OFFICE OF
THE SENIOR
VICE PRESIDENT
FOR RESEARCH

ANNUAL REPORT
OF RESEARCH
ACTIVITY FY 2008

PENN STATE
Ideas and innovation are the precious currency of the 21st century economy, driving new products and technologies, and solving many of society’s pressing problems.

At Penn State, innovation begins with education. The spirit of collaboration between students and faculty infuses the research enterprise.

Learning the methods of inquiry—how to develop and test ideas, how to express and extend them—is the core of graduate education. The process of learning to do research teaches people how to solve problems, whether scientific, economic, or societal. The object is to create new knowledge, and then to take it out of the university, for the benefit of society as a whole.

Across this great University, our faculty scientists and scholars and their students are working closely in interdisciplinary teams, along with their partners in industry and our communities, to approach critical issues from many different viewpoints. Their efforts are reflected in a record $717 million in research funding for FY 2008, an annual increase of nearly eight percent. Industry-funded research rose to $104.8 million.

Through top-ranked and funded research, Penn State attracts and builds communities of talent, and brings high-paying jobs to Pennsylvania. Through undergraduate and graduate education and workforce training, the University enables the state and the nation to remain competitive globally with a skilled workforce. In addition, companies large and small tap into our faculty and student expertise to move into new technologies and markets and to find solutions.

Through the thoughtful integration of research, education, and outreach, Penn State continues to fulfill its land-grant mission.

Eva J. Pell, Senior Vice President for Research and Dean of The Graduate School
Total and Federal Research Expenditures, 1989-2008

Over the past 20 years, the University’s research expenditures have risen steadily, from $226 million in FY 1989 to $717 million in FY 2008, a 217 percent change overall. Of the 2008 total of $717 million, about $411 million were awarded by federal agencies, led by the U.S. Departments of Defense and Health and Human Services.

Industry and Private Research Expenditures, 1999-2008

For the past 10 years, industry and private research funding at Penn State has seen constant growth from $62 million in 1999 to nearly $105 million in FY 2008, an increase of 69 percent, despite significant downturns in the U.S. economy during the same period. According to National Science Foundation statistics for FY 2007, the latest available, Penn State ranks third nationally in industry-sponsored research.
Sources of Research Funding
FY2008 Total - $717,244,000

Expenditures from Federal Agencies
FY2008 Total - $411,444,000

Expenditures By Performing Unit
FY2008 Total - $717,244,000
THE GRADUATE SCHOOL

Total enrollment
(Includes Resident Instruction and World Campus)

Degrees conferred

Masters

Doctoral

Applications

New and returning international students

New
Returning
Scientists and inventors have often been inspired by the changing designs of nature. “For over a billion years,” Akhlesh Lakhtakia says, “many structures have evolved to display interesting and useful properties. This is an idea we humans should exploit.”

The complexity of biological processes makes mechanical reproduction extremely difficult, he acknowledges. But the surface geometry of structures can be readily copied using modern coating technologies. And if the copy is true enough, it may retain properties of the original that are particularly useful in advanced materials.

The cost of producing such replicas has been prohibitive. Now, however, Lakhtakia and colleagues Carlo Pantano of Penn State and Raul Martin-Palma of the Universidad Autónoma de Madrid have developed a fast and inexpensive technique for making copies that are accurate down to the nanoscale. As a demonstration, they have used this process, called conformal evaporated film by rotation (CEFR), to produce exact replicas of two of nature’s most delicate designs: a fly’s eye and a butterfly’s wing.

As Lakhtakia explains it, the copying process works this way: Inside a low-pressure chamber, a solid material—in this case glass—is heated until it becomes a vapor. The vapor then settles on a rapidly rotating substrate—eye or wing—and the result is a thin (500 nanometer) layer of glass that perfectly conforms to the object beneath it. “In the case of the eye,” Lakhtakia says, “we coated the entire head of the fly, then blasted out the remains of the fly, leaving only the coating.”

Because a fly’s compound eye is a very efficient collector of light, Lakhtakia explains, a replica such as the one they created might be adapted to fabricate solar-cell covers and other energy-harvesting structures, as well as high-resolution lenses. The researchers are hoping that the development of compound-eye-based miniature cameras and sensors would stimulate applications in many other areas.

