COLLEGE OF ENGINEERING

ALUMNI NEWSLETTER

SPRING 2014

LEAD STORY

From Inside Human Cells to Outer Space, Robust Faculty Research Spans the Gamut

A “pediatric brain on a chip” that *The Scientist Magazine* hailed as one of the top 10 innovations for 2013. A novel adsorbent that is more effective than activated carbon at removingemerging contaminants from wastewater. Superior, soy-based wound dressings. Accurately beaming solar energy back from space.

These are just some of the investigations College of Engineering faculty members are conducting as part of the college’s growing, multi-million dollar research portfolio:

Mechanical Engineering:

In collaboration with CFD Research Corp. in Huntsville, Ala., Mohammad Kiani, PhD, chair of the Mechanical Engineering Department, and Temple neuroscientists are developing a pediatric blood-brain barrier system on a chip. The SynVivo microfluidic chip offers great potential for studying the role of the blood-brain barrier—which is more permeable in children—in pediatric neurological diseases and for testing the blood-brain-barrier permeability of various therapeutic drugs.

Funded by a three-year, $600,000 grant from Shriners Hospitals for Children, Kiani—in collaboration with Barbara Krynska, PhD, assistant professor of neurology at the Shriners Hospitals Pediatric Research Center in the School of Medicine at Temple—is leading the effort, which uses neonatal rats as models for mapping brain vascular networks. Those networks are then reproduced on chips that resemble microscope slides.

Kiani’s pediatric blood-brain barrier on a chip is a dynamic system made up of a vascular compartment of pediatric endothelial cells (cells that line the interior surface of blood vessels) with fluids traveling through the vessels and a brain-tissue compartment that consists of brain cells.

Previously, Kiani had developed the technology to map the vascular networks of various animal organs. Prabhakar Pandian of CFD Research Corp., a former graduate student of Kiani’s, approached him with the idea of reproducing detailed maps on chips or slides.

“Essentially, we created a microvascular network on a chip,” says Kiani, who, with Pandian, received funding from the National Institutes of Health to develop the original chips. “But I never thought it would go beyond a one-time thing.” Kiani then began to delve into the possible applications of reproducing vascular systems, tissues and even tumors on chips.

“Aside from all the ethical issues, doing these on chips instead of in animal models is inexpensive, reproducible and provides higher throughput,” he said. “Using these systems on chips can give you an overview of the important disease processes or permeability of therapeutics before you ever begin the more expensive animal and human studies.

“If you successfully test a new therapeutic drug in this system, there is a very good chance it will also be successful in vivo.”

Other medically related mechanical engineering research includes the development of a so-called ‘smart needle” by Parsaoran Hutapea, PhD, associate professor of ME. While needle-based interventions are among the most common diagnostic and therapeutic techniques, the success of such procedures depends on accurate needle placement at target locations. To create the new needle, Hutapea is working with a bendable shape-memory alloy called Nitinol.

“If you could bend a needle you could target certain locations inside the body much more accurately,” notes Hutapea. The research is being funded by the Department of Defense’s Prostate Cancer Research Program.

Meanwhile, three years ago Svetlana Neretina, PhD, was awarded a National Science Foundation CAREER Award, one of the most prestigious NSF research awards for young faculty members. That funding has resulted in two developments:

* a lithography-free process for fabricating periodic arrays of nanomaterials: The technology, which is being patented by the university’s Office of Technology Development and Commercialization, offers a simple, quick and effective means to prototype nano-based devices, including pixel detectors for digital cameras and X-ray imaging;
* a new class of hollow nanomaterials that offer the kind of large surfaces needed to speed up chemical reactions in catalytically driven processes, such as those used in hydrogen fuel cells.

“The most popular catalyst material is platinum, which is expensive,” Neretina notes. “But if you increase the surface area of platinum nanomaterials both inside and outside by making them hollow, it’s more effective and, because you are using less material, cheaper.”

To detect hydrogen, Neretina is also collaborating with a Temple chemistry professor, Eric Bourguet, PhD, to develop a new class of hollow palladium materials and, as a new member of the Temple Materials Institute, she is also collaborating with materials science researchers in Japan and South Korea.

