Photo by Chris Emery

Putting the squeeze on batteries

Princeton engineers have found a surprising link between battery life and the day-to-day physical forces acting on an overlooked battery component that could make batteries last as long as the gadgets, laptop computers and cars they power.

"People think of batteries as chemical devices," said Craig Arnold, an associate professor of mechanical and aerospace engineering. "We're looking at how mechanics or physical forces affect the electrochemical performance of the system."

Efforts by others to study the mechanics of a lithium-ion battery have focused on the battery's electrodes, the "plus" and "minus" connectors. Arnold and his graduate student Christina Peabody Ph.D. '11, were the first to correlate battery performance with the mechanics of a part called the separator, which divides the positive and negative components, but allows electrically charged particles to pass through. They found that typical forces acting on a battery compress the separator, thereby limiting the flow of lithium ions and dramatically diminishing charge capacity.

"That's an interesting and surprising result," said Arnold, who is affiliated with the Andlinger Center for Energy and the Environment, and the Princeton Institute for the Science and Technology of Materials. "The role of the separator in this sense hadn't really been appreciated before."

Taking their work one step further, Arnold and Peabody recommend ways to mitigate this effect: modify the surface of the electrodes or change the separator's properties. A separator made of a less compressible material could result in longer battery life. The researchers published their findings in the *Journal of Power Sources*. **–Prachi Patel**

Graduate student Christina Peabody (left) and Associate Professor Craig Arnold investigated a previously unexplored cause of shortened lifetimes in batteries and are developing technology to extend battery performance. Scan the QR code to watch Arnold explain his work in a video (**www.bitly.com/uRZb4f**).

SignalGuru helps drivers avoid red lights and save gas

Photo by Zachary Donnel

Princeton graduate student Emmanouil Koukoumidis (left) worked with Professor Margaret Martonosi and Professor Li-Shiuan Peh of the Massachusetts Institute of Technology to develop a cell phone-based system, called SignalGuru, to help drivers save gas.

A cell phone networking project led by Princeton engineers could reduce fuel consumption by letting drivers know how to adjust their speed to avoid having to brake heavily or stop at traffic lights.

The system, called SignalGuru, involves a network of cell phones mounted on car dashboards, with each device using its camera to detect traffic lights and then reporting the status of the lights to a central computer system. Drivers using the system receive tips about when to slow down or make a detour to avoid stop-and-go situations that consume fuel.

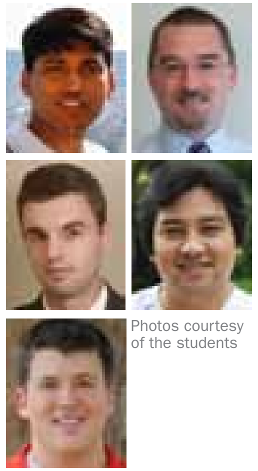
Emmanouil Koukoumidis, a graduate student in electrical engineering, and Professor of Computer Science Margaret Martonosi are developing the system in collaboration with Li-Shiuan Peh, a former Princeton professor of electrical engineering, now at the Massachusetts Institute of Technology. The team received one of two Best Paper awards presented at the Association for Computing Machinery 2011 MobiSys conference in Washington, D.C, in June.

The researchers tested the system in Cambridge, Mass., and Singapore and found that it helped cut fuel consumption by up to 20 percent.

Cars are responsible for more than a quarter of the energy consumption and carbon dioxide emissions in the United States, according to Koukoumidis. "If you can save even a small percentage of that, then you can have a large diminishing effect on the energy that the U.S. consumes," he said.

Martonosi said the project fits into her goal to identify opportunities where multiple mobile devices collaborate to solve a problem more effectively or efficiently than a single device could. "Individual SignalGuru cellphones collect data," she said. "But by collaboratively sharing their observations with other nearby SignalGuru users, the prediction error is reduced by four-fold and the usefulness of the system is greatly increased." **– Teresa Riordan**

Siebel Scholars program recognizes top computer science graduate students



Photos courtesy of the students

Clockwise from top left: Anirudh Badam, Robert Dockins, Chong Wang, Nicholas Jones and Wyatt Lloyd

Top graduate students in the Department of Computer Science will receive a prestigious award and lifelong membership in a network of leading scholars under the newly established Siebel Scholars program. The program is funded by a $2 million gift from the Thomas and Stacey Siebel Foundation.

The Siebel Scholars program was founded in 2000 to recognize the most talented students in bioengineering, business and computer science, and empower them to solve the world's most pressing problems through lifelong community and support. Princeton's computer science department is now among 17 academic departments throughout the United States and China included in the program. The dean of each participating school selects five Siebel Scholars each year based on outstanding academic achievement and demonstrated leadership.

