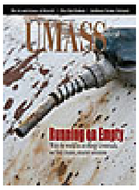

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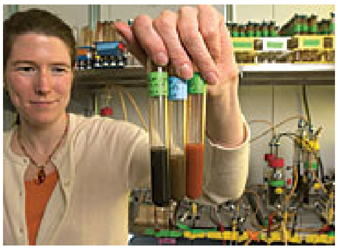
It's Electric!

Geobacter is cleaning up pollution; it proves to be a petite powerhouse as well

—Patricia Sullivan

IMAGINE YOU GET OFF A plane and want to use your laptop, but your battery is dead and there's nowhere to plug in your computer. You go to the nearest Starbucks, buy a coffee, grab more than your share of sugar packets, and empty half into your cup and half into your laptop. Voila! Both you and your computer are powered up.


Post-doctoral researcher Kelly Nevin with electricity-producing bacterial isolates in Derek Lovley's Morrill Science Center lab.

This sweet scenario could become reality in the not-too-distant future, says Derek Lovley, director of the Environmental Biotechnology Center at UMass Amherst. His lab is researching microbial fuel cells powered by Geobacter, a remarkable microorganism he discovered in 1987 on the mucky bottom of the Potomac River. These small, multitalented bacteria have revealed big surprises: They clean up toxic waste, generate electricity, and sport minuscule wires that could become vital components of complex microscopic machines.

Members of the microbial family Geobacteraceae fill the beakers and the minds of the 60 workers in Lovley's year-old lab in the Morrill science building. These single-celled organisms, shaped like short-grained rice, are nearly ubiquitous in soils and sediments around the globe. Lovley's Geobacter studies have garnered millions of dollars in grants from the government and from private sources. Most recently, the U.S. Department of Energy awarded Lovley's Amherst team and his affiliates $22 million to study the bacteria's electrical properties. A major automotive manufacturer is involved, providing funding for fuel cell research at UMass Amherst.

Analyzing Geobacter's potential for energy production started out as a hobby project, Lovley says. The bread and butter of his lab is Geobacter's ability to gobble up pollution. In his fourth-floor office, eye-level with flocks of geese swooping down to Campus Pond, Lovley patiently simplifies the process: "Geobacter evolved over billions of years to use organic compounds and metals in the soil to make energy, in the way we use oxygen and food," he says. "It lives in

It's Electric!

It's Electric!: more images

oxygen-depleted environments, where it converts pollutants to forms that are no longer soluble in groundwater and are easier to remove." Geobacter has already successfully mopped up underground oil spills and removed uranium from contaminated groundwater.

While studying Geobacter's cleansing prowess, Lovley's team observed that the bacteria generate electrical energy. Using a simple science-fair setup of glass jars, graphite, and wires, UMass Amherst scientists have powered calculators and light bulbs with cheap, clean energy from lab-grown microbes. The discovery of Geobacter's ability to harvest electricity from organic matter was "surprising and fortuitous," Lovley remarks, and it expanded the scope of the lab's research.

"We know that Geobacter is really efficient at making electricity, but we think there's a lot of ways their electrical production could be improved," says Lovley. "It's useful for charging up batteries but not for drawing immediate power. We want to make it go faster. One way we're trying to do this is to make it feel like it's hungry so it will spit out electrons faster. Those are the kinds of games we are playing now in the lab."

In the very near future, Geobacter power could be harvested to provide electricity in remote locations where it is difficult and expensive to change batteries. "This application is basically here," Lovley says. DARPA (the Pentagon's Defense Advanced Research Projects Agency) is already running monitoring devices in the Potomac River using Geobacter. Fittingly, deploying Geobacter power on the Potomac floor would bring Lovley's research back to where he discovered the organism 19 years ago while studying water quality for the U.S. Geological Survey.

The next step might be bringing bacterial batteries that run on organic matter to rechargeable consumer devices, such as cell phones, digital cameras, and that sugar-stoked laptop. You could harness the microbes that break down your grass clippings to run your lawn mower, or you could use your compost pile to light your home's lampposts.

While it could save us money on battery packs, Geobacter is not destined to become a substantial contributor to the country's power grid, because it would be too difficult and costly to replace our existing energy infrastructure, Lovley says. However, bacterial batteries could have wider applications in less-developed countries, powering refrigerators, for example.

After discovering first that Geobacter could clean up pollution and second that it generates electricity, Lovley's team uncovered yet another marvel of this microorganism. They wondered just how Geobacter gets its electrons outside its cell when it makes electricity. "We joked that maybe there were wires," Lovley says, "but we knew of no way to measure the electricity flow to prove it."

On the sidelines of their sons' soccer game, Lovley broached the problem with Tom Russell '76G, '79G, a UMass Amherst polymer scientist and nanomaterials expert. One expert led to another, until professor Mark Tuominen and Kevin McCarthy of the Physics Department worked with microbiologist Gemma Ruegera to demonstrate that Lovley's guess was correct. Geobacter have pili (protein wires 20,000 times finer than a human hair) that reach outside the cell to conduct electricity. The pili are more than a thousand times long as they are wide. "An electrically conductive structure like this is unprecedented in biology," says Lovley.

Kevin McCarthy, a doctoral candidate in physics, exudes enthusiasm for Geobacter as he demonstrates how the team used an atomic force microscope to probe the incredibly thin nanowires and measure the electric current zipping through them. "A nanometer is one billionth of a meter," he explains. "In nanotechnology we make really small tools to make and study really small things. These wires are just three to five nanometers wide. We couldn't even come close to building something as small and complex as Geobacter."

The Geobacter's naturally strong and skinny wires have the potential to play a key role in nanotechnology's promising future, when scientists envision that computers and medical and manufacturing devices will shrink to invisibility. "We now make nanowires out of carbon or silicon, which is expensive," McCarthy says. "With Geobacter, we may simply be able to grow highly conductive wires for use in nanoscale devices."

Back at the microbiology lab, Lovley's team is using everything from barrels teeming with Boston Harbor Geobacter to a state-of-the-art gene-sequencing machine to bring light to the grow-in-the-dark bacteria. They are analyzing Geobacter's complete gene sequence, modifying genes to discover what they do and how they work, peering at them with DNA microarray technology, analyzing computer models of Geobacter, even studying how the little bacteria swim. Elsewhere, engineers affiliated with the project labor at the practical aspects of harnessing Geobacter power.

Already, Lovley's team has made an impact on environmental cleanup and bio-electronics. His lab is one of the top grant recipients at UMass Amherst as well as a media magnet. But in his bare office, dressed in a plaid shirt and cords like the boots-in-the-mud environmental scientist he remains at the core, Lovley views his mission in simple terms. "The job of science is to observe phenomena and figure out how it works," he says. "That's the fun of it."

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