

By Christine Cardelino

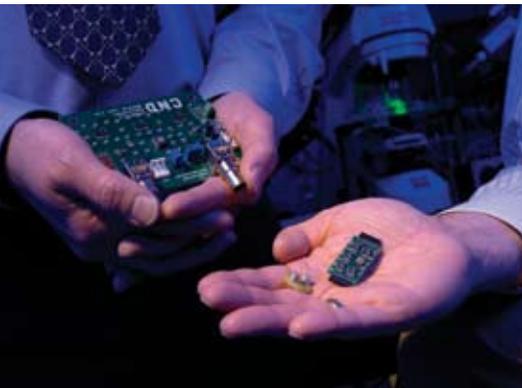
# Partners in Hope:

Center for Neural Engineering Researchers Explore the Intricacies of Brain Disease and Novel Brain-Machine Interfaces

Bruce Gluckman, Ph.D., (left) associate professor of engineering science and mechanics, and associate professor of neurosurgery in the College of Medicine, and Steven J. Schiff, M.D., Ph.D., (right) director of the Penn State Center for Neural Engineering, professor of neurosurgery, and Brush Chair of Engineering Science and Mechanics.

The new Penn State Center for Neural Engineering will direct University resources in engineering, materials, and neurosciences to the creation and commercialization of implantable medical devices in the rapidly expanding field of neurostimulation.

photography by Fred Weber



Nanotechnology is one area of neural engineering exploring the development of tiny devices that can be safely implanted in the body to control certain neurological functions. Pictured here is a prototype adaptive feedback system for controlling epilepsy.

As a pediatric neurosurgeon, Steven J. Schiff, M.D., Ph.D., has performed major invasive procedures to lessen or eliminate seizures in children with epilepsy, but it's his work in the research lab that holds even more potential to transform the treatment of neurological disease.

"We are beginning to lay the foundation for the next generation of what you might call 'smart devices' that can be more effective in treating epilepsy, Parkinson's disease, and more," says Schiff, director of the Penn State Center for Neural Engineering, professor of neurosurgery, and Brush Chair of Engineering Science and Mechanics. The Center, a collaborative effort between Penn State College of Medicine and the College of Engineering, was started this past year thanks to a \$250,000 Keystone Innovation Zone (KIZ) grant with matching funds from the University.

The Center positions Penn State to be a leader in an emerging biomedical field. Implantable medical devices (neural prosthetic devices) are gaining widespread clinical use for the treatment of brain tumors, Parkinson's disease, epilepsy, psychiatric disorders, vascular diseases, spinal injuries, and stroke. In 2005, more than 80,000 devices are estimated to have been implanted worldwide.

"These devices provide remarkable improvements in the quality of people's lives. The deep brain stimulator, implanted to control the symptoms of Parkinson's disease, is capable of canceling tremor and restoring full function in patients previously unable to drink from a cup or walk independently," says Robert E. Harbaugh, M.D., F.A.C.S. '78 MED, chair, Department of Neurosurgery, Penn State Hershey Medical Center, who was awarded the original KIZ grant, to develop the Center for Neural Engineering.

## Neural Engineering

"People in this field encompass different realms—from developing engineering tools for looking at and understanding neural systems to developing all types of brain stimulation and recording systems and systems for providing direct brain-machine interfaces," says Bruce Gluckman, Ph.D., associate professor of engineering science and mechanics, and associate professor of neurosurgery in the College of Medicine. "Our work also involves the design and development of neural prosthetics, which may one day enable signals from the brain to allow patients to control high-tech artificial limbs as though they were their own."

The field also incorporates nanotechnology, the miniaturization of devices for implantation and use within the body, adds Judith A. Todd, Ph.D., P.B. Breneman University Department Head's Chair, of Engineering Science and Mechanics at Penn State University Park.

"Nanotechnology will have many applications in the work of the Center for Neural Engineering. For the prosthetic devices, researchers need to look how interfaces work between the device and the brain. We'll use nanotechnology to develop new materials and new coatings for implants to make them biologically compatible. Nanotechnology also comes in when you are looking at neurons and how they transmit information between each other and among neural networks," she says.

## Pressing Medical Challenges

Technologies in development at the Penn State Center for Neural Engineering take aim at some of the greatest areas of medical need.

“The impact of neurological and psychiatric diseases on society is inestimable,” says Harbaugh. “If you look at neurological diseases—stroke, Alzheimer’s disease, Parkinson’s disease, epilepsy, multiple sclerosis, brain trauma, spinal cord injuries—you’ll realize that a majority of Americans are afflicted at some time in their lives with a neurological problem. These problems can have a devastating effect on the lives of individuals and their families.”

“In the psychiatric realm, as many as 40 percent of adults at some point in their life will be clinically depressed,” he adds. “In the area of neurobehavioral problems, we see a huge spectrum of issues, such as morbid obesity and addiction. The Center for Neural Engineering is at the forefront of new treatment possibilities by applying engineering and technology to human disease.”

## Innovating the Future

The creation of implantable devices requires the development of nanoscale and microscale electronic circuitry, biocompatible materials, new sensor technologies, wireless communication systems that provide real-time monitoring of brain/body functions, miniaturized power sources, and mechanically robust, fail-safe systems.

“You have to use materials which very gently can pass electricity into the biological organ without generating toxic chemicals or passing too much current, which can burn a hole in the brain. These are hard to do, but we feel it is extremely important to develop effective and safe neural prosthetic devices. We will make sure the devices developed at Penn State are known for extensive R&D into safety,” says Schiff.

