tional health at Johns Hopkins University. "Each side was willing to give credit, to make the extra effort, and to keep up communication," he says. "The American and British groups had a gentle and sensitive approach to accommodating [the Chinese] and their way of doing things. They maintained the posture that the ultimate decision rests with Chinese."

Taylor adds that several serendipitous events also helped. The first of the two studies began when the Chinese government initiated the "four modernizations" campaign, which stressed the idea of using science to solve problems. At the same time the relevance of good nutrition to good health was gaining visibility in China.

The process of building trust "is still evolving," Colin Campbell says. Meanwhile, he has been advising Chinese authorities and officials at the World Bank, one of the agencies supporting the study, that it is not advisable to encourage the growth of a livestock industry, and that the Chinese need not make a radical change in agricultural development. "This study," says Campbell, "offers the Chinese an opportunity to learn from our mistakes."

■ ANNE SIMON MOFFAT

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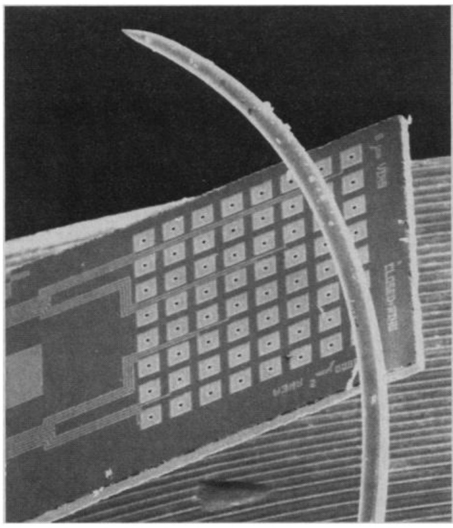
Tapping into Nerve Conversations

For several months a group of electrical engineers and physicians at Stanford University has been able to tap directly into the electrical conversations of individual neurons in a rat's leg. Their listening device is a tiny microchip, designed to withstand the corrosive environment inside living tissue, that they implanted between the severed ends of a bundle of nerves.

The device itself is an impressive piece of engineering, but it is only a crude prototype of what the researchers eventually hope to develop: a computer chip that can be used to link an artificial hand directly to an amputee's nervous system so that the hand can be controlled by the individual's brain, much as a natural hand is.

The device was described at the annual plastic surgeons' meeting in Washington, D.C., this month by Gregory Kovacs, a student of electrical engineering and of medicine at Stanford University. Kovacs reported that he and his colleagues, Joseph Rosen and Bernard Widrow of Stanford University and Chris Storment of the Department of Veterans Affairs, have shown that their latest model chip can both record and stimulate the activity of individual nerve cells in the rat's leg. This is the first time such work has been done with a chip implanted for the long term. "Since our last presentation [at the 1988 plastic surgery meeting] we've shown we can actually communicate with the device," says plastic surgeon Rosen.

To make the chip, Kovacs' group resurrected an old method of stenciling electrodes onto silicon and used it to arrange one of the most stubborn of metals—iridium—in a precise array of square electrodes on the chip's surface. Then, with a laser, they riddled the chip with 1024 tiny holes, each centered on an iridium square. Finally, the chip was coated with silicon nitride to protect it from the destructive effects of body fluids.



C.W. Storment

Early Chip. *This chip has 64 iridium microelectrodes. The current model has 1024.*

When the chip was implanted between the severed ends of the rat's nerves, it not only survived inside the animal for 400 days, but individual regenerating nerve cells grew through the holes. That accomplishment, says Robert White, one of Kovacs' former professors of electrical engineering, was a major breakthrough. Though other researchers have been able to get regenerating nerves to grow through latticework, none have achieved such neural resolution.

Moreover, as the nerves grew through the holes, they made electrical contact with the chip's circuitry, creating a direct link between the peripheral nervous system and the chip. By applying probes to the chip, the Kovacs team could record neural signals as they passed through. The researchers could also stimulate the nerves leading to the animal's foot, which twitched in response.

After hearing Kovacs describe these results, Court Cutting, a plastic surgeon from New York University, described the talk as "one of the most exciting I've seen in my 15 years of coming to this conference."

But the Kovacs team still has a long way to go to achieve its ultimate goal. In the current work, external probes had to be applied to the chip to record and transmit the electrical signals. The next step, Kovacs says, will be to design a chip capable of communicating, through an implanted radio transceiver, with the outside world and, eventually, with an artificial hand.

Implanted processors used with an artificial hand would also have to convert neural impulses into commands. Widrow says the processors, called neural networks, could learn to interpret the thousands of electrical signals. Perhaps most difficult to build would be a device that can restore an amputated limb's sensory linkage to the brain—giving a sense of touch, heat, and position in space. But Kovacs says 40 chips implanted from the elbow on down could provide "every little bit of sensory perception and function" for an artificial hand, although the hand would probably have a limited repertoire of at most 100 movements.

Other experts on artificial limbs are skeptical about these claims, however. William Sauter, the head of a prosthetic team at the Hugh MacMillan Medical Center in Toronto, is "a bit wary of implants." When they fail, he says,"a patient must go into surgery again, and I think most amputees don't like to be opened up." Citing also the risk of infection, the expense of such a device, and the tendency a chip implant might have to migrate under the skin, Sauter says that great advances must be made, and that they will require decades of development, before Kovacs' device will be practical.

Another researcher in prosthetics, Robert Scott, director of the Institute of Biomedical Engineering at the University of New Brunswick, also has doubts about the feasibility of an artificial nervous system. The most difficult task will be to ensure that neurons attach to the electrodes within the chips and remain attached for an extended period of time without decay. This has not been demonstrated. But "the idea is wonderful," he says.

Kovacs remains confident, however, and is moving on to the next hurdle: the design of the "active" chip that will use a radio transceiver to send and receive information between a rat's nervous system and an external data processor. "By the middle of next year the chip will be made," Kovacs says with assurance, and the next cycle of testing and debugging will begin. ■ SARAH WILLIAMS

Sarah Williams is a Science *intern.*