Princeton's inaugural group of Siebel Scholars includes Ph.D. candidates Anirudh Badam, Robert Dockins, Wyatt Lloyd and Chong Wang, and master's degree student Nicholas Jones. Each received $35,000 to support their final year of study. The Siebel Scholars program also brings together its current and past recipients — currently around 700 — for an annual conference and other networking events.

"The Siebel Scholars program not only provides terrific recognition for some of our finest computer science students," said Dean of Engineering H. Vincent Poor Ph.D. '77, "but it also creates opportunities to strike up interdisciplinary collaborations on issues of global importance. We are honored that the Siebel Foundation selected the Princeton computer science department to participate." **–Steven Schultz**

Photos by Denise Applewhite

Above from left, freshmen Jillian Wilkowski, Isaac Lederman and Edward Fashole-Luke.

From left, Sheffield and Wood join students Ray Chao, Marina Kaneko and Joan Cannon in a discussion of global food crises.

Tackling tough questions about global environmental change

by Nick DiUlio

Gazing up at a projected map displaying the changing dietary habits of people from countries around the world, students in Professor Eric Wood and research scholar Justin Sheffield's freshman seminar faced a difficult question.

"Why do you think we're seeing a global transition to a meat-based diet?" Sheffield asked the 14 freshman gathered for the session of "Global Environmental Change: Science, Technology and Policy." The seminar, offered for the first time this fall, addresses the issue of climate and sustainability through the lens of many disciplines.

One student posited that the shift in diet may indicate that consumption of meat connotes high social status in some cultures. Another student suggested that the increasingly globalized economy could be a factor in the transition — or, perhaps, that more and more people simply like the taste of meat.

With each question posed during the three-hour session, Wood and Sheffield extend the initial query into a further exploration of complex issues.

"OK, well, this creates an interesting dilemma," said Wood, the Susan Dod Brown Professor of Civil and Environmental Engineering at Princeton University and director of the Program in Environmental Engineering and Water Resources. "If the world switches to a U.S.-style, meat-based diet, is that going to be sustainable?"

It had been less than 30 minutes since class began and already the room hummed with discussion that would continue until everyone was dismissed. Focusing primarily on global food crises that afternoon, Wood and his students — along with co-instructor Sheffield, a research scholar and lecturer in civil and environmental engineering — touched on a range of topics including the impact of modern technology on global agriculture, the importance of food security, the causes of recent spikes in food prices, and the pros and cons of U.S. foreign aid policies.

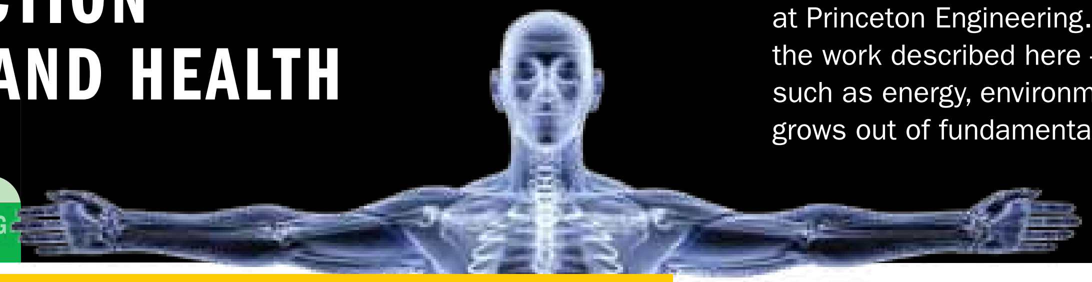
The previous week, their students focused on the environmental causes and socioeconomic effects of natural disasters around the world. Before that, the class focused on water scarcity and its impact on economic development. And earlier sessions covered the impact of rapid population growth on communities and the environment. The aim of the seminar, said Wood, is to explore the threads linking each of these issues and to challenge students to consider possible solutions.

"One of the things the students are starting to understand is the interconnectedness of all these issues," said Wood, whose research focuses on climate, terrestrial hydrology, remote sensing and water resources. "We want students to realize that these aren't one-dimensional problems. You can't think of energy, food security or land degradation in isolation."

Students are required to compose biweekly essays addressing environmental and policy quandaries. While he admitted they are very challenging, freshman Ray Chao likes these essays.

"We're encouraged to create our own solutions and ideas," Chao said. "It requires a lot of creativity, and it's exciting to take what we're learning to come up with something new." E

EXPLORING THE INTERSECTION BETWEEN ENGINEERING AND HEALTH



The following pages offer a snapshot of health-related research at Princeton Engineering. The research often extends well beyond the work described here — sometimes into entirely different fields such as energy, environment and security — because the research grows out of fundamental approaches to broadly relevant problems. For more details visit **www.princeton.edu/engineering**.

