-premiere performance as a trio at Penn State's Eisenhower Auditorium. Their only other performance together took place the following night at New York's Carnegie Hall.

The sold-out concert and medal ceremony were planned jointly by George Trudeau, director of the Center for the Performing Arts, and Marica Tacconi, director of Penn State's Institute for the Arts and Humanities (IAH).

"Trudeau and his staff secured the performance and worked out the arrangements," explains Tacconi. "Then we, at the institute, offered the three virtuosi the honor of our medal, which they gladly accepted."

The award, presented by Penn State President Graham Spanier at the end of the concert, is the 2009 Institute for the Arts and Humanities Medal for Distinguished Contributions to the Arts and Humanities, bestowed in past years upon novelist Salman Rushdie; architect Daniel Libeskind; and novelist, essayist, and political activist Mario Vargas Llosa.

Established in 2006, the IAH Medal honors individuals whose work has reached a wide public audience while maintaining the highest standards of scholarship, creativity, and originality. As Tacconi explains, "In choosing these three extraordinary musicians as the recipients of the 2009 IAH Medals, we celebrated not only their individual and collective contributions to the arts, but also their commitment to uniting the peoples of the world through music."

The all-Mendelssohn concert program celebrated the bicentennial of Felix Mendelssohn's birth. The distinguished trio performed Mendelssohn's *Piano Trio No. 1 in d minor, Opus 49*, and *Piano Trio No. 2 in c minor, Opus 66*, as well as a sampling of the German composer's *Songs Without Words*.

"What we experienced that evening was not only some of the finest music, played by three of the most distinguished virtuosi of our time," Tacconi enthused. "It was, in essence, a celebration of the power of music, an example of the ability the arts have to bring joy and to transport our minds and souls to a loftier place. With each stroke of the key and draw of the bow, these distinguished musicians spoke to our humanity by reminding us that music, like the other arts, has the power to transcend differences and bring us together as citizens of the world."

The evening was a highlight in a year in which the IAH presented more than seventy events, many as part of the institute's Moments of Change initiative, focused in 2008–09 on the turn of the twentieth century (1889–1914). The multidisciplinary program included lectures, roundtable discussions, performances, exhibitions, the second annual Josephine Berry Weiss interdisciplinary humanities seminar, and even a halftime show at a football game in Beaver Stadium. Tacconi says, "It was a remarkably stimulating year that brought together faculty, students, and community members to explore one of the most remarkable periods of transformation in the arts, culture, and society."

TO LEARN MORE, SEE: [live.psu.edu/album/2009](http://live.psu.edu/album/2009)



For **MIA TOOTILL**, "interdisciplinary" is more than a buzzword—it's the main reason she came to Penn State for graduate studies. "The Institute for the Arts and Humanities was one of the big draws for me," says Tootill, a native of England and clarinetist. "Yet I wasn't sure what to expect when I started here."

What she found: a "wide variety" of courses across the disciplines; an "inspiring and supportive

mentor" in her academic adviser, Marica Tacconi; and a thesis adviser, Charles Youmans, whom she calls "a top Strauss scholar—what an opportunity to work with him!"

One of eight graduate students chosen for a summer residency at the institute this past summer, Tootill says her attendance at the Moments of Change events helped her define a master's thesis topic: musical depictions of the Helen of Troy story from the turn of the twentieth century.

"I'm looking at Saint-Saëns' opera *Hélène*, Lili Boulanger's cantata *Faust et Hélène*, and Richard Strauss' opera *Die Ägyptische Helena*, and am interested in the ways mythology can be interpreted through the combination of music and text," explains Tootill.

Says Tootill, "I certainly never could have anticipated the level of support that I've been given here."

## Wine into Hydrogen?

**It's been several years since Bruce Logan showed the world how to produce electricity from wastewater.** Logan's microbial fuel cell uses bacteria to turn the trick, and cleans up the wastewater to boot. But there's yet another twist. By applying a small electrical current, he can reconfigure the cell to produce not electricity, but hydrogen.

Now the first demonstration of a renewable method for hydrogen production from wastewater using Logan's microbial electrolysis system is under way at the Napa Wine Company in Oakville, California.