In the case of the butterfly, Lakhtakia points to certain species within the genus Morpho, known for their iridescent wings. “These exhibit what is known as structural color,” he says. “Their coloring is a result not of pigment, but of the way light interacts with the wing’s surface structure.” When white light hits this surface, he explains, all visible wavelengths are absorbed, except for a narrow range of blue that is reflected back. The result of this “narrow band gap” is color of great purity and intensity.

“We could say that this is a natural photonic material,” Lakhtakia says, referring to optical properties that have many potential applications. “It’s not perfect, but it’s far better than what we can produce.” Such a material could be useful for building photonic circuits, crucial for light-powered communication devices and sensors. In addition to optics, the wing’s surface may have thermal properties that could be useful for solar cells or heat exchangers.

At Pantano’s suggestion, the first replicas were made using chalcogenide glass, which “has some wonderful optical properties,” Lakhtakia says, and is robust enough to hold up as a thin film. The group is currently experimenting with other glasses as well as with polymers. They have reported their results in the journal Applied Physical Letters and Nanotechnology, and have filed a provisional patent application on their copying process.

As they move forward, Lakhtakia and Martin-Palma are organizing an interdisciplinary conference on biomimetics for next year. “We are past the point of replication for its own sake,” Lakhtakia explains. “The point is to gain a better understanding of natural structures and their properties. As engineers, we need to be able to ally ourselves with people who know something about biology.”

To learn more, see: live.psu.edu/story/34610
**STOPPING THE SPREAD OF DISEASE**

Bryan Grenfell, Alumni Professor of Biology at Penn State, is among a team of scientists to be awarded a $10 million grant from the Bill and Melinda Gates Foundation for the study of vaccines to help stop the spread of global infectious disease outbreaks.

The grant will help to fund the Vaccine Modeling Initiative, a collaborative research partnership headquartered at the University of Pittsburgh. The grant’s lead investigator is Donald S. Burke, dean of the University of Pittsburgh’s Graduate School of Public Health; Grenfell will be co-principal investigator on the grant along with Neil Ferguson, of Imperial College, London.

The project aims to amass information on the incidence and prevalence of infectious diseases, and to identify patterns of spread, particularly in developing countries, in an attempt to isolate new and more effective vaccines and to improve delivery methods.

Says Donald Burke, “Infectious diseases create an enormous burden on the world’s population, from both a human suffering and an economic development perspective. One of the major challenges we face in stopping infectious disease outbreaks is predicting how control strategies, such as vaccines, will work. By using computer models to conduct ‘epidemiology in silicon’ we will be able to test the impact of new candidate vaccine technologies and select the most effective strategies.”

The initial phase of the research at Penn State, adds Grenfell, will be concerned with the control of measles in Niger, specifically the development of a new measles vaccine. “The project will then consider a variety of other infections,” he explains, including dengue fever, influenza, whooping cough (pertussis), poliomyelitis, malaria and tuberculosis, which are responsible for considerable morbidity and mortality worldwide.

“We plan to explore methods for deploying existing and novel vaccines that maximize the abilities of the vaccines to reduce the spread of infections and diseases,” says Grenfell, who describes himself as “a population biologist, working at the interface between theoretical models and empirical data.”

The use of sophisticated computer-modeling techniques will enable investigators to simulate infectious disease outbreaks and determine the likelihood of disease spread.

Several years ago, Penn State graduate student Nita Bharti found herself in just the right place at the right time.

“I was an anthropology grad student,” explains Bharti. “But I was primarily interested in studying human behavior and transmitted diseases. The Center for Infectious Disease Dynamics (CIDD) at Penn State was brand new and full of excellent disease researchers. I wanted to be a part of it.”

Bharti’s interests overlapped with Bryan Grenfell’s research, so she transferred to the biology department and is currently in her fourth year with Grenfell’s lab.

“I wanted my work to have elements of both theory and application,” notes Bharti. “The Vaccine Modeling Initiative has given me opportunities to do some theoretical work as well as some things that may have public health implications.”

Bharti recently attended a professional meeting in Ethiopia and calls Grenfell’s research group a “very productive participant” in a global network of infectious disease researchers. “This work has been a fundamental part of my Penn State education,” she says emphatically. “It has given me some amazing opportunities and I have met wonderful colleagues and collaborators.”