Bioengineering

Peter I. Lelkes, PhD, founding chair of the department and inaugural director of the School of Medicine’s Institute for Regenerative Medicine and Engineering, is investigating:

* soy-based wound bandages: “It seems to be a very good way to promote a more natural way of wound healing that costs a fraction of what’s commercially available now,” he says.
* engineering lung tissue and organs: “We’re trying to coax embryonic stem cells into making little lung organoids with the long-term goal of ultimately either implanting whole organs or using a patient’s own cells or stem cells to rebuild a functional organ,” Lelkes says.
* repairing damaged spinal cords: Lelkes is working with Michael Lemay, PhD, professor of bioengineering, and the Shriners Hospital for Children’s Center for Neural Repair and Rehabilitation to construct stem-cell derived scaffolds that have the potential to re-connect axions above and below severed spinal cords.
* a pancreatic cancer model: Working with Temple’s Fox Chase Cancer Center, Lelkes is growing tissues that mimic the cancer’s stages. The goal: to identify unique cancer markers and develop a routine, early-stage screening for a cancer that presently is the deadliest because symptoms appear too late for treatment.

Also, Andrew Spence, PhD, associate professor of bioengineering, is teasing apart the roles that the brain and body play when we move as part of a three-year, $1.365 million research grant he originally initiated at the University of London’s Royal Veterinary College. When mice run fast, they push the limits of their sensory input systems so far that they instead rely on body mechanics to keep moving.

To study the phenomenon, the first-year Temple professor is using optigenetics. He employs sequenced proteins within neurons that, in response to light, turn brain and spinal cord neurons off or on.

“For the first time in history we can switch parts of the nervous system on and off to understand whether and how they contribute to locomotion,” says Spence. “The more we understand about how your brain, spinal cord, muscles and skeleton all work together to allow you to move in potentially rough terrain ,for example, the better we’ll be able to help people with neurological disorders , damaged limbs or prostheses.”

Electrical & Computer Engineering

Using mega databases to help physicians diagnose and treat their patients is one of medicine’s most rapidly growing trends. At Temple, Associate ECE Professor Iyad Obeid, PhD, and ECE Professor Joseph Picone have teamed up with Mercedes Jacobson, MD, professor of neurology in the Temple University School of Medicine, to use Temple University Hospital’s rich database of electroencephalograms (EEGs) to help diagnose neurological conditions, particular epilepsy and stroke. The database includes 12 years’ worth of EEG recordings, which total more than 24,000 EEGs from more than 15,000 patients.

“Developing software to help doctors make diagnoses isn’t new,” says Obeid. “But training our software system with massive amounts of data is novel. A neurologist may look at 10,000 EEGs over his or her entire career, but never look at all of them at the same time to be able to spot trends to subtle to see with the naked eye.”

Using such a “deep learning” concept, the professors hope to develop software that can accurately diagnose a patient’s condition as well as identify the exact cause and location of the problem within the brain.

Funding for the $185,000 research project is being provided by the dean’s office, the Office of the Senior Vice Provost for Research, the Department of Defense’s Defense Advanced Research Projects Agency and the University City Science Center’s QED Proof-of-Concept Program—which is providing advisors to help the concept become commercially viable. “The preliminary results are promising,” says Obeid. “What makes this challenging is building something that actually functions at a level that will be clinically meaningful.”

Meanwhile, earth-based solar panels are limited in the amount of energy they can collect by both nighttime and daytime cloud cover. But what if space-based orbiting panels could beam solar energy back to Earth 24 hours a day?

Chang-Hee Won, PhD, associate professor of ECE, is working on a three-year, $350,000 National Science Foundation grant to develop an accurate two-axis gimbaled laser targeting system for such usage. In a paper currently submitted for publication, Won’s laboratory developed two algorithms that reduced the standard deviation of pointing error by 48 percent and 53 percent, respectively, compared to the standard controllers currently used in space and elsewhere.

The issue is critical, Won notes, because less accurate targeting would require a larger collection rectenna, increase the cost and degrade the power transmission efficiency. If a solar energy collector orbited 20 kilometers above the Earth, a system with a target error rate of 1 degree would require a rectenna of 2.5 km in diameter vs. a 17.5-km diameter rectenna if the targeting error range was 5 degrees.

Enhancing target accuracy is also critical for public acceptance. “Laser beams are not harmful,” he says, “but whether people are on the ground or in airplanes, psychologically they don’t want to go through laser beams.”