Last September, a refrigerator-sized hydrogen generator began taking a fraction of the winery's wastewater and, using bacteria and a small amount of electrical energy, converting the organic material it contains into hydrogen, according to Logan, Kappe Professor of Environmental Engineering at Penn State.

"This is a demonstration to prove we can continuously generate renewable hydrogen and to study the engineering factors affecting the system performance," he says. "The hydrogen produced will be vented except for a small amount that will be used in a hydrogen fuel cell." Eventually, Napa Wine Company would like to use the hydrogen to run vehicles and power systems.

Like any large agricultural operation, Napa Wine Company generates millions of gallons of wastewater per year. Water is used for cleaning equipment, grape disposal, wine making, and other processes. The company already has on-site wastewater treatment and recycling and the partially treated water from the microbial electrolysis system will join other water for further treatment and use in irrigation.

"It is nice that Napa Wine Company offered up their winery and facilities to test this new approach," says Logan. "We chose a winery because it is a natural tourist attraction. People go there all the time to experience wine making and wine, and now they can also see a demonstration of how to make clean hydrogen gas from agricultural wastes."

The demonstration microbial electrolysis plant is a continuous flow system that will process about 1,000 liters of wastewater a day. Microbial electrolysis cells consist of two electrodes immersed in liquid. Logan uses electrode pairs consisting of one carbon anode and one stainless steel cathode in his system, rather than an electrode coated with a precious metal like platinum or gold. Replacing precious metals keeps down costs, he explains. The wastewater enters the cell where naturally occurring bacteria convert the organic material into electrical current. If the



**Bruce Logan checks demonstration wastewater processor at Napa Wine Company.**

voltage produced by the bacteria is slightly increased, hydrogen gas is produced electrochemically on the stainless steel cathode.

"There is almost ten times more energy in the wastewater than we currently use to treat it," Logan told ABC News. "If we get out a tenth of that energy, we could run the treatment system by itself, but we've still got nine times more energy in there that we could extract. We're wasting that; we're throwing it away."

The demonstration plant is made up of twenty-four modules, each with six pairs of electrodes. "The composition of the wastewater will change throughout the year," says Logan. "Now it is likely to be rather sugary, but later it may shift more toward the remnants of the fermentation process." The bacteria that work in the electrolysis cells will consume either of these organic materials.

"This is the first time that a reactor of this size has been attempted either in the laboratory or the field," Logan told the LiveScience Web site in early November. "Performance continues to improve," he added, though "we are not yet at our goal of daily production of one liter of hydrogen per liter of reactor. We hope to generate more energy in the form of hydrogen than was used to treat the wastewater, thus making the winery a net power producer."

The project is supported by Air Products and Chemicals, Inc.; the Water Environmental Research Foundation's Paul L. Busch Award; and other donors. Brown and Caldwell, an environmental engineering consulting firm, was contracted to build the demonstration plant. The Napa Wine Company is donating its facilities and wastewater for the demonstration.

TO LEARN MORE, SEE: [www.engr.psu.edu/ce/enve/logan](http://www.engr.psu.edu/ce/enve/logan)

## A farm in Africa

### Jonathan Lynch gets to the root of things.

A professor of horticulture at Penn State, Lynch believes that understanding plant root architecture may be the key to producing enough food to feed the world's 6 billion people.

"One of the main problems (in global agriculture) is low yields of plants because of drought, low soil fertility, and lack of access to fertilizer and irrigation in many parts of the world," he explains. His research over the past twenty-five years with collaborators in the United States, Asia, Latin America, and Africa has shown that root architecture plays a critical role in determining plant yields under stressful soil conditions. Correlated with genetic information, root traits can be harnessed to create higher-yield varieties of important crops like corn, bean, and soybean, he says. "We can then give farmers seeds that will do well in poor soils, without fertilizer and irrigation."

In the developed world, Lynch adds, stronger roots can have economic and environmental benefits. "The biggest cost in growing corn is nitrogen fertilizer," he explains. "Nitrogen is also the biggest pollutant, since half of the fertilizer gets leached into the soil before the roots can get it." He is currently working on developing corn varieties with roots that absorb the nutrient more efficiently.