Notes Grenfell, “A special feature of the grant is that we will be allowing for the impact of the logistics of vaccine delivery (in particular regional and national supply chains) in order to establish how vaccines with different characteristics can be delivered optimally and how they might perform in different contexts.”

“Many infectious diseases are preventable by simple vaccination, yet children in poor countries die of these diseases because they lack access to vaccines,” Burke adds. “By providing computer models to aid in decision-making, we will support efforts by the Gates Foundation and other partners to make vaccines safer and easier to administer, and ultimately protect more children and adults against deadly infectious diseases.”

To learn more about the CIDD, see: www.cidd.psu.edu
EXPLORING EXTRAORDINARY TIMES

Every era can lay claim to its own particular advancements and innovations. Yet some periods of history have been particularly rich in their cultural and artistic contributions, scientific breakthroughs, and political development. These transformative periods are the inspiration for the Institute for Arts and Humanities (IAH) “Moments of Change” initiative, an annual series of symposia, performances, lectures and other events launched in the fall of 2007, and funded in part by the National Endowment for the Humanities.

“Moments of Change is creating interdisciplinary conversations and bringing faculty and students together around a focused, but multidimensional yearly theme,” explains IAH’s director, Marica Tacconi. “It is also raising the profile of the arts and humanities by bringing to campus distinguished guest scholars and artists and by engaging in a dialogue with the non-academic community.”

In its inaugural year, MoC programs turned a spotlight on the first quarter of the 17th century (ca. 1600-1625), a time of extraordinary development. Shakespeare, Cervantes, Caravaggio and Monteverdi were profoundly changing the shape of Western literature, drama, art and music. Scientific breakthroughs—such as Galileo’s improvements to the telescope and Kepler’s writings on the laws of planetary motion—laid the foundations for today’s modern scientific and technological world. Exploration of the New World began during this era as well, with the first English settlers arriving on the shores of Virginia in 1607, Quebec was colonized by the French in 1608 and, by 1621, the “first Thanksgiving” was celebrated in Plymouth between the Pilgrims and the Wampanoags.

Highlights of the year-long project included The Palmer Museum of Art’s display of its new painting, St. Sebastian Healed by an Angel (ca. 1601-03) by Giovanni Baglione (ca. 1573-1644), a Roman artist in the school of Caravaggio; theatrical productions of Shakespeare’s As You Like It (first acted 1598-1600), performed by Penn State’s School of Theatre, and of Macbeth (first acted ca. 1606), performed by Actors from the London Stage, a professional theatre troupe from England; and a performance by Apollo’s Fire, the internationally acclaimed Cleveland Baroque Orchestra, playing selections from Claudio Monteverdi’s L’Orfeo in commemoration of the 400th anniversary of the opera’s premiere (1607).

In the spring of 2008, the IAH launched the first annual Josephine Berry Weiss interdisciplinary humanities seminar series, with the theme “Four Hundred Years Ago: A Decade in the Life of Europe and the Americas, 1599-1609.” This program is generously funded by the Josephine Berry Weiss Chair in the Humanities Endowment.

Following the success of its first year, the second annual Moments of Change explores the twenty-five-year period at the turn of the 20th century, from the 1889 World Fair in Paris to the 1914 outbreak of World War One. This year’s initiative includes over forty events: interdisciplinary roundtables and symposia, a series of four salon evenings, lectures, exhibitions, performances, the second annual Josephine Berry Weiss interdisciplinary humanities seminar, and even a halftime show at a football game!

Notes Tacconi, “More than ever, Moments of Change is a collaborative effort. Over a dozen Penn State units have joined the Institute in supporting our programming as partners and co-sponsors, and faculty and students from across the arts and humanities (and beyond) have provided their input and will share their expertise to make this year’s program exciting and far-reaching.”

Tacconi’s mission with this initiative? To raise the profile of the arts and humanities and create an exciting dialogue with the non-academic community. As one patron put it, “Moments of Change is the type of program that embodies what a university should be all about.”

To learn more, see: iah.psu.edu/programs/moments.shtml
FOLLOW THE PEOPLE

“Major unsolved problems affecting human welfare in the 21st century are closely related to core concepts of population science—fertility, marriage and family transitions, mortality, migration, population aging,” Gordon De Jong has written. “Addressing these pressing problems will entail crossing traditional disciplinary as well as geographic boundaries.”

