62 PERCENT How much more radiation an obese man receives from a CT scan than a man of normal weight. Nuclear engineers at Rensselaer Polytechnic Institute, in Troy, N. Y., created software to help radiologists reduce the dose.

Snails in a Race for Biological Energy Harvesting

Blood-based fuel cells could power implanted electronics

Bioengineers are getting better at replacing and enhancing body parts, but so far they've struggled to power implantable bionics without resorting to clunky batteries. Recently, researchers have turned to blood as a power source, because it carries energy in the form of electron-rich molecules like glucose and delivers it to all parts of the body. Chemist Evgeny Katz of Clarkson University, in Potsdam, N.Y., and his colleagues tested a new kind of fuel cell that, when implanted in *Neohelix albolabris* snails and immersed in the snails' blue, blood-like hemolymph, produced a small, steady supply of electricity over a period of months.

They started by coating the cell's anode with an enzyme that goes by the initialism PQQ-GDH. That enzyme pulls electrons from glucose molecules. The researchers then coated the cathode with a plant enzyme, laccase, which pushes electrons onto oxygen molecules. When immersed in hemolymph, the electrodes delivered a measurable current.

Choosing the right material for the electrodes is important because the intermediate enzymes usually interact little with electrodes, Katz explains. His team used buckypaper, a rough, 3-D structure built of tiny conducting carbon nanotubes. "Buckypaper electrodes are very practical," says biochemical engineer Sven Kerzenmacher at the University of Freiburg, in Germany, who was not involved with Katz's team but is also experimenting with buckypaper electrodes for biological energy harvesting. The nanomaterial exposes more of the electrode to electron-bearing molecules in the snail's hemolymph than other electrode materials would.

In the snails Katz studied, the electrodes extracted as much as 7.45 microwatts in a 20-minute burst and sustained 0.16 μW for up to an hour. Researchers at Case Western Reserve University, in Cleveland, recently implanted similar biofuel cells in cockroaches, extracting slightly less power. By comparison, a modern human pacemaker typically requires a steady supply of around 1 μW.

Other scientists are working on energy harvesters that could be powered by human blood instead of hemolymph. There are important differences: Human blood is better than snail hemolymph at distributing glucose, but most of its oxygen is trapped in hemoglobin. Humans also have strong immune systems that attack foreign bodies.

Biomedical engineer Philippe Cinquin of Joseph Fourier University in Grenoble, France, has tested his glucose biofuel cells for a period of 40 days in living rats, but in contrast with the Potsdam team's snail experiments, he had to build membranes to keep some harmful biochemicals away from his electrodes.

An initial application for human biofuel cells could be to power short-term implants, such as blood glucose sensors for diabetes, says Kerzenmacher. But once long-term, implantable electricity harvesters are available, they could enable tiny distributed devices to stimulate nerves and alleviate chronic pain, researchers say.

"There are a lot more biomedical devices we could build if we know we have energy for them," says Cinquin. —Lucas Laursen

LEFT: MIKE KEMP/GETTY IMAGES; RIGHT: VIENNA UNIVERSITY OF TECHNOLOGY/REUTERS

A version of this article appeared online in April.

news brief

Small, Swift, but not Svelte

This grain-of-sand-size statue doesn't evoke speed, but in fact it has set a world record. Scientists at the Vienna University of Technology used a new 3-D laser-printing technique to construct the little fellow in just 4 minutes. Previously, the technique took hours or even days. The researchers hope to use it to make custom parts for medical procedures.