MATERIALS RESEARCH

Bioelectronics that vanish in the body

Wire-free devices that dissolve could expand the use of electric pulses in medicine

By **Robert F. Service**, *in Boston*

Implanted electronics can steady hearts, calm tremors, and heal wounds—but at a cost. These machines are often large, obtrusive contraptions with batteries and wires, which require surgery to implant and sometimes need replacement. That's changing. At a meeting of the Materials Research Society here last month, biomedical engineers unveiled bioelectronics that can do more in less space, require no batteries, and can even dissolve when no longer needed.

"Huge leaps in technology [are] being made in this field," says Shervanthi Homer-Vanniasinkam, a biomedical engineer at University College London. By making bioelectronics easier to live with, these advances could expand their use. "If you can tap into this, you can bring a new approach to medicine beyond pharmaceuticals," says Bernhard Wolfrum, a neuroelectronics expert at the Technical University of Munich in Germany. "There are a lot of people moving in this direction."

One is John Rogers, a materials scientist at Northwestern University in Evanston, Illinois, who is trying to improve on an existing device that surgeons use to stimulate healing of damaged peripheral nerves in trauma patients. During surgery, doctors suture severed nerves back together and then provide gentle electrical stimulation by placing electrodes on either side of the repair. But because surgeons close wounds as soon as possible to prevent infection, they typically provide this stimulation for an hour or less.

Rogers and his collaborators wondered whether they could extend the treatment by harnessing the soft, flexible, dissolvable electronic materials they developed a few years ago (*Science*, 28 September 2012, p. 1640). They used a mix of metals, semiconductors, and polymers to fashion a simple coil with two electrodes. The coil was designed to act as an antenna, picking up radiofrequency pulses transmitted wirelessly from outside the body, and converting them into mild electrical pulses. Rogers and his team implanted the devices in 25 rats in which they had cut the sciatic nerve to one of the hind legs, and stimulated the nerve ends for 1 hour a day for up to 6 days.

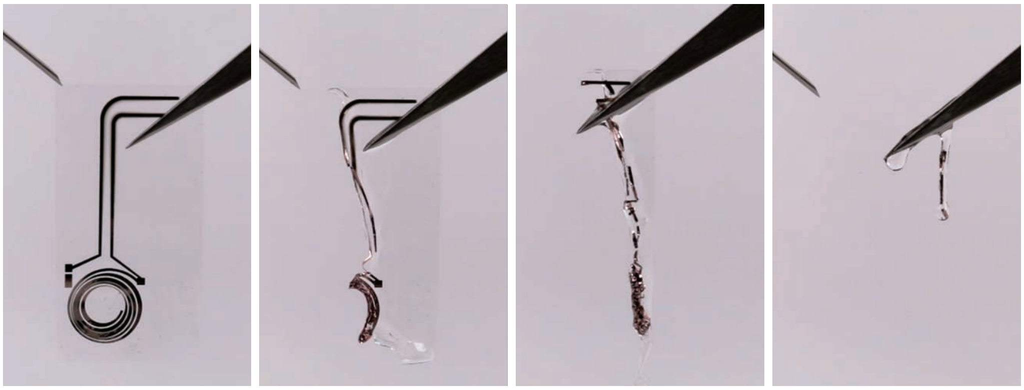
The stimulation sped nerve healing by about 50% compared with animals that received no stimulation or just one or a few days of it, they reported in the 8 October issue of *Nature Medicine*. And there was no need to reopen the wounds to remove the gadgets. The materials broke down and were excreted. "After 21 days the device is completely gone, and there appeared to be no adverse effect" from degradation, Rogers says.

"There is no doubt there is a potential clinical application here," Homer-Vanniasinkam says. However, she notes that before dissolvable electronics make their way into people, researchers will need to confirm that all the materials from the devices degrade safely.

Xudong Wang, a bioelectronics expert at the University of Wisconsin in Madison, is developing miniature, wireless devices that take advantage of a technology pioneered by others to convert the body's motion into electrical current. In one study reported on 29 November in *ACS Nano*, a fingertip-size generator that delivered a stream of tiny electrical pulses to wounds on rats' skin sped healing. And at the meeting, Wang described similar generators that mimic commercially available implanted electrodes meant to help patients with obesity lose weight.

These devices stimulate a branch of the vagus nerve, which runs from the colon and stomach to the brain stem, helping relay signals of fullness after eating. Available devices are pacemaker-size and contain batteries that often need replacement, requiring repeated surgeries. Wang and his colleagues wanted to see whether their much smaller device, which requires no batteries, could do the same job.

They implanted their device on the outer wall of a rat's stomach, so the organ's motions during eating would power the generator. At the meeting, Wang reported that animals with the generator ate at normal times, but less than control animals. The rats lost 38% of their weight over 18 days, at which point their weight stabilized.



This implantable electronic device can speed nerve healing and dissolves when its work is done.

Jacob Robinson, an applied physicist at Rice University in Houston, Texas, shrank his implantable stimulator even further, to the size of a grain of rice. It is powered not by movement, but by magnetic field pulses delivered from outside the body, and is intended to replace the large, battery-powered brain stimulators used to control tremors in some patients with Parkinson's disease. In rats with a version of the disease, Robinson implanted his minuscule device in the subthalamic nucleus, the same brain region targeted by larger devices. The animals' tremors disappeared, and their movements became normal, he said at the meeting.

"It's very encouraging," Rogers says. Robinson and others are aiming their stimulators at well-established clinical areas with an urgent need for better devices, he notes. "Having immediate use is going to be very powerful," Rogers says, because it could help speed the approval of such devices by regulators—and smooth their way into patients. ■

PHOTOS: J. ROGERS/NORTHWESTERN UNIVERSITY

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