With its interdisciplinary graduate training program in demography, Penn State is uniquely prepared to do just that.

At most of the top population research centers in the U.S., demography is regarded as a sub-speciality within sociology or economics, explains De Jong, distinguished professor of sociology and demography. At Penn State, however, demographic training transcends departments and even colleges. In the broadest dual-degree program of its kind in the U.S., the University offers seven distinct demography Ph.D. degrees, each one twinned with another academic focus.

“We started offering demography to graduate students as a specialty within sociology and economics in the 1960s, like other universities,” DeJong notes. “But as we began to have more and more students, and particularly more international students, we found that a lot of these students were sponsored by their governments, and their governments were keenly interested in their working on population issues.”

“In that context we approached the graduate school to see if we could raise the visibility of population science training by initiating a different training model.”

The dual-degree model, pioneering in its day, was passed by the graduate council in 1987. De Jong credits the foresight of Howard Palmer, then senior associate dean of the graduate school. “He was a chemist, and he was well aware that the frontiers of knowledge in his own science were interdisciplinary,” De Jong says.

Today, Penn State offers Ph.D.s in demography in combination with sociology; economics; anthropology; rural sociology; agricultural, environmental, and regional economics; human development and family studies, and health policy and administration. Fed by students from these seven departments, the demography training program is the nation’s largest, with 66 students—and was recently ranked in the top five by U.S. News & World Report.

Instead of being housed in a college or department, the Demography program is attached to the University’s Population Research Institute, a vibrant interdisciplinary center that is home to some 68 affiliated research scholars. “We think that the best science results from taking the core concepts of population dynamics and importing them into economics or sociology or another discipline, rather than confining scholarship to a narrowly defined field of study,” says De Jong.

The National Institutes of Health evidently agrees. Since 1999, the program has held an NIH training grant that supports five pre- and post-doctoral trainees per year. “We’re in now for another renewal this year,” De Jong says. “Most NIH training grants are awarded in basic science, but they and other federal agencies have identified demography as an area of critical manpower shortage.”

Penn State graduates are particularly well-suited to fill that gap, he says. “We talk about value-added scholarship—that the dual-degree knowledge-base makes trainees better scientists. And from a student perspective, the dual degree opens up additional job opportunities. They’re qualified in two fields, and not just within the academy. From the U.N., the Census Bureau, the Centers for Disease Control, down to the level of state agencies: We’ve placed graduates in all of these organizations. They’re all looking for people with population science training who can analyze large population-based data sets. There is a demand for the skills of a demographer.”

To learn more, see: www.pop.psu.edu/general/training.htm

While working as a physician in his native Ghana, Arnold Degboe routinely ran into problems related to health care costs and lack of access. “An average doctor in general practice can see over 60 patients a day,” he says. “I decided to move into health policy because it would afford me the opportunity to contribute to resolving some of these difficulties.”

In 2006 Degboe entered Penn State’s graduate program in health policy administration, and soon became involved in the dual-degree program in demography. “The problems related to health care provision in sub-Saharan African are partly due to our inability to rein in the rate at which our population is growing,” he says. “It became clear that demography was going to be very relevant to my training.”

Degboe wants to return to Ghana and work in a governmental or international agency focused on public health. “Increasingly in these sectors the challenges are multi-dimensional,” he says. “If you can analyze situations drawing on different perspectives, your recommended solutions are likely to be much more effective.”
On September 1, 2007, Penn State began its five-year tenure as the central project office and administrator of one of NASA’s oldest and longest running educational projects, the Aerospace Education Services Program (AESP). The program, which is funded for up to $27.3 million over the next five years, is directed by William S. Carlsen, professor of science education and director of Penn State’s Center for Science and the Schools.

The overarching aim of the program is to help connect Penn State science and engineering departments with schools at the K-12 level throughout the country. As part of this outreach, Penn State will be awarding mini-grants to 10 to 15 other colleges and universities each academic year to help them develop courses for teachers. There are 550 eligible colleges and universities nationwide. Competition for the grants will be administered by the National Space Grant Foundation, and will be organized around a different theme each year, this year’s theme being lunar exploration.