PREVENTING | DIAGNOSING | TREATING | UNDERSTANDING

PREVENTING

SIMPLE, LOW-COST WATER PURIFICATION COULD IMPROVE GLOBAL HEALTH

Photo by Frank Wojciechowski

Above, graduate student Ismaiel Yakub pours water into a filter system as sophomore Megan Partridge collects filtered water to demonstrate a system designed for use in Africa. Led by Professor Wole Soboyejo (at left in upper right photo), a Princeton research group created clay pots that can be made easily from local materials but have been shown to eliminate bacteria and even viruses from water.

Photo courtesy of Tiffany Tong

by Prachi Patel

Two Princeton engineering groups hope to use technologies based on inexpensive, easily available materials to give villagers in developing countries access to safe drinking water and help create local jobs.

One group led by Wole Soboyejo, a professor of mechanical and aerospace engineering, has developed a ceramic filter made from a clay-and-sawdust mixture to remove pathogenic bacteria from water. Baking the mixture burns off the sawdust, leaving behind tiny pores that block microbes.

Currently available filters and treatment methods based on heat, the sun or chlorine are costly, inaccessible or ineffective. The clay filter developed in Soboyejo's lab eliminated water-borne diseases within weeks in a Nigerian village near Abeokuta, where the researchers have helped set up a factory. They are now transferring the technology to Burkina Faso and Kenya.

"Local people need to generate income from making these filters," Soboyejo says. "That's the key to making this sustainable."

Other than filter-maintenance, the biggest challenge is educating villagers about sanitation and the filter's benefits, he said. "You'd think it's as easy as telling people 'You should use these because it's good for you,'" Soboyejo said, "but that's like telling me to eat salad because it's good for me."

Another group led by Peter Jaffe, a professor of civil and environmental engineering, is using apatite, a phosphate compound, to make filters for well water that remove fluoride, which can deform teeth and bones if ingested in high amounts. Lab tests show that apatite composed of lime and phosphoric acid works as well as today's more expensive activated alumina filters.

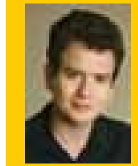
Once the engineers optimize the filter's operation, they hope to test it in a village in India where excess fluoride is endemic and study the spent apatite's potential as a fertilizer, Jaffe said. "It would be irresponsible if we don't figure out what to do with the used material," he said.

Soboyejo and Jaffe, both funded by Princeton's Grand Challenges program on global health, are now collaborating to develop filters made from both clay and apatite that could remove pathogens and fluoride from drinking water at once. **E**

Photo by Frank Wojciechowski

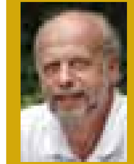
Above: Hagar ElBishlawi, a graduate student in the lab of Professor Peter Jaffe, is developing a low-cost system for removing excess fluoride from water, which is endemic in various parts of the world and which can deform bones and teeth.

AVOIDING HOSPITAL RE-ADMISSIONS



Mark Braverman, an assistant professor of computer science, is helping solve a pressing problem in health care: how to prevent patients from relapsing soon after being discharged from a hospital. During a previous stint at Microsoft Research, Braverman helped develop software that allows computers to "learn" based on actual patient data those patients that are most at risk so that hospitals can tailor their post-discharge care and avoid re-admissions. Microsoft released the software as part of its hospital-data management product in spring 2011. **– SS**

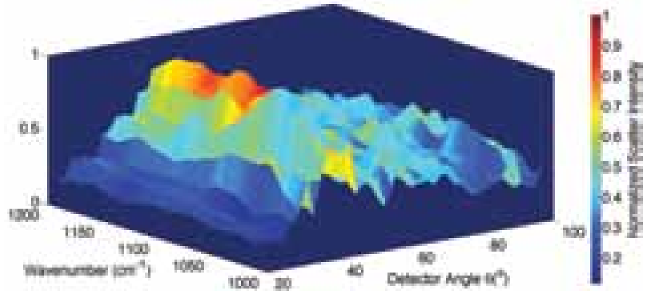
PROTECTING BLOOD TO PREVENT NEUROLOGICAL DAMAGE

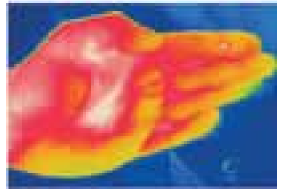


Alexander Smits, chair and the Eugene Higgins Professor of mechanical and aerospace engineering, is working with students to understand the ways that sheer forces and turbulence damage blood cells. The work could lead to new designs for heart-lung bypass machines, which are commonly used in surgeries but are thought to cause neurological damage and other complications. The researchers have described the behavior of blood over a very wide range of conditions, more precisely than ever done before. **– SS**

DIAGNOSING

PAINLESS: LASERS ALLOW NON-INVASIVE TESTS





A very low-power infrared laser could measure blood sugar without the conventional pinprick. Above, a plot of the light reflected from skin is one of many tests to demonstrate that the laser penetrates deeply enough to monitor glucose. At right, the white dot on the forefinger of the lower image shows the infrared beam hitting the skin. The power of the laser is on par with the heat generated at the palm of the hand, which also appears white in the infrared image.

