The untapped potential of the 'ear battery'

Biologically based energy harvesting offers a viable solution to the long-term powering of implantable electronics for medical use, which currently require large external energy sources. Methods such as heat capture using thermoelectric devices and muscle-movement capture using piezoelectric devices or induction generators offer some hope but are typically not suitable for daily use as they require bulky, externally worn apparatuses.

Researchers at Massachusetts Institute of Technology (Cambridge, MA) have, however, recently identified another untapped source of stable energy (*Nat. Biotechnol.* published online 8 November 2012; doi:10.1038/nbt.2394). Inside every mammalian ear resides a biological battery. Endocochlear potential (EP) is an electrochemical gradient found in the inner ear; at 70–100 mV, it is the largest positive direct current electrochemical potential in mammals. Arising from the difference in ionic concentration between endolymph (an extracellular fluid in the inner ear) and perilymph (an extracellular fluid that bathes the surrounding spaces), EP drives cochlear mechanotransduction of sound

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pressure vibrations to neurotransmitter release and excitation of the auditory nerve. Further, its intrinsic stability over the lifetime of a mammal makes it an ideal candidate for powering long-term, energy-autonomous implantable devices.

In 'proof of concept' experiments, Konstantina Stankovic and her colleagues implanted tiny electrodes into the biological battery of a guinea pig's ear. Attached to the microelectrodes was an electronic chip equipped with an ultralow-power radio transmitter and power conversion device. Powering up the chip required an initial 'kick-start' from an external source, but after that, the biological battery took control, extracting a minimum of 1.12 nW from the EP for up to 5 hours, enabling the 2.4-GHz radio to transmit every 40–360 s. Insertion of the electrodes did not adversely affect the guinea pig's hearing or cause excessive trauma to the ear tissue.

This study is the first of this kind, and although the results indicate great promise, the amount of energy extracted from the EP is still too low to provide any applicable use. The authors believe that major improvements in their electrode design are necessary, reasoning that smaller diameter electrodes would be less invasive and thereby reduce the amount of ion leakage across the endolymph-perilymph barrier.

In the future, energy harvesting from the cochlea may be applicable to humans. Self-sustaining, implantable electronics could provide myriad medical benefits, including monitoring deafness and hearing loss or tracking the health of organs in and around the inner ear (e.g., the carotid artery, facial nerve or temporal lobe).

Thomas Rowley

USING NANOPARTICLES TO TEACH IMMUNE TOLERANCE

Autoimmune diseases such as multiple sclerosis and type 1 diabetes are the third largest cause of morbidity and mortality in the US. In these and other autoimmune diseases, immune cells mistakenly attack and destroy healthy tissue; in the case of multiple sclerosis, the target is myelin, which creates the protective sheath around nerve cells. As a result of the autoimmune response to myelin, nerve cell communication is disrupted, causing numbness, paralysis and blindness. It has been estimated that about 400,000 people in the US and more than 2 million people worldwide suffer from multiple sclerosis.

Current treatments for many autoimmune diseases involve suppression of the whole immune system, leaving the affected individuals vulnerable to infections and more susceptible to cancer. Rather than suppressing the total immune response, an ideal treatment for autoimmune diseases would instead 'retrain' the immune system to recognize the target tissue as harmless and to tolerate it instead of attacking it.

A team of researchers led by Stephen D. Miller (Feinberg School of Medicine, Northwestern University, Chicago, IL) recently reported successfully doing exactly that in a mouse model of multiple sclerosis. Treated mice had no relapses or symptom flare-ups for up to 100 days after treatment, a time frame that could be equivalent to years in a person with multiple sclerosis.

The treatment strategy combined myelin antigens with nanoparticles 200 times smaller in diameter than a human hair. When these myelin-loaded particles were injected into mice with relapsing experimental autoimmune encephalomyelitis (a model for relapsing-remitting multiple sclerosis, which is the most common form of the disease, accounting for roughly 80% of cases), they were engulfed by macrophages as if they were normal apoptotic blood cells and carried to the spleen, where they were presented to T-cells. This introduction inhibited the attack on myelin and calmed the autoimmune response (*Nat. Biotechnol.* published online 18 November 2012; doi:10.1038/nbt.2434).

"This is a highly significant breakthrough in translational immunotherapy," stated Miller in a press release. "Our approach resets the immune system so it no longer attacks myelin but leaves the function of the normal immune system intact." The approach could be modified for use in treating other autoimmune disorders as well. According to Miller, "The beauty of this new technology is it can be used in many immune-related diseases. We simply change the antigen that's delivered." Miller's group plans to test this strategy in people with multiple sclerosis and those with type 1 diabetes.

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