The long term aim of the program is to develop a whole new cadre of science and engineering talent that can essentially take over from the generation of NASA engineers, now mostly retired, who were the driving force behind the 1969 moon landing and the initial phases of lunar exploration that followed that momentous event. “NASA needs a new generation of top notch engineering talent,” says Carlsen. “What’s really driving the education enterprise right now is to make sure that the pipeline is well supplied with talented people who can go on to the type of work not just done by NASA itself but also by all the contractors such as Boeing and Lockheed Martin who currently work alongside NASA.”

The Penn State program has a unique ability to reach out to the schools on a wide variety of site-sensitive levels, notes Carlsen. “Last year, for example, AESP ran 1,500 events ranging from family nights to courses taught at museums to professional development courses for teachers after school hours. These courses spanned every state and included Puerto Rico and the Virgin Islands. We have a national workforce that can travel to bring the program’s message to educational forums across the nation.”

Carlsen is also proposing some fundamental changes to the way the program has traditionally been run. In the past, the program “reached a lot of people, but for a very brief time,” he explains. “I envision a program that thinks harder about the consequences of the work, as opposed to simply getting to lots of people.” One-time after-school workshops, for example, will be replaced by extended professional development efforts. A new form of shorter-term school outreach will be provided by efforts such as Robots On The Road, run by Penn State trained education specialists who’ll crisscross the United States to bring science into school communities.

Carlsen also plans to shift the educational focus in a way that will make the relationship between NASA and the universities the educational and conceptual fulcrum of the program. Currently, relatively little of NASA’s K-12 education budget involves universities centrally. Carlsen hopes to guide the program towards providing a stronger emphasis on long-term professional development for teachers through coursework. In this way, he says, “we hope to connect schools and universities in ways that are mutually beneficial and sustainable.”

Carlsen hopes that the legacy of Penn State’s management of AESP will be an ongoing collaboration between a wide network of universities and K-12 education in areas related to NASA’s mission. Penn State’s Center for Science in the Schools has offers a glimpse of this new model in action. “I would love for the AESP project to help enable other schools and institutions to do the same thing as we have done,” Carlsen says.

To learn more, see: csats.psu.edu/aesp.htm

Taunya Sweet, education specialist with Penn State’s Center for Science in the Schools, behind the wheel of the Airstream motorhome in which she’ll take Robots on the Road.
“Systems engineering.” Unless you work in either the aerospace or the defense industry, the term might not mean much to you.

“One of our standard descriptions is that it brings together all the other engineering disciplines, with respect to large complex systems or projects,” explains Jim Nemes, head of the engineering division at Penn State Great Valley School of Graduate Professional Studies. “It can be a challenge to define, but we think it’s appropriate to what many engineers actually do.”

Systems engineers are “big-picture” engineers, Nemes says, who also serve as an interface between various experts and customers and suppliers. “They integrate everything, all the way from the conceptual stage to retirement of a project.”

The term was coined at Bell Laboratories in the 1940s, and the systems approach soon became common within defense circles and the space program. In recent years it has been adapted and adopted by many other industries. “Transportation engineers—whether designing a highway or a subway—are systems engineers,” Nemes says. “Automotive engineers don’t use the term, but they are integrating many different components into the automotive product.”

Penn State Great Valley has been offering master’s degrees in the field for almost 10 years. Two years ago, Nemes says, the campus instituted a graduate program at the resurgent Philadelphia Navy Yard. This fall, working with Penn State’s World Campus, Nemes and colleagues unveiled a full-fledged master’s degree program in systems engineering that can be completed entirely online.

The response has been gratifying. “The first online cohort filled up so quickly that we decided to start another in the spring,” Nemes reports. Students hail from all over the country, the bulk coming from the aerospace and defense industries, the government, and the military. “But we also have students from the pharmaceutical, telecommunications, and manufacturing industries,” Nemes says. Employers represented include Lockheed Martin, Westinghouse, Merck, Motorola, Verizon Wireless, Nucor Steel and Raytheon.

“Almost all of our students are working engineers,” he adds. “Usually these are people who have been working three or four years after their undergraduate degree and are looking to advance. For a lot of them, taking a residential program is a real challenge.”

Instead, students join an online cohort of 30 peers that moves through the 36-credit program together, one web-based course at a time, to finish in two years. Courses are delivered via a course-management system, incorporating video, email, discussion boards, and other interactive tools. “We encourage working together,” Nemes says.

The early returns are positive. “The discussion boards have been a big help,” wrote one student in a feedback survey. “The online experience is much better than I anticipated,” wrote another. “The course structure has been well-thought out,” commented a third.

