TECHNOLOGY

NEUROSCIENCE

Reconnecting the Brain

Researchers are working to reconstruct the nervous system so that paralyzed limbs might be active again. By Jonathan Fahey

THE BRAINS OF THE PATIENTS Hunter Peckham and John Donoghue are trying to help fire off instructions by the millions, every second of the day. The messages, little packets of electrical information, are intended for the far reaches of the patients' bodies, where perfectly capable muscles await word. But none of the messages gets through; the muscles lie dormant. Injuries, strokes or disease have severed the connection between brain and body.

Peckham, a biomedical engineering professor at Case Western Reserve University, and Donoghue, a neuroscience professor at Brown University, have been able to reestablish that connection with stunning results, enabling partially paralyzed patients to stand up or write a letter. Peckham, 65, has since 1986 been outfitting paralyzed patients with implanted devices that hijack nerve signals from unaffected regions of patients' bodies and use them to move otherwise lifeless parts. Now he is developing a networked system that he hopes will allow people control of up to five areas of their body at once.

Donoghue, 60, has been working at the other end of the nervous system, trying to decode the brain's language and use that information to spur an action. Between 2004 and 2006 Donoghue implanted devices in the brains of four patients that enabled all of them to move a computer cursor around a screen and one to power a motorized wheelchair simply by mentally willing it.

Now the two professors' labs are working together in hopes of some day developing a system that allows a paralyzed patient to move his or her own hand or to sit up straight by thinking about it, the way most of us do. "We are bridging the gap by using small pulses of electrical current to turn the nerves back on," says Peckham.

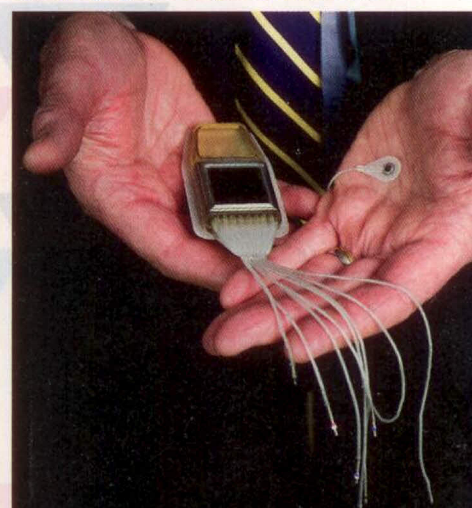
While Peckham and Donoghue have proved what once seemed impossible can indeed be done, they have struggled to turn their huge technological leaps and flashy lab results into practical devices. Peckham has helped 1,000 patients in a 32-year career; only one of Donoghue's patients remains outfitted with his implanted device. Peckham started a company in 1993 called NeuroControl, and Donoghue started one called Cyberkinetics in 2003. Both companies failed. They were hampered in part because the market they were initially targeting was too small. Their devices were designed to help people with severe paralysis, only 5,000 new patients a year in the U.S., not enough to sustain the investment needed to perfect and produce the technologies.

Now the hope—of Peckham, Donoghue and many other researchers working to develop what are called neural prosthetics—is that their devices can be made more useful, safe and adaptable so they might also help some of the 800,000 annual stroke victims in the U.S., along with people suffering from certain manifestations of amyotrophic lateral sclerosis (ALS) and Parkinson's disease, and as a way to stave off seizures in the 3 million Americans with epilepsy.

Applying an electric current and getting a muscle to jump is easy. (Alessandro Volta jolted a frog's legs 218 years ago.) Peckham is harvesting the body's own electrical signals to control muscles that have been cut off from the nervous system, a process called functional electrical stimulation, or FES. Peckham runs a group called the Cleveland FES Center, a collaboration among Case Western Reserve and two Cleveland hospitals.

A paralyzed patient almost always has several muscles that retain feeling and movement. Peckham implants a sensor that reads the electrical signals from one of these muscles, usually in the neck or forearm. He then transmits those signals through thin implanted wires to, say, one of the patient's hands. With practice a patient can control his hand by moving muscles in his neck. Peckham has provided patients with the ability to move a hand, cough, control bladder and bowel function, roll over and stand up. So far he hasn't been able to help a paralyzed person gain control of more than two lost functions. The problem: It would be impractical to implant several of the devices in a patient. There's a limit to how many controllers, actuators and wires the body can accommodate.

Eric Schremp, 40, was paralyzed in a 1992 swimming accident. An implanted device *(below)* invented by Hunter Peckham *(standing)* allows Schremp to use his right hand by employing nerve impulses in his shoulder.