Images courtesy of Sabbir Liakat

by Steven Schultz

What if a person with diabetes could measure blood sugar without a pinprick? What if a quick scan of a person's breath could reveal how their kidneys are doing or whether they have asthma?

These are the kinds of potential technologies that drew more than 100 business leaders, investors, medical researchers, scientists and engineers to Princeton on Oct. 12 for a meeting that underscored how one fundamental technology can spur multiple benefits for human health.

The meeting explored the medical applications of lasers and sensors tuned to operate with mid-infrared light, a part of the spectrum that is particularly useful for detecting biologically relevant molecules. It was the most recent Investment Focus Group workshop hosted by Mid-Infrared Technologies for Health and Environment (MIRTHE), a multi-institutional research center funded by the National Science Foundation and based at Princeton.

Behind the technologies is a device known as a quantum cascade laser, which offers a compact, inexpensive and easy-to-use method for producing and detecting mid-infrared light. Among the uses currently being developed is a device that scans a persons' skin to reveal his or her blood glucose level — a project that is now supported by Princeton's Eric and Wendy Schmidt Transformative Technology Fund. Compared to the current method of drawing and testing a drop of blood, the innovation could provide much more control over diabetes.

Another area of research involves sensing nitric oxide or ammonia in a person's breath. Technology under development at Princeton could allow much more finely tuned detection of nitric oxide than was previously possible, allowing a more fundamental understanding of the role of the gas in the body and in disorders such as asthma. A similar scan for ammonia could give doctors critical information about the kidneys. More precise and frequent monitoring of these conditions might allow reduced use of steroids or dialysis, saving medical costs and avoiding potential complications.

Dr. Raed Dweik, a professor of medicine at the Cleveland Clinic, and a collaborator with MIRTHE, said mid-infrared sensing has the potential to overcome the drawbacks of existing technologies, which are either too bulky, require too much expertise or provide too little information to be useful in day-to-day medicine. "I think it has great potential for moving breath sensing forward," he said.

The increasing understanding of quantum cascade lasers also is leading to their possible use in laser surgery, because they could provide more controlled, less damaging incisions than conventional lasers. Princeton engineers are helping develop surgical lasers that are currently being tested in experimental corneal surgeries at Johns Hopkins University.

Claire Gmachl, the Eugene Higgins Professor of Electrical Engineering and director of the MIRTHE research center, said the technology and science have matured dramatically since the center was created in 2006.

"The energy was quite amazing," Gmachl said of the investment workshop. "To see the technology grow and spread and be taken up by other people is very gratifying." E

PRINTABLE SENSORS FORM BASIS FOR MANY TESTS

Princeton engineers are collaborating with Maryland-based Vorbeck Materials to develop printable sensors that greatly improve the performance of many basic medical tests.

The researchers in the laboratory of Ilhan Aksay, professor of chemical and biological engineering, are using "functionalized graphene" — a single-atom-thick sheet of carbon with certain structural and chemical modifications — that could form the basis for inexpensive, highly reliable tests for chemicals such as glucose and dopamine.

The technology is being commercialized by Vorbeck, which recently established a research lab in Princeton near the University to continue the collaboration. –SS

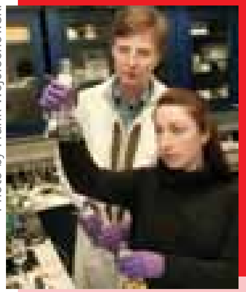


Photo by Frank Wojciechowski

Christian Punckt (left), a scientist with Vorbeck Materials and a visiting research collaborator at Princeton, works with postdoctoral researcher Sibel Korkut Ph.D. '08, on testing the properties of "functionalized graphene," which holds promise for sensing important biological molecules.

SEEKING GLOBAL ACCESS TO CERVICAL CANCER PREVENTION

Women in the developing world have a far greater chance of dying of cervical cancer than American women largely because of the lack of screening programs that could detect precursors of the cancer when it's more treatable.