“That’s reassuring that we’ve designed the program well,” Nemes says. “It seems to be a good fit for a lot of people.”
When lung cancer is suspected in a patient, physicians typically rely on imaging tests such as chest x-rays and computed tomography (CT) scans to diagnose and stage the disease. Obtaining a complete and accurate diagnostic picture is vital, since treatment decisions depend on information about a tumor’s size, type, location, stage, and aggressiveness. Often, minimally-invasive biopsies are performed to extract a sample of the suspicious lung lesion for analysis, by inserting a long, lighted tube (a bronchoscope, or in broader terms, an endoscope) into the patient’s airways to excise a small tissue sample.

Today’s imaging and surgical technology—such as high-definition CT scans and flexible fiber optic endoscopes with real-time video equipment—represent significant advancements. Yet there are still problems to be solved regarding optimal endoscopy technique, says Bill Higgins, professor of electrical engineering and director of Penn State’s Multidimensional Image Processing Laboratory.

Explains Higgins, physicians are hamstrung by inefficient work tools. “They have the single CT scan up on the screen, but it doesn’t correspond to what they’re looking at through the bronchoscope,” he says. “One is a 2D video through the airways and deep in the airways are hard to get to.”

Much depends on the bronchoscopist’s skill—which varies greatly,” he notes—especially when biopsy sites are beyond the airway walls. In those cases, finding the right spot to insert the bronchoscope’s needle for a tissue sample can be “hit or miss,” Higgins adds. If the bronchoscopists lose their anatomic orientation during the procedure, they must pull the endoscope back through the airways to a recognizable landmark such as the main bifurcation (branching point) of the trachea and try again.

Each successively smaller bifurcation of the airway tree—called a “generation” and assigned a number—becomes more difficult to navigate. Notes Higgins, “Studies at Penn State Hershey Medical Center have shown that by generation three, bronchoscopists are down to a 50 to 60 percent success rate. At generation four, it’s down to about 30 percent. It’s abysmal. They’re just lost.”

Higgins and his research group, including Hershey Medical Center pulmonologist Rebecca Bascom, are hoping to show them the way. Funded by the National Institutes of Health, the National Science Foundation, and the Whitaker Foundation, the team has developed and tested an interactive software program for 3D image processing and visualization called Virtual Navigator. Designed to interface with standard videobronchoscopy equipment, the software converts each patient’s CT scans into a virtual three-dimensional construction of their particular lung anatomy.

The system then uses techniques from computer graphics and computer vision to generate a detailed ‘procedure plan’—essentially a road map to particular tumors and nodules—prior to the bronchoscopy. “The computer procedure plan is directly linked to the bronchoscope procedure, through a live registration and fusion of the 3D CT data and bronchoscopic video,” Higgins explains. While performing the procedure, the doctor and technicians coordinate their surgical instruments with three-dimensional CT images as they explore the lungs by direct view through their endoscopes. This new approach provides physicians with significantly improved visual feedback and quantitative distance measures to help them decide how to maneuver the bronchoscope and where to insert the biopsy needle.

“Virtual endoscopy permits a level of precision and safety never before achieved in biopsying suspicious lung lesions and staging lung tumors,” says Higgins, who founded a company called Endographics Image Systems, Inc. in 2000 and has made applications to the U.S. Patent and Trademark Office.

Most importantly, says Higgins, initial results from trials led by Bascom at Hershey indicate that the variation in skill level between different physicians is greatly reduced by the system, and biopsy effectiveness is increased.

To learn more, see: www.mipl.ee.psu.edu
For the sensitive work of detecting explosives and drugs in airports and other high-risk areas, humans have long relied on a marvel of evolutionary biology: the sniffer dog. The canine nose can detect a seemingly infinite range of odors, alone and in combination, at concentrations down to the parts per trillion level.

But dogs are expensive and time-consuming to train, and some environments are too dangerous for their deployment. As a result, researchers have recently developed a variety of chemical sensing technologies, or artificial noses. So far, though, these devices work only for a limited range or a certain class of chemicals, and are typically stymied by mixtures of chemicals.

A few years ago, with funding from the Office of Naval Research, Eric Paterson, a senior research associate at Penn State’s Applied Research Lab and an associate professor of mechanical engineering, decided to go back to the source, studying the fundamental fluid mechanics and odorant transport of canine olfaction with the object of coming up with a better mechanical equivalent.

