# The Brain

## The Bionic Age Begins

### Neural implants will treat tremors, paralysis, and even memory loss

By John Horgan

DISCOVER Vol. 26 No. 10 | October 2005

Theodore Berger, a professor of engineering at the University of Southern California, is ready for the era of the bionic brain. He has spent 30 years developing computer chips that can link with neurons in an effort to compensate for memory loss. The chips that can do it exist. Most of the software exists. The challenge is to make a reliable, long-term connection between the hardware and the wetware—one that is unaffected by corrosion, scar tissue, or the shifting and dying of cells in the brain. "That's the big showstopper," Berger says.

He is part of a growing movement of researchers struggling to perfect neural prostheses, devices that employ electrodes to receive signals from and transmit them to the brain. Cyberkinetics, a company cofounded by neuroscientist John Donoghue at Brown University, has begun clinical trials on an implant that can transmit signals from a paralyzed person's motor cortex to a computer or to a prosthetic limb. Several groups, including one led by Ali Rezai of the Cleveland Clinic Center for Neurological Restoration, have tentatively shown that stimulation of the thalamus can relieve chronic pain, obsessive-compulsive disorder, and depression. Similar devices may be able to treat blindness, epilepsy, and Parkinson's disease. All these applications will depend on solving the connection problem.

Groups at the University of Arizona and elsewhere have crafted arrays containing 500 or more electrodes, trying to maintain a good link through sheer numbers. Other strategies include building electrodes out of conducting polymers, which are more compatible with neural tissue than are silicon or metal, or coating electrodes with molecules that adhere to brain cells. A team at Emory University is embedding electrodes in glass cones filled with nerve-growth factors that encourage brain cells to sprout more dendrites and axons. Several paralyzed patients using the Emory device have learned to control a computer with their thoughts. But the ideal fix would be an electrode that constantly moves to maintain connections.

Joel Burdick, a mechanical engineer at Caltech, and his colleagues are developing an electrode array to do just that. Each electrode determines the direction from which the neurons' signals are strongest. A tiny motor then moves the contact in that direction. The electrodes will be programmed to search for specific types of neural signals—for example, those corresponding to a subject's desire to move her hand rather than her foot.

**A LINK THAT LASTS**
Caltech's prototype brain prosthetic, contains miniature motors that move its electrodes up and down to maintain a strong,consistent contact with neurons in the brain.

The first prototype of this device, which was successfully tested in monkeys by Burdick's Caltech colleague Richard Andersen, had only four electrodes. The motors were



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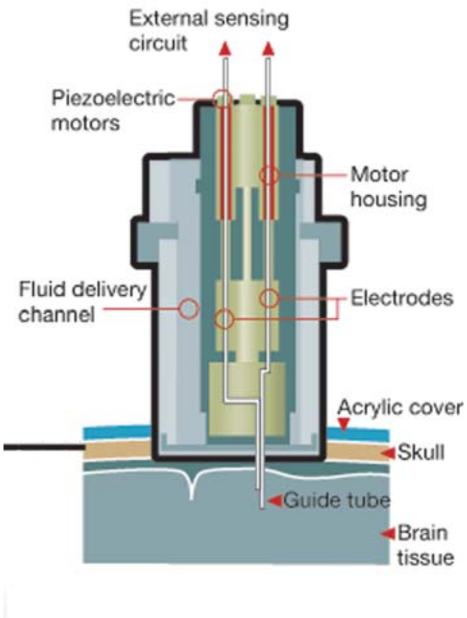


mounted outside the skull, and electrodes passed through plugs in the scalp. The Caltech team is now working on downsized versions that will have as many as 100 electrodes and be small enough to be implanted inside the skull, thereby reducing the risk of infection. A companion set of miniature injectors could administer compounds to inhibit the formation of scar tissue or to stimulate the activity of surrounding neurons. Power will be supplied by an external source that beams radio waves through the skin and skull.

Andersen is still preparing a second round of animal tests to prove the electrode array works. But ethicists already worry about a day when implants are so effective that even healthy people elect to upgrade, lest they fall behind like some obsolete computer.

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## A LOCKSMITH FOR THE MIND

**RICHARD ANDERSEN is a professor of neuroscience at Caltech. His investigations of how monkeys plan their actions led him to study implants that can tap into the motor-control regions of the brains of paralyzed people.**

**Could brain implants reveal the thoughts of people so paralyzed they can't speak?**
**A:** We could put electrodes in the speech area of the brain and ask a patient to think of different words and observe how the cells fire in different ways. So you build up your database, and then when the patient thinks of the word, you compare the signals with your database, and you can predict the words they're thinking. Then you take this output and connect it to a speech synthesizer. This would be identical to what we're doing for motor control, just in a different part of the brain, so I think it's doable. The method would be for locked-in patients, who are so paralyzed they can't speak or communicate in any way, but they can still think about making words.