Recently, Lynch's work received an important boost with a grant from the Howard G. Buffett Foundation. Howard Buffett, a farmer, photographer, conservationist, and philanthropist, is interested in improving crop yields as a means to increase

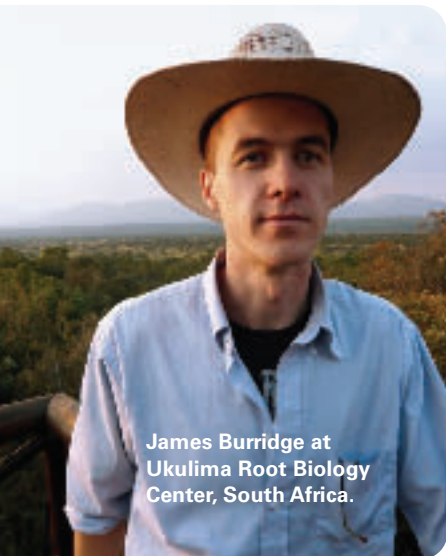
food supply, Lynch notes. When Buffett read about Lynch's work in a Midwestern farm publication, "he called me," says Lynch. The two met at the end of 2008, and in early 2009 Lynch and members of his lab visited Buffett's 6,000-acre farm in South Africa. When Lynch pronounced the sandy, low-fertility African soil ideal for his research, Buffett offered him the use of a fifty-acre field, along with a \$1.5 million research grant. The Ukulima Root Biology Center was born.

Having an experimental base in the southern hemisphere, Lynch says, will give him access to two growing seasons and the ability to study drought and other stress factors on a large scale. In addition, "we can wash nitrogen out of the sandy soil and create low nitrogen conditions very easily," he says. "And the sandy soil makes it easy to dig out roots for study."

Lynch says he is amazed at how rapidly the Ukulima Center has taken off. "Howard Buffett is a man of action," he says. "He built us a very nice, fully equipped laboratory, with housing and Internet access."

In January 2010, several of Lynch's graduate students and postdoctoral researchers will deploy to South Africa to begin a large and complex field planting of thousands of corn and bean genotypes. "This new partnership has created an additional resource to add to our existing projects," Lynch says. "It will allow us to work faster and better."

TO LEARN MORE, SEE: [roots.psu.edu/ukulima](http://roots.psu.edu/ukulima)



James Burridge at Ukulima Root Biology Center, South Africa.

**JAMES BURRIDGE** worked on a small farm in Ohio for four years while majoring in international relations at the University of Dayton. Later he worked in Mexico and Chile, where he experienced firsthand the intimate connection between agriculture and development. Burridge's desire to contribute to global development eventually drew him to graduate study in Penn State's Department of Horticulture.

"Working with Dr. Lynch gives me the opportunity to work with critically important foods like corn and bean," he explains, and to work toward a sustainable food supply. He values the diverse opportunities offered by his Penn State experience.

"I have had the ability to work with projects in many different places," he says. Those places include South Africa, where Burridge and other lab members

traveled earlier this year to help lay the groundwork for what has become the Ukulima Root Biology Center.

After graduation, Burridge hopes to continue to use his expertise in root biology to impact global development. "If we can learn to control the factors involved," he says, "we can have dramatic impact all over the world."

## Across the Galaxy

**With tremendous advances in DNA sequencing and the advent of microarray technology in the 1990s, biology embarked on a new age of discovery.** Researchers suddenly had access to unprecedented amounts of data—and faced unprecedented complexity in its analysis.

Necessity sparked the rise of a whole new field: the hybrid of biology and computer science now known as bioinformatics. But as sequencing technologies continue to evolve more and more rapidly, the challenge has grown more and more acute.

“Biology is in a state of shock,” says Anton Nekrutenko, assistant professor of biochemistry and molecular biology at Penn State. “We have biochemistry and biology labs that are generating mountains of data, and then they say, ‘What do we do now?’”

“Computational biologists write the programs they need to solve their own problems,” Nekrutenko adds, “but they are generally not interested in providing interfaces for experimental biologists.”