When a dog sniffs, Paterson explains, odorant-laden air passes through the nasal vestibule and then through a labyrinth of exquisite complexity. This is nature’s solution to packing a large surface area in a small volume—crucial for delivering odors to millions of olfactory receptors, specialized proteins embedded in the olfactory epithelium. “Smelling” occurs when odorant molecules bind to these receptors and produce signals that are interpreted by the brain.

To get a closer look at the process, Brent Craven, then a graduate student in mechanical and nuclear engineering and now an ARL research associate, created a computational fluid dynamics model based on the equations of fluid motion and high resolution magnetic resonance imaging (MRI) of an actual dog’s airway.

The model yielded some important insights, Paterson reports. “One key finding was an explanation of how odors were transported to the olfactory region within the nasal cavity. Our computer simulations showed that a single passageway, known as the dorsal meatus, was responsible.” In the olfactory region, the air flow over the mucous-coated receptors is remarkably smooth, “albeit pulsatile due to sniffing,” which presents a consistent signal to the receptors. “All of this maximizes efficient transport of odorants to the receptors, and sets up chemical deposition patterns that are interpreted by the brain,” Paterson says.

Partly as a result of this work, Paterson and colleagues were chosen this summer as one of three teams to participate in RealNose, a multi-institutional project sponsored by the Defense Advanced Research Projects Agency (DARPA) whose object is to build a mechanical nose that closely simulates the entire canine olfactory system. In addition to Paterson and Craven, the Penn State team includes Gary Settles, director of the Gas Dynamics Lab and distinguished professor of mechanical engineering, as well as researchers from Tufts University, the University of Pennsylvania, Temple University, the University of Illinois, and the University of Miami. The team, which is led by Evolved Machines, Inc. of Palo Alto, California, also includes industry partners from CogniScent, Inc., of North Grafton, Massachusetts; iSense, Inc. of Champaign, Illinois, and Northrup Grumman.

DARPA’s directive outlines four elements in its first phase. First, Paterson says, the team will have to develop an odorant-intake system that incorporates their earlier airflow and odorant-transport modeling work. Next the team will develop an odorant detection system that incorporates canine olfactory receptors engineered from actual cells. Paterson expects this to be the most challenging part of the project.

“Work needs to be done to identify the receptors that respond to individual chemicals,” he explains, “and then these receptors must be expressed in sufficient numbers to be used in an actual sensor.” The team is exploring several approaches, one of which involves depositing receptors onto carbon nanomaterials capable of converting scents into electronic signals. A pattern-recognition system would then enable the machine to identify specific odorants in a complex mixture.

As Paterson explains, the RealNose project is a typical “DARPA-hard” program: high-risk, high-payoff. Should marketable technology evolve from the research, however, it could be tailored to sniff out drugs, explosives, chemical and biological weapons, and even certain types of cancer.

“It’s fun to find the projects at the seams of different technologies,” he says, and Craven agrees. “This is the realm of discovery and unsolved problems. Plus there are practical applications that could positively impact all of our lives.”

To learn more, see: www.mne.psu.edu/psgdl/ Craven-AR-final-2007.pdf

Three-dimensional computational fluid dynamics model of a canine nose reconstructed from high-resolution MRI scans.
WASTE MAKES POWER

The rising need for clean, renewable forms of energy. The lack of adequate sanitation in many developing countries. These are two global problems that may not seem to go together. But what if a wastewater treatment plant could actually generate power, instead of using it? That’s the promise of microbial fuel cells (MFCs).

As Bruce Logan, Kappe professor of environmental engineering at Penn State, explains it, MFCs represent a completely new method of renewable energy recovery: the direct conversion of organic matter to electricity using bacteria.

It has been known for many years that bacteria could be used to generate electricity, Logan explains. But the organic material was always glucose, or some other high-energy carbohydrate. “We showed that you can do it with any biodegradable material,” he says. Even the wastewater that’s flushed down drains and toilets.

To make a microbial fuel cell, Logan continues, “you take bacteria, give it food but no oxygen, and add two conductive electrodes, an anode and a cathode. The bacteria oxidize the organic material, and transfer electrons to the anode,” or negative electrode. Then the electrons flow from the anode through a wire to the cathode, “and you have current,” he says. (On the cathode side, the electrons recombine with the protons and with oxygen to form water.)