Across Penn State, the Center for Neural Engineering will support advanced research in a number of important areas—and then work to translate these discoveries into clinical practice. For example, in addition to increasing basic understanding of brain rhythms and techniques for applying electricity to the brain, Schiff’s research interests include development of new devices for hard-to-control epileptic seizures.

“We focus on ways of directly interacting with the part of the brain that is causing symptoms to turn off symptoms when they occur. We believe it is possible to predict seizures and prevent them from occurring, or to suppress them once they begin,” he explains.

Harbaugh hopes the Center will help advance his work with intracranial aneurysms and predicting aneurysm rupture.

“Most of my clinical career has been devoted to treatment of patients with cerebrovascular disease. One difficult problem we face is the patient with an unruptured aneurysm: Should we make a recommendation for a potentially dangerous treatment or simply wait and observe? If we could predict which aneurysm will cause problems and treat only that type, we can avoid unnecessary treatment while potentially reducing the incidence of stroke,” he says.

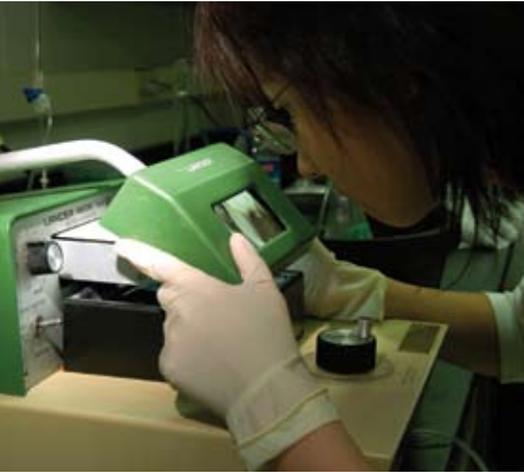
James R. Connor, Ph.D., vice chair for research in the Department of Neurosurgery, believes the Center will expand his team’s expertise in Parkinson’s disease and amyotrophic lateral sclerosis (ALS), or Lou Gehrig’s disease.

photography by Fred Weber



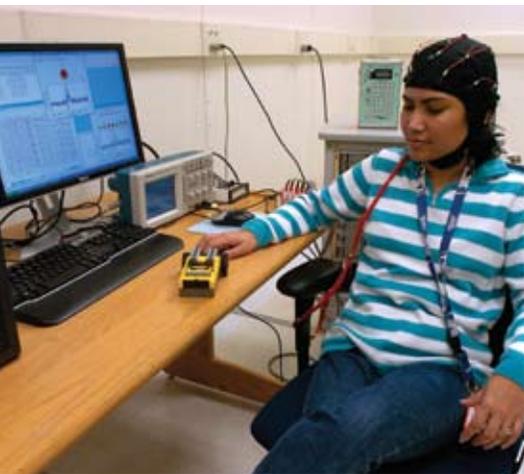
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Ning Dong, a graduate student in neuroscience, prepares biological samples for testing.

photography by Fred Weber



Research associate Kamrun Kamrunnahr demonstrates a device that reads signals from the brain to control a robot car. It is hoped the interface can one day be used to control a wheelchair.

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“Penn State researchers are using deep brain stimulation—the use of battery-operated electrical mechanisms attached to electrodes implanted in the brain—to stop some of the movement disorders associated with Parkinson’s. As a next step, we’re trying to develop telemetry to send signals when there is an abnormal movement. Some of the robotic ideas are to implant electrodes in the brain to help people with paralysis or Lou Gehrig’s disease to move objects and body parts by thinking about the movement,” notes Connor.

Developments in deep brain stimulation also may lead to breakthroughs for people who have suffered severe head trauma, according to Harbaugh.

“Neural stimulation may increase neurotrophic factors in the brain and cause the brain to produce new brain cells. This is very early work and definitely an area of interest for the Center for Neural Engineering. If you can induce the brain to make new neurons through a stimulation paradigm, you may have effective treatments for people with traumatic brain injuries,” he says.

In addition to partnering with Schiff on treatment advances for epileptic seizures, Gluckman is exploring the therapeutic potential of neural prosthetic devices for people with paralysis due to stroke or spinal cord injury, or those who have lost a limb.

“A developing area in the field of neural engineering is sensory input replacement. We’ve seen some early successes in implanting devices for recording neural activity and using that output to control prosthetic limbs or computer-controlled monitors. The big challenge with this system is that it’s all output; there’s no sensory feedback to the individual. We’re hoping to develop prosthetic devices that are directly wired to somebody’s brain and can provide immediate sensory feedback, such as knowing how hard you are gripping a cup,” explains Gluckman.

“Without a doubt, there are revolutionary advances to be made in these fields. Historically, human disease has been studied from medical and biological perspectives, but now we’ve added engineers and scientists into mix. With these different disciplines working together to solve common problems, it may be possible to develop interventions never thought of before,” says Todd.

Associate Vice President for Health Sciences Research, Chief Scientific Officer and Vice Dean for Research & Graduate Studies Jay Moskowitz, Ph.D., believes the Center for Neural Engineering will lead to an acceleration of both basic science and clinically relevant research innovation, which will hasten progress towards better treatments for brain disease and neurological disorders. Additionally, he says the center will promote economic growth across the state through the commercialization of new technologies and products to support cutting-edge patient care.

“We have more than \$530 million in research expenditures from University Park and almost \$100 million from the College of Medicine. Bringing all of that expertise together enhances Penn State’s reputation as a first-ranking academic institution when it comes to R&D efforts. The evolving collaboration between University Park and the College of Medicine not only will generate multidisciplinary approaches to problems, but also will help us develop new disciplines, which will be important as we move forward with science and society,” he notes. ■