That’s where Galaxy comes in. Developed by Nekrutenko and others at Penn State, along with James Taylor at Emory University, Galaxy is a Web-based framework that pulls together a variety of tools that allow for easy retrieval and analysis of large amounts of data, simplifying the process of genomic analysis. Galaxy “combines the power of existing genome annotation databases with a simple Web portal to enable users to search remote resources, combine data from independent queries, and visualize the results.”

“Essentially we are providing a unified interface to many different tools,” Nekrutenko explains. As a trade review puts it, Galaxy “amplifies the strengths of existing resources.”

The response has been gratifying. “Since last year the project has really taken on legs,” Nekrutenko says. The Galaxy Web site now has 10,000 registered users. It runs 4,000 to 5,000 analyses daily.

“It’s also available as software, so people can download and run it on their own hardware,” Nekrutenko says. “We encourage this because there’s a limit to how much data our computers can handle.

“Our goal is proliferation,” Nekrutenko adds, “and right now we are really the only genomic solution. We allow biologists to do very complicated analyses quite easily. And we have all sorts of cool features,” including an automated workflow management tool and a host of short video tutorials. “There’s even an iPhone app so you can check your analysis as it’s running,” he says.



Anton Nekrutenko (top right) and his Galaxy team.

As with most of the software in this rapidly evolving field, Galaxy is completely open source. “That’s how biology works these days,” Nekrutenko explains. “There are commercial solutions, but they’re a waste of money, because the technology changes so often.”

He and his collaborators continue to work on improvements. One is to make computational analyses transparent and reproducible, a basic tenet of experimental research. Nekrutenko points to one of his own papers, recently published in the journal *Genome Research*. With the aid of Galaxy, every stage of the analysis that he and his co-authors conducted is published as supplementary data, alongside the online version of the article.

The pace of change keeps things interesting, he says. “There are emerging technologies that will produce 100 times more data than the so-called next-generation sequencing. We’re already at next-next-generation sequencing. It’s reaching the point where storage becomes an issue, never mind analysis.”

It’s exciting to be in the middle of such ferment, he allows, and also stressful. “But we have a very good team assembled, and a lot of momentum. We have had generous early support from the Huck Institutes at Penn State, and we are now well funded by NSF and NIH.

“The funding agencies have finally recognized that they need to pay not only for data generation, but also for data management,” Nekrutenko concludes. “I think we’re in a really good place.”

TO LEARN MORE, SEE: [galaxy.psu.edu](http://galaxy.psu.edu)

## Sharper Imaging

**2009 was an exciting year for Penn State's Social, Life, and Engineering Sciences Imaging Center (SLEIC).** In mid-April, the center celebrated the opening of its new multidisciplinary research facility, housed in the basement and first floor of the renovated Chandlee Laboratory on the University Park campus.

The newest component of the SLEIC facility is an MRI machine, a Siemens Magnetom Trio 3T, that records a human body's structure and measures brain function via blood flow. The machine is a twin of the MRI machine at the Center for Nuclear Magnetic Research at the Penn State Milton S. Hershey Medical Center, and will permit the two centers to collaborate more effectively.

SLEIC has three components, explains Rick Gilmore, associate professor of psychology and the center's acting director. "There is a high-field facility with two MRI scanners used for biomedical and materials imaging; a 3T human MRI facility; and the Human Electrophysiology Facility (HEF) focusing on EEG and psychophysiological studies."

"Penn State has a strongly collaborative intellectual environment, and our center's facilities are specifically designed to be shared," says Gilmore.

The center is a partnership of the Huck Institutes of the Life Sciences and the Social Science Research Institute, with co-funding from the Colleges of Engineering, Health and Human Development, and the Liberal Arts, as well as the Offices of the Provost and the Senior Vice President for Research. It has a long-range goal of fostering outstanding multidisciplinary research of all kinds, from engineering to materials science, from biology to the social and behavioral sciences.

"Our near-term goals," says Gilmore, "are to expand our user base, facilitate successful grant applications by principal investigators (PIs), and train PIs and students in the use of imaging methodologies."