Civil & Environmental Engineering

Besides the research at its WET Center, which explores novel treatments of emerging contaminants (see this page [or previous page]), the CEE Department is pursuing a broad range of civil and environmental engineering research.

Joseph Coe Jr., PhD, assistant professor of CEE, is exploring the use of nondestructive methods to assess the condition of subsurface bridge foundations. One of his targets: subterranean effects of “bridge scour.” That occurs, he says, “when the velocity of flooded stream water erodes away some river bank soil around bridge piers. If it’s extreme enough, it can undermine the entire foundation.”

Design plans or as-built specifications are unavailable regarding the foundation type, depth and/or geometry for more than 40,000 U.S. bridges. To gauge the pier depth and infrastructure vulnerabilities of such bridges, preliminary field tests of various techniques Coe has conducted at two local PennDOT bridges seem to indicate that borehole radar is the most accurate; borehole ultrasound and electric resistivity techniques also show promise.

Huichin Zhang, PhD, an assistant professor of CEE, is current engaged in two multi-year research projects funded by two National Science Foundation grants totaling more than $480,000. In both cases, she is investigating what happens when emerging contaminants interact with naturally occurring elements in the environment. The first of her two studies is assessing the potential toxic impacts on soil-water environments—the sediments found in a lake bed, for example—when emerging contaminants such as triclosan, a common antibacterial and antifungal agent found in toothpaste, hand soaps and plastic ware, interact with commonly found iron and manganese oxides.

“This study is the first to examine the nature of these interactions,” says Zhang, “and we’ve found that the combination of these elements significantly slows down the breakdown of these contaminants and makes their effects on the environment both more toxic and longer lasting.”

Her second study is focusing on the oxidation effects that occur when veterinary pharmaceuticals, including antibiotics, are released into wastewater and then impact soil-water environments.

Meanwhile, Benoit Van Aken, PhD, assistant professor of CEE, focuses on the biodegradation of toxic organic pollutants by plants and bacteria. Funded by the U.S. Department of Agriculture, Van Aken is using molecular biology techniques to assess the ability of soybean plants to both clean up soils (phytoremediation) contaminated by PCBs and explosives such as TNT—while also providing a usable fuel stock for biodiesel production.

“The ability of soybeans to mitigate contaminants has been previously known, but we are also finding that the soybeans’ lipids can be both a safe and effective biofuels source,” says Van Aken.

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SIDEBAR

WET Center Scales Up Four Promising Technologies

Making good on the promise of a $1 million 2011 National Science Foundation grant, over the past year the college’s Water and Environmental Technology (WET) Center has scaled up its investigations of four promising technologies aimed at treating water and wastewater for emerging contaminants by installing four compact, pilot-scale treatment plants in its new first-floor laboratory.

The technologies variously target such emerging and often unregulated contaminants as pharmaceuticals, personal care products, flame retardants, soap-molecule surfactants and pesticides. The pilot-scale treatment technologies—which can treat 250 gallons of water at two gallons per minute compared to just two gallons per bench-scale experiment—include:

* carbon adsorption and ion exchangers made from cyclodextrins, a family of compounds comprised of glucose molecules
* advanced oxidation processes
* ultrasound; and
* micro-filtration processes to remove particulates from the water that vary, based on the size of the targeted particulates, from filters made of sand to very fine membrane filters.

“At the bench scale all four of these have been very promising,” says Rominder Suri, PhD, director of the WET Center and chair of the Civil & Environmental Engineering Department. That’s particularly true of the first technology, which has proven significantly more effective than standard-use carbon in removing organic and inorganic contaminants as well as metals. The novel adsorbents can also be reused and are environmentally friendly.

“We have filed a couple of patents on this technology and a number of companies have already applied with us to test the technology on an even larger scale at their treatment plants in the U.S. and possibly the United Kingdom,” says Suri.

Students are benefiting as well. For example, during the first six months that the oxidation pilot treatment plant was operational, graduate and undergraduate students conducted 300 experiments. “It has really increased their research efficiency,” Suri says.

Besides NSF support, the new lab has also been funded by the Department of Defense and Temple University, which spent $250,000 to renovate space previously occupied by the Architecture Department.