Princeton senior Shivani Sud, a molecular biology major working toward an engineering biology certificate, has a plan to change that. Working with Wole Soboyejo, a professor of mechanical and aerospace engineering, Sud is developing a system that uses an off-the-shelf digital camera and freely available software produced by the National Institutes of Health to help clinic workers who have modest training identify women who should receive further care.

With the Princeton system, a clinic worker takes a picture of a woman's cervix during a gynecological exam then swabs the cervix with vinegar or a similar solution and takes another picture. The software performs a pixel-by-pixel comparison of the two pictures to identify cancerous or precancerous tissue, which changes color when exposed to vinegar.

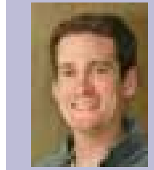
"Sometimes it's not invention," Sud said, "but innovation that's needed, taking things that we take for granted and putting them together in a novel way that is a practical solution for another community."

Sud tested the system in India last summer and planned to return during winter break to continue refining it. –SS

Photo by Frank Wojciechowski

Shivani Sud, a senior majoring in molecular biology, is working with engineering professor Wole Soboyejo on a simple system with off-the-shelf parts to test for cervical cancer in the developing world.

OUTSMARTING BACTERIA



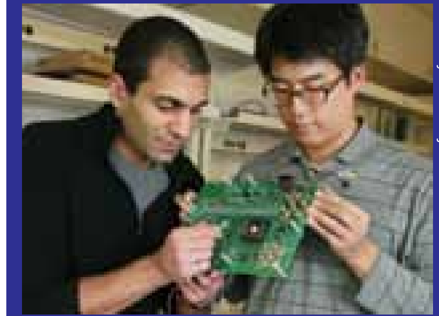
Bacteria are survival experts, but Mark Brynildsen, an assistant professor of chemical and biological engineering, is on to their tricks.

In one project, Brynildsen studies bacteria's ability to enter and exit a quiescent state that makes them impervious to antibiotics. "You're basically nuking them and they're OK," he said. "If we could figure out how they do that we could learn how to kill them" and avoid relapses of infections.

Other work involves understanding and predicting the formation of biofilms, structured colonies of bacteria that pose major problems for prosthetics and other implants. In a third area of work, Brynildsen is developing antibiotics called "anti-virulence therapies" that fight bacteria indirectly by disrupting their interactions with their host. **–SS**

BODY LANGUAGE:
LOW-POWER DEVICES READ SIGNALS TO STAVE OFF HEALTH PROBLEMS

Naveen Verma, an assistant professor of electrical engineering, is designing wearable or implantable electronic devices that monitor brain or heart signals to prevent acute problems and perform long-term assessments in patients with chronic illnesses such as heart disease and epilepsy.



Photos by Frank Wojciechowski

Verma collaborates with medical researchers to create devices that analyze large databases accumulated by hospitals and provide information about what to look for in monitoring a patient's heart and brain activity. He seeks to feed this information into lightweight, low-power devices that patients would wear daily.

The devices would use machine-learning techniques to identify the unique signals from a patient's body and send a warning to clinicians in advance of a heart attack or seizure. The devices may also initiate treatments, such as electrical stimulation that wards off a seizure.

"The goal of these devices is to transform healthcare from a curative discipline to a preventative or preemptive discipline, yet in a low-cost and scalable way," Verma said. **–SS**

Top inset: Graduate student Kyong Ho displays a tiny chip he is developing as the core component of medical devices that could help manage chronic illnesses. Above: Assistant Professor Naveen Verma, left, and Ho examine a prototype device that will eventually be shrunk to a wearable or implantable size.

SMALL PACKAGES: NANOPARTICLES IMPROVE DRUG DELIVERY

A technique for encapsulating drug molecules in tiny plastic-like coatings shows promise for improving treatment of cancer and tuberculosis, while aiding the laboratory testing of new drugs.

Robert Prud'homme, professor of chemical and biological engineering, developed the fundamental method, called "flash nanoprecipitation," and has numerous collaborations with companies, medical researchers and engineering colleagues to develop it into therapies and diagnostics.

In one project, Prud'homme is working with Howard Stone, the Donald R. Dixon '69 and Elizabeth W. Dixon Professor of Mechanical and Aerospace Engineering, as well as Pat Sinko, a professor of pharmacy at Rutgers University, to develop nanosized, medicine-filled particles that accumulate in the lungs, where they deliver concentrated doses of cancer drugs.

Prud'homme also is working with Maryland-based biosciences company Sequella, Inc., and the University of Sydney in Australia to use nanoparticles to deliver anti-tuberculosis drugs to the lungs.