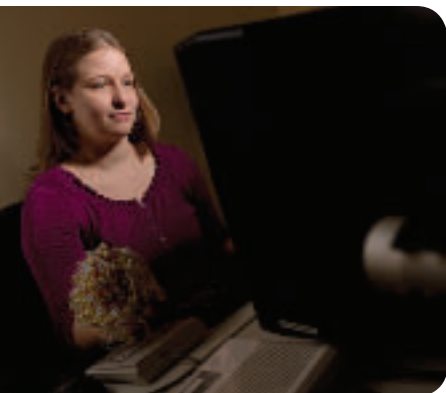
Noting that Penn State has particular strength in the biological sciences, engineering, and behavioral sciences, Gilmore says that SLEIC will capitalize on these strengths and serve as a catalyst for the next generation of interdisciplinary research projects in these and related disciplines.

Doctoral candidate Sarah Karalunas represents that next generation of researcher. In collaboration with Professors Lisa Gatzke-Kopp in Human Development and Family Studies and Cynthia Huang-Pollack in Psychology, Karalunas designed a study that involves collecting behavioral and brain wave measures during a cognitively demanding task in children with and without ADHD, to determine how children with ADHD differ from those without the disorder in terms of basic cognitive and neural function (see sidebar for more).

Gilmore notes that Karalunas' project is typical of those that use the center's facilities in that it involves teams of investigators from multiple University departments. "Imaging requires specialized expertise across a range of disciplines that no single person can really master," he says. "The center's staff have come to be expert generalists in a variety of scientific fields, and they enjoy the challenge of learning about new fields in order to help investigators effectively answer their specific scientific questions."

"Although our center is new relative to other universities," concludes Gilmore, "we are poised for rapid growth."

TO LEARN MORE, SEE: [www.imaging.psu.edu](http://www.imaging.psu.edu)



**SARAH KARALUNAS** is an articulate person. But when the doctoral candidate in Psychology recently learned she had received a National Research Service Award (NRSA) grant from the National Institutes of Health, the e-mail she sent off to her adviser simply read, "YES YES YES YES YES YES YES YES!"

Says Karalunas, "The process of applying, then reapplying, and then waiting took more than a year, so finding out that all that work paid off was pretty great."

Her project aims to determine how children with ADHD differ from those without the disorder in terms of basic cognitive and neural function. To do so, she'll use SLEIC's Human Electrophysiology Facilities (HEF) lab to collect behavioral and brain wave measures on child subjects while they perform cognitively demanding tasks.

"Not all kids with ADHD have the same issues," Karalunas notes. "Looking at the brain activity associated with perfor-

mance can help us understand these differences, so we can, in time, design more customized interventions for each child."

Karalunas is collaborating with Lisa Gatzke-Kopp in Human Development and Family Studies and Cynthia Huang-Pollack in Psychology, as well as several consulting faculty members across the disciplines. "Without SLEIC," she says, "collecting EEG data would have been impossible for me."

## Switching off Leukemia

**Thanks to research that combines molecular biology with computer modeling, we may be several steps closer to winning the battle against a rare form of blood cancer known as large granular lymphocyte leukemia.**

Thomas Loughran, director of Penn State Hershey Cancer Institute, and Reka Albert, professor of physics and biology at the University Park campus, worked together to better understand the molecular pathways and hundreds of genes and proteins inside a cell that determine its life cycle.

Their study—published in October 2008 in the *Proceedings of the National Academy of Sciences* (PNAS)—suggests that there are two key proteins controlling “the on/off switch” in the malfunctioning killer T-cells that cause this type of leukemia. Says Albert, “Our model suggests that if we keep a specific signaling protein called NfκB in the ‘off’ state, we can reverse the disease.”

The study, funded by the National Institutes of Health and the National Science Foundation, first took shape because Loughran and his colleagues at the Cancer Institute wanted to investigate why, in rare cases, the body’s normal immune response to fighting infection goes awry and causes disease.

In a normal immune system, explains Loughran, the body produces large numbers of a type of white blood cell called cytotoxic T-cells or killer T-cells. These cells are “programmed” by the body for a very narrow and specific mission: to kill infected cells and then die themselves.