The real beauty of Logan’s MFC, however, is that while it produces electricity, it also cleans the wastewater it uses. As Logan explains it, the air flow into the cathode tube reduces oxygen, providing the same cleaning effect normally accomplished by aeration. Since four to five percent of all U.S. electricity is used to treat wastewater, the potential savings are huge.

And there’s yet another twist. By applying a small electrical current to boost the action of the bacteria in a microbial fuel cell, Logan can reconfigure the cell to produce not electricity from wastewater, but hydrogen. Call it a microbial electrolysis cell, or MEC.

Not surprisingly, these parallel technologies have attracted a lot of attention, both at home and abroad. In March 2008, Logan was one of 12 scientists worldwide to receive a Global Research Partnership Investigator award from Saudi Arabia’s fledgling King Abdullah University of Science and Technology (KAUST). Logan will receive up to $10 million over the next five years to further his bioenergy research program.

“[Saudi Arabia] uses a tremendous amount of energy for desalination, and of course it’s all supported by fossil fuels,” Logan says. “The idea is to try and use wastes and waste waters and agricultural residues as a renewable energy source, and also to provide additional energy for desalination. “But mostly our focus will remain on providing a global solution for energy sustainability of the water infrastructure. The heart of the whole thing is to come up with a way to allow for water and wastewater treatment which doesn’t suck up energy.”

To learn more, see: www.engr.psu.edu/ce/enve/logan/default.htm

Rachel Wagner found out about Bruce Logan’s research while she was serving in the Peace Corps. After she graduated from Virginia Tech with a master’s in biological systems engineering, she and her husband had taken off for a two-year hitch in Belize.

“We didn’t have Internet in our village,” Wagner says, “but we would ride the bus to the big city once a week, to shop for groceries and to get online. I knew I wanted to get into alternative energy. A few places sparked my interest, but—working for Dr. Logan—you don’t turn down an opportunity like that.”

After a year in Logan’s lab, Wagner was awarded a graduate research fellowship by the National Science Foundation. For her Ph.D., she’s zeroed in on learning exactly how the bacteria within microbial fuel cells do their work.

“That’s what research is really all about,” Wagner says. “You generate a big idea, and then you figure out all the little details to make it happen.”
For faculty and students at Penn State, the opportunity to do relevant and applied research is central to the educational experience. Such research is also vital to our country’s economic health. The mission of the Research and Technology Transfer Organization (RTTO) is to serve as a catalyst for economic growth through the transfer and utilization of University research, knowledge and resources to benefit society. Five RTTO units carry out this mission:

The **Industrial Research Office (IRO)** helps companies to identify and access both Penn State faculty expertise and targeted research centers, and serves as a liaison for long-term, mutually beneficial University-industry research partnerships. During FY 2008, IRO staff facilitated 164 projects with 44 companies, amounting to $18.7 million in industry-sponsored research.

The **Intellectual Property Office (IPO)** manages and protects the intellectual property of all Penn State employees and promotes commercialization of University inventions through licensing agreements with industry partners. In calendar year 2007, IPO filed 167 U.S. patent applications, and 34 patents were awarded. Not including the equity Penn State holds in start-up and established companies, Penn State intellectual property generated revenues of $3 million.

The **Research Commercialization Office (RCO)** assists the Penn State community in the creation of new companies based on University research and technologies, and identifies sources of early stage capital and management expertise.

**Innovation Park at Penn State** is a 118-acre business park that provides companies with multiple real-estate options. In 2008, Penn State’s Research Park Management Corp. entered into a contract with Wallace Roberts & Todd, Philadelphia, to update the Innovation Park Master Plan to determine development of the remaining 35 acres.

**Ben Franklin Technology Partners of Central and Northern PA** provides funding and business support services to both emerging tech-based start-up companies and existing manufacturers within a 34-county area of Pennsylvania. In 2007/2008 the Center’s Board of Directors approved investments totaling more than $6.2 million. These investments were made in 37 emerging companies and 7 existing manufacturers, as well as a variety of entrepreneurial support efforts such as business incubators, university-based centers of excellence, and workforce development and training projects.

To learn more, see: [www.techtransfer.psu.edu](http://www.techtransfer.psu.edu).