**Isn't the brain so plastic that the signals for a given word are constantly changing?**
**A:** The brain's plasticity actually makes the algorithm work better. It's like riding a bicycle. In our experiments with monkeys, over a period of a couple of months, the monkeys got better at doing the task. We got a better signal.

**How would you stop the chip from picking up thoughts the person doesn't want to reveal?**
**A:** We can all think of something and not say it. I would be looking at parts of the brain that similarly are under personal control for speech.

**Could you use this brain chip to read the thoughts of a terrorist or a serial killer?**
**A:** It would require cooperation. The only application for this would be to help mute patients who are cooperating and want to do this.

**What about receiving knowledge directly from someone else's mind?**
**A:** Transmitting information to another person is complicated because you need to electrically stimulate parts of the brain. But the cochlear prosthetic [which can restore hearing by stimulating the auditory nerve] works pretty well. If I were in that research, I'd try to stimulate the central nervous system rather than the cochlear nerve. Although patients wouldn't hear the words the way they are formed, they could interpret them through learning. I think all these things are within the realm of possibility, but from our point of view we're only doing research. Anything could have devious applications, and it's important for scientists to speak out against them.

But I don't think we should stop working on the good aspects of these technologies.

**Is the Department of Defense studying ways to communicate with troops via brain chips?**
**A:** They're changing their emphasis. They're interested in prostheses now from the point of view of the soldiers who've been injured in Iraq. If soldiers aren't injured, they're probably not going to want electrodes put into their heads.

**Roboticist Rodney Brooks at MIT has predicted that by 2020 ordinary people will have chips implanted in their brains so they can surf the Web just by thinking.**
**A:** [Laughing] People do some wacky things, but I don't think so.

## HOW TO BUILD A BETTER BRAIN

Neuroscientists are looking at places in the brain where electrical implants could help alleviate injury and disease.

**MEMORY LOSS**
Theodore Berger of the Center for Neural Engineering at the University of Southern California is designing and building chips that can restore or supplement functioning of the hippocampus, which underpins memory. He has tested the chips in slices of rat brain tissue but is at least a year from testing them in live animals, much less humans.
**More than 4 million Americans suffer from memory loss due to Alzheimer's disease.**

**PARALYSIS**
Neural Signals, founded by Philip Kennedy of Emory University, has implanted electrodes in a handful of paralyzed people, who can now control a computer and other devices. Richard Andersen of Caltech has a prosthetic device that can detect neural signals corresponding to plans or intentions rather than actions themselves.
**More than 2 million Americans suffer from paralysis.**

**PARKINSON'S SYMPTOMS**
An FDA-approved "brain pacemaker" built by Medtronic in Minneapolis suppresses tremors and other movement disorders caused by Parkinson's disease. It also reduces other ailments, such as Tourette's syndrome, by stimulating the thalamus.
**More than 1 million Americans suffer from movement disorders caused by Parkinson's disease.**

**EPILEPSY**
A few companies, such as NeuroPace in Mountain View, California, are carrying out clinical trials of brain pacemakers, similar to the ones used to treat Parkinson's, that detect signals in the brain that presage a seizure and suppress it with electrical stimulation.
**2.3 million Americans suffer from epileptic seizures.**

**DEAFNESS**
Several companies—including Advanced Bionics in Sylmar, California; Cochlear Corporation of Australia; and Med-El of Austria—have implanted more than 80,000 artificial cochleas in deaf people around the world. This is by far the most commercially and clinically successful neural prosthesis.
**2 million Americans have complete hearing loss; 28 million have hearing impairment.**

**EPILEPSY AND DEPRESSION**
Cyberonics, based in Houston, has received FDA approval to treat epilepsy and, more recently, depression using devices that stimulate the vagus nerve. More than 30,000 epileptics globally are already being treated with vagus-nerve stimulators.
**10 million Americans suffer from major depression.**

**BLINDNESS**
The late William Dobelle, founder of the Dobelle Institute in Lisbon, Portugal, tested artificial-vision devices that bypassed the optic nerve and stimulated the brain's visual cortex. Several researchers are developing artificial retinas that stimulate the nerves attached to the real retina.
**1.3 million Americans are classified as legally blind.**



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