Occasionally, Loughran says, these killer cells fail to follow their scripted lifecycle. “When these cells don’t die as expected, they expand gradually over time and start attacking the body itself,” he notes. “They can attack the joints to cause autoimmune diseases such as rheumatoid arthritis and attack the bone marrow to cause leukemia.”

Loughran knew that, to find answers, he’d need to zero in on the exact location of the malfunctioning signaling system. This system is the way cells send and receive instructions—and a broken system might

explain why some T-cells never receive the crucial “self-destruct” message. To unravel the mystery of these rogue killer-T cells, Loughran called on Reka Albert to construct an intricate computer model of the signaling network involved in the activation of the T-cells as well as their programmed death.

Albert brought impressive knowledge to bear on the problem. A disciple of acclaimed network researcher Albert-László Barabási and co-author with him of the concept now known as the Barabási-Albert model, she explains her work as an attempt “to find the mathematical model that will most accurately describe how a system changes over time.”

Albert notes that when researchers investigate a complex problem in a biological system, such as drought stress in plants or diseases in animals or people, a computational representation can help them predict likely outcomes. In this case, says Albert, “the biggest challenge for constructing the computational model was to think about the disease as a state that includes the deregulation of the signaling network that guides activation-induced cell death in T-cells.”

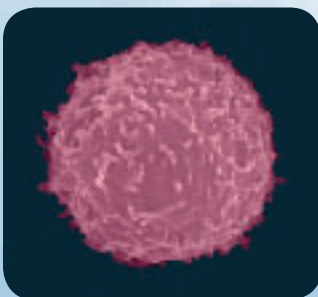
It took several years of effort by a very talented graduate student, Ranran Zhang (the first author of the PNAS paper), guided by two mentors, to make this crucial step. “Afterward, we were able to use methodology that my group has developed and used successfully in the context of other biological regulatory networks. Nevertheless, this is the most complex dynamic model we have constructed so far,” says Albert.

Among the billions of possibilities projected by the model, the researchers determined that two proteins—IL-15 and PDGF—appear to be crucial in keeping the T-cells alive and growing. “You need the presence of both these proteins, as well as the signaling protein NfκB, to create conditions in which the cytotoxic T-cells can proliferate,” explains Loughran.

Essentially, says Loughran, “we are looking for the master control switches that keep these cells alive. When we used drugs to block NfκB in cells from leukemia patients, we found a significant increase in mortality among the abnormal T-cells,” he adds.

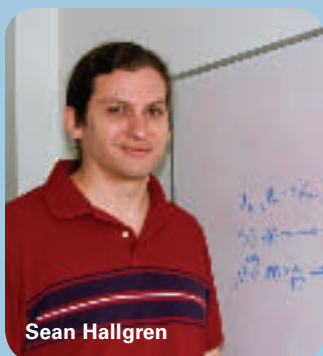
Loughran hopes that someday our control of these “master switches” may allow us to turn off the long-lived killer T-cells that cause leukemia, as well as harness their errant behavior to combat other deadly infectious diseases.

TO LEARN MORE, SEE: [www.phys.psu.edu/~ralbert](http://www.phys.psu.edu/~ralbert)

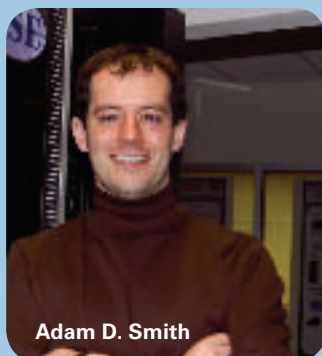


**A human T lymphocyte or T cell, magnified 2,600x. Such precursors develop into killer T cells, which are “programmed” by the body to kill infected cells and then die themselves.**