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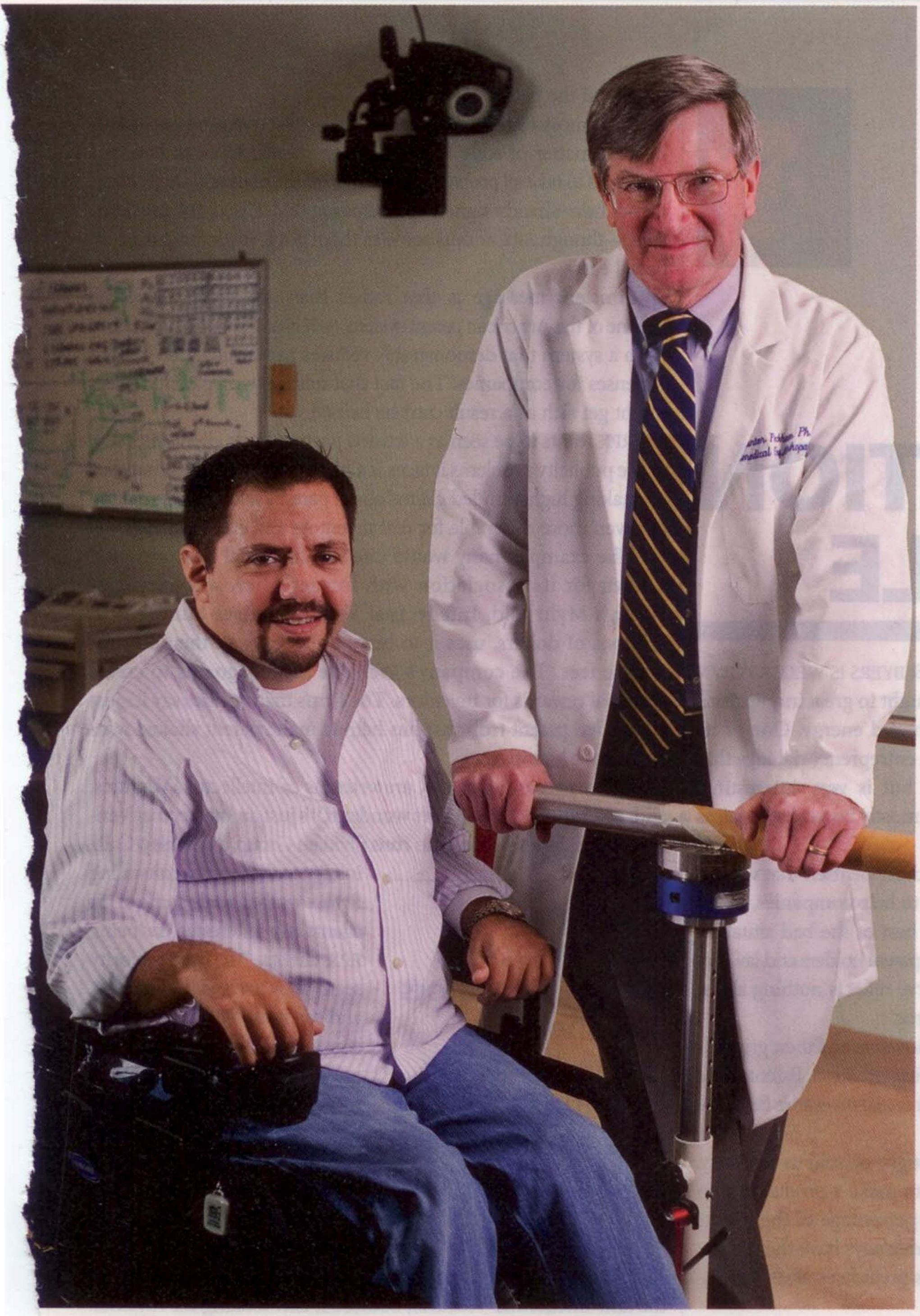

developed a system called Brain Gate that was implanted in four patients. It consisted of a 100-electrode panel about the size of a baby aspirin that was placed on the surface of the brain at a fold in the motor cortex where hand movement is controlled. The pinlike electrodes, which protrude into the brain's gray matter, picked up signals from the neurons nearby. The signals were relayed through a port fastened to the patient's skull and wired to a set of electronics that helped translate the signals.

Now Donoghue is working to make a far more practical system. He has shrunk the electronics dramatically, from a cart the size of a washing machine to just a computer and something the size of a DVD player. And he hopes to be able to relay the signals wirelessly through a person's skull to a receiver implanted beneath skin on the head, eliminating the need for an open port into the brain.

Once Donoghue collects the brain signals, he has to make sense of them. Listening to 100 neurons firing is like listening to static, but a computer can pick up different patterns in the nerve impulses as a person thinks about moving in different ways. With the help of algorithms and filters to smooth out anomalous signals, the computer can translate those intentions into instructions that can move a cursor or a wheelchair.

Or, eventually, a patient's own arm. Robert Kirsch, who works in Peckham's lab, is directing the collaboration with Donoghue. Using videogame software code, he has built a virtual reality arm based on an arm wired with FES. Donoghue translates brain signals, and Kirsch uses them to drive the arm on a computer screen. Kirsch says initial results are great, but there is a ways to go.

Even if the complete repair of a broken nervous system is a distant dream,

Now Peckham is building a system that will allow a patient to control up to five of these functions at once. The trick is a single implanted power source and a distributed system of controllers that will manage several different physical functions. "We would wire the body with what would look like a computer network," Peckham says.

Donoghue, at Brown, works with people who can move nothing below their necks. He discovered that if a person who has long been paralyzed thinks "move my arm to the left," the region in the brain responsible for moving arms—the motor cortex—fires away as if everything were connected. "Just looking at the brain, you wouldn't know whether the person was paralyzed or not," he says.

If Donoghue could decode that information in the brain, he could use it to help people control a wheelchair or a computer. He

researchers think that engineering better neural prosthetics will help treat different nervous system diseases. An epilepsy patient could have a pacemaker for the brain: An electrode array like Donoghue's could pick up signals that lead to a seizure, and a stimulator could fire and reset the brain before the seizure takes hold. "If we could re-create the physical nervous system, then we could help many, many more people," says Donoghue. **F**