In a separate project, Prud'homme is collaborating with Pennsylvania-based company Optimeos Life Sciences to develop a method for using nanoparticles to track tumor growth in lab animals, which could provide better information throughout a drug trial and avoid the need to euthanize animals to gather data during the course of an experimental therapy. **–SS**

DESIGNING NEW BIOLOGICAL MOLECULES TO FIGHT BACTERIA AND CANCER

by Prachi Patel

Princeton researchers are applying Darwinian evolution principles to naturally occurring antibacterial molecules to create novel antibiotics for the food and drug industries.

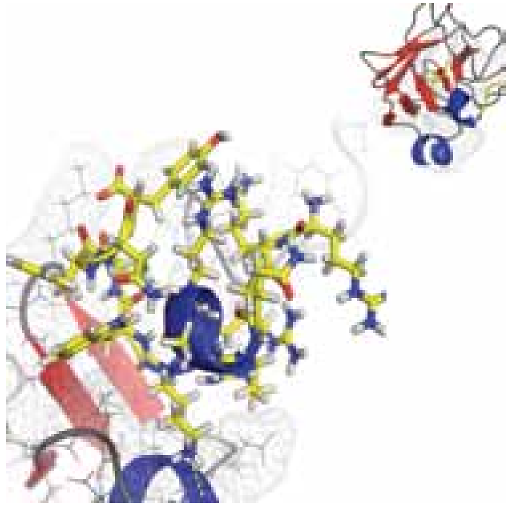
Bacteria secrete antimicrobial peptides — short chains of amino acids — for defense against other species. James Link '00, an assistant professor of chemical and biological engineering, is pioneering research on a class of such peptides that are lasso-shaped, which makes them resistant to the body's defense mechanisms and hence good drug candidates. "We're understanding how these amazing structures are made by bacteria," Link said. "Thermodynamically they shouldn't exist."

Starting with one particular lasso peptide, Link and his graduate student Jessica (Si Jia) Pan have created a dozen variants with more antibiotic potency. The researchers use a method called directed evolution in which they create random mutations, test for desirable properties and repeat. They screened 20,000 variations of the peptide for the most promising molecules and found the most promising to be as potent as the antibacterial peptides used in the food industry to protect perishables.

The researchers are now trying to beat bacteria at their own game. "We're trying to use directed evolution to find a peptide that can kill E. coli that are resistant to it," Link said. "In the same way that a bacteria evolves resistance, we can try to evolve peptides that overcome that resistance."

While Link's approach to designing drugs is experimental, Christodoulos Floudas, the Stephen C. Macaleer '63 Professor of Chemical and Biological Engineering, has spent more than a decade developing computational methods for the same purpose.

Floudas and his graduate students have found a way to calculate whether a peptide, based on its structure and amino-acid sequence, will bind to a specific protein. They have designed seven new peptides that bind to a human enzyme linked to cancer progression. Experiments by a Boston company have shown that the peptides inhibit the enzyme's function. "There's no currently available inhibitor for this enzyme," Floudas said. **E**



This computer-generated image shows a computationally designed drug, shown in yellow and blue, binding to a cancer-related enzyme called EZH2, shown in red. Professor Christodoulos Floudas and colleagues have created mathematical methods to predict, from billions of possibilities, what combinations of amino acids would bind to naturally occurring proteins, thus leading to promising drug candidates.

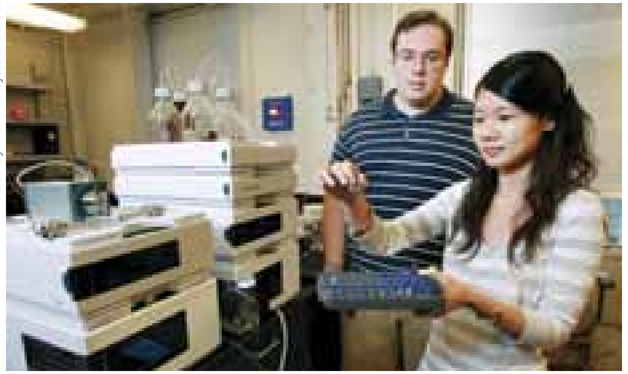
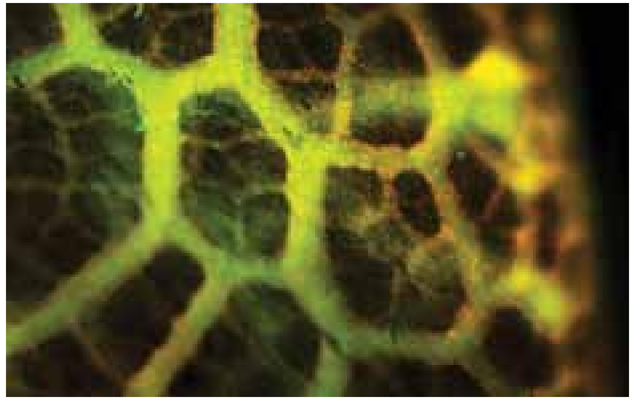


Photo by Frank Wojciechowski

Assistant Professor James Link and graduate student Jessica (Si Jia) Pan are developing peptide drugs that could treat bacterial infections that have become resistant to antibiotics.