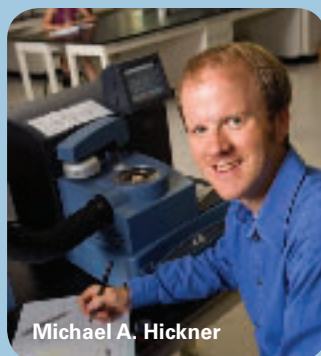
## Presidential Awards



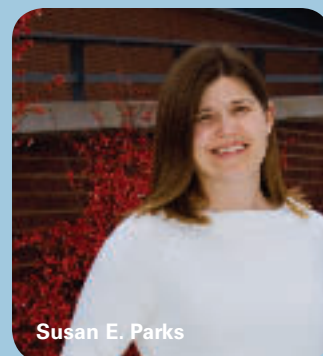
Sean Hallgren



Adam D. Smith



Michael A. Hickner



Susan E. Parks

This summer, four Penn State researchers were named recipients of the prestigious 2009 Presidential Early Career Award for Scientists and Engineers (PECASE).

**SEAN HALLGREN** and **ADAM D. SMITH**, both assistant professors in computer science and engineering; **MICHAEL A. HICKNER**, assistant professor of materials science and engineering, and **SUSAN E. PARKS**, assistant professor of acoustics and research associate at the University's Applied Research Laboratory, were among 100 researchers named by the White House to receive this honor, the highest presented to beginning scientists or engineers in the United States. They will be recognized at a White House ceremony in January 2010.

The PECASE program was established in 1996 to identify and honor outstanding researchers who are beginning their independent research careers and provide recognition of their potential for leadership across the frontiers of scientific knowledge in the twenty-first century.

According to a White House statement, "The Presidential Early Career Awards embody the high priority the Administration places on producing outstanding scientists and engineers to advance the nation's goals and contribute to all sectors of the

economy. Nine Federal departments and agencies join together annually to nominate the most meritorious young scientists and engineers—researchers whose early accomplishments show the greatest promise for strengthening America's leadership in science and technology and contributing to the awarding agencies' missions."

"These extraordinarily gifted young scientists and engineers represent the best in our country," President Obama said. "With their talent, creativity, and dedication, I am confident that they will lead their fields in new breakthroughs and discoveries and help us use science and technology to lift up our nation and our world."

Recipients are nominated by the National Science Foundation, NASA, and the Departments of Health and Human Services, Defense, Energy, Agriculture, Education, Commerce, and Veterans Affairs.

The NSF nominated two of Penn State's recipients, Hallgren and Smith, from among the recipients of its 2008 Faculty Early Career Development Program (CAREER) awards. The Foundation also nominates twenty of the PECASE recipients.

Hallgren works in the area of quantum computation, which aims to use quantum mechani-

cal systems for computation. Quantum computers can break widely used cryptosystems, including those used to protect e-commerce transactions. Hallgren is exploring new applications for these computers and seeking to determine which cryptosystems are secure against them.

Smith studies cryptography and information privacy and their connection to such diverse fields as quantum mechanics, combinatorics, information theory, and statistics. He looks at preserving privacy in the publication of statistical data, cryptography based on noisy secrets, and quantum cryptography. His CAREER award focuses on the problems stemming from conflicts between data access and privacy in collections of personal and sensitive data such as census surveys, social networks, and public health data. His work addresses the need for formal privacy guarantees that remain meaningful even against an intruder with partial knowledge of the sensitive data.

Hickner and Parks were among the forty-one recipients nominated by the Department of Defense. Hickner's research interests include polymer chemistry, polymer micro- and nanostructure, transport properties in heterogeneous materials, electrochemistry, and new materials for energy applications. He has active research programs in fuel cells,

polymer photovoltaics, antifouling surfaces, and water treatment membranes.

Parks' primary research interest is in bioacoustics, integrating the fields of biological oceanography, behavioral ecology, and physiology to address questions related to acoustic communication. She studies the use of sound for communication, hearing abilities, and the impacts of noise on both sound production and reception. Her current research focuses on the use of sound by the North Atlantic right whale, studying behavioral aspects of sound production, perceptual abilities, and impacts of noise on acoustic communication.

The PECASE program is coordinated by the Office of Science and Technology Policy within the Executive Office of the President. Awardees are selected on the basis of two criteria: pursuit of innovative research at the frontiers of science and technology, and a commitment to community service as demonstrated through scientific leadership, public education, or community outreach. Winning scientists and engineers receive up to a five-year research grant to further their study in support of critical government missions.

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