UNDERSTANDING

ORIGINAL THINKING: PROBING EARLY GROWTH MAY REVEAL NEW PATHS TO TREATMENT



The development of the airways of the lungs is a focus of research in the lab of Celeste Nelson. This image of a lung of a bearded dragon lizard is featured in Princeton's 2011 Art of Science exhibit, which runs through November 2012. Scan the QR code at left to view the Art of Science gallery online (**www.bitly.com/tM64os**).

by Steven Schultz

Biologists have long been fascinated by the first moments when cells divide to become complex tissues and organisms. Now engineers — with an eye toward treating cancer and regenerating tissue — are increasingly joining the hunt for the quantitative principles and underlying mathematics that determine how these processes succeed or fail.

Stanislav Shvartsman Ph.D. '99, a professor of chemical and biological engineering who also holds an appointment in Princeton's Lewis Sigler Institute for Integrative Genomics, is developing statistical approaches to understanding the way chemicals spread signals across an embryo. Shvartsman and colleagues published a breakthrough in this work Oct. 17 in the journal *Development*.

In the lab of Celeste Nelson, assistant professor of chemical and biological engineering, Cecillia Lui '11 recently turned her senior thesis into a peer-reviewed article on the mechanics of stem-cell differentiation in breast tissue, which could have implications for understanding breast cancer. Another former undergraduate, Jay Kwak '09, is co-author with Nelson of a new study revealing that normal lung-tissue development is governed by a single mathematical equation.

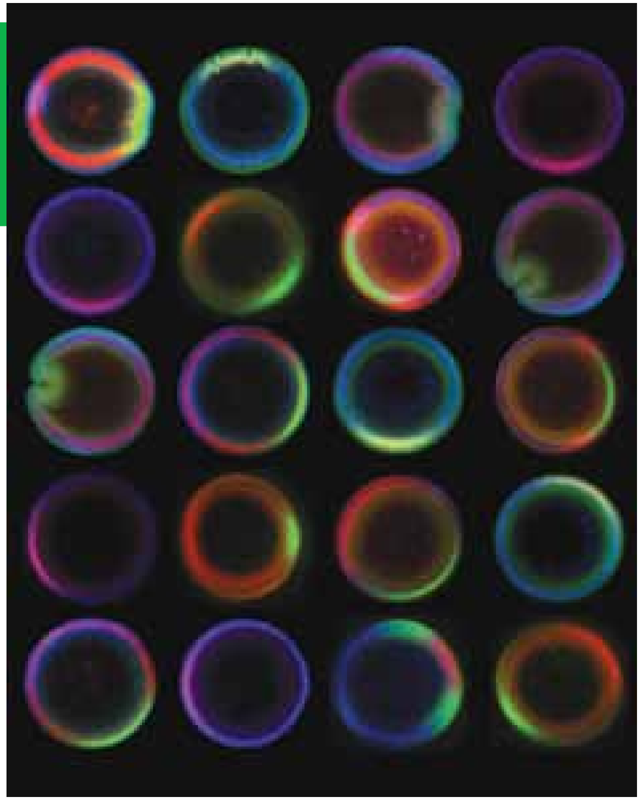
In the same department, Assistant Professor Clifford Brangwynne focuses on a cell component called the nucleolus, a loose confederation of proteins and RNA that produces the hardware that builds cells from the inside out. A long-term goal is to tune the properties of this tiny bioreactor to adjust cell growth, which could be useful in battling the runaway expansion that characterizes cancer. **E**

FUNDAMENTALS OF FLUIDS

Researchers in the lab of Howard Stone, the Donald R. Dixon '69 and Elizabeth W. Dixon Professor of Mechanical and Aerospace Engineering, are applying a deep understanding of fluid flows to reveal the mechanics behind critical biological functions.

In one project, Stone's group found the unexpected formation of bacterial ribbons in the middle of flowing fluids, which has implications for understanding serious infections and has led to a collaboration with Bonnie Bassler, the Squibb Professor of Molecular Biology, and Ned Wingreen, a professor of molecular biology and associate director of the Lewis-Sigler Institute for Integrative Genomics.

Scan the QR code to learn about Stone's work in a video by science photographer Volker Steger (**www.bitly.com/voZppu**). **– SS**



Above: In a recent breakthrough, researchers in the lab of Stanislav Shvartsman used a micro-sized device that traps fruit fly embryos and stands them on their ends, which allows scientists to obtain critical data on early development processes using large numbers of embryos at once. This image, which shows development patterns in 20 embryos, was featured in Princeton's 2011 Art of Science exhibit.

ASSEMBLING THE GENETIC "HUMAN-IN-A-BLENDER"

The field of biology is awash in data about human genes, but as Olga Troyanskaya points out, databases often represent a "human-in-a-blender" — an undifferentiated average of genetic activity throughout the body.

Photo by Frank Wojciechowski

Troyanskaya, an associate professor of computer science who is jointly appointed at Princeton's Lewis-Sigler Institute for Integrative Genomics, is developing computational methods to determine exactly what genes are turned on or off in specific tissues — whether the kidneys or the lungs — without doing any further laboratory experiments.

"It is very accurate — more accurate than experimental approaches in mice," Troyanskaya said.

The next step in her work is to develop a similar method for elucidating the pathway of signals from one gene product to another, bypassing the need for time-consuming experiments and offering clues to disease processes and therapies. **– SS**

TECHNOLOGY, POLICY AND MEDICAL RESEARCH

Information technology is transforming biomedical research by creating formalized networking platforms through which researchers share knowledge. Benedicte Callan, a University of Texas health-policy expert currently a visiting fellow at Princeton's Center for Information Technology Policy, is studying these networks

Photo by Frank Wojciechowski

and how might they affect government policy toward funding, openness and commercialization of biomedical research.
– SS

MIND READING: ENGINEERS HELP REVEAL MEANING IN BRAIN SCANS

Photo by Frank Wojciechowski

Neuroscientist Ken Norman (left) and computer scientist David Blei are using machine learning techniques to analyze brain imaging data to understand how the meanings of words are represented in the brain and shape the retrieval of other memories.

by Steven Schultz

Princeton engineers are working closely with neuroscientists to understand how visual information and words are encoded in the brain.

In a five-year collaboration, a team led by Princeton's Peter Ramadge, chair and the Gordon Y.S. Wu Professor of electrical engineering, and James Haxby, a neuroscientist at Dartmouth College, have found common patterns in data from brain scans, called fMRI, that reveal brain activity as people perform tasks. The researchers are solving a long-standing challenge of comparing one person's brain activity to another, which until now has been difficult because both the anatomy and functional processes of each person's brain are different.

In one recent result, published in the journal *Neuron*, the researchers had subjects watch the entire movie "Raiders of the Lost Ark" while undergoing fMRI scans and used the data to derive a "common neural code" for how the brain recognizes complex visual images. Based on data from the first half of the movie, the researchers were able to predict, using only a person's fMRI results, what scene he or she was watching in the second half of the movie.

Ramadge said the collaboration has not only revealed deep insights for neuroscience but has pushed the limits of the engineering techniques in ways that could be useful in many other areas. "It's been a two-way street," he said.

Ramadge attributed the success in part to weekly interdisciplinary meetings initiated by Jonathan Cohen, the Eugene Higgins Professor of Psychology and co-director of the Princeton Neuroscience Institute.

"It's been a great way for my students and me to learn the language of neuroscience," Ramadge said.

In a separate project, computer scientist David Blei and neuroscientist Ken Norman also are using fMRI data to understand how word meanings are represented in the brain and how these meanings shape memory retrieval. The researchers are showing how the meanings of words that were presented recently can linger in the brain and serve as a mental context that time-stamps memories, so that memories evoke words and vice versa. The work may aid the development of technologies for diagnosing and remediating memory problems. **E**

EVOLUTION OF CANCER

Photo by Frank Wojciechowski

James Sturm '79, the William and Edna Macaleer Professor of Engineering and Applied Science, and director of the Princeton Institute for the Science and Technology of Materials, is working with physics professor Robert Austin, of the Princeton Physical Sciences Oncology Center, on an interdisciplinary approach to understanding the evolution of cancer.

In one project, Sturm and colleagues created an array of tiny posts that hold cancer cells and allow precise control over their microenvironment. The researchers use the device to wash cancer drugs over the cells and watch how the cells develop resistance to the drugs. **– SS**

Above: James Sturm (left) with graduate student Amy Wu.

SIMULATING BRAIN DAMAGE

Researchers in the lab of Professor of Electrical Engineering Sigurd Wagner are using their expertise in flexible electronics to give medical researchers an unprecedented view of brain damage.

Doctors would like to model brain damage in the lab by rapidly stretching nerve cells, but the electronics needed to monitor the effects typically do not stretch. Wagner's group has developed a flexible electronic array and is testing it with biomedical engineers at Columbia University. **– SS**