# Microbes Can Produce Electrical Nanowires

June 23 2005

Researchers at the University of Massachusetts Amherst have discovered a tiny biological structure that is highly electrically conductive. This breakthrough helps describe how microorganisms can clean up groundwater and produce electricity from renewable resources. It may also have applications in the emerging field of nanotechnology, which develops advanced materials and devices in extremely small dimensions.

The findings of microbiologist Derek R. Lovley's research team are published in the June 23rd issue of *Nature*. Researchers found that the conductive structures, known as “microbial nanowires,” are produced by a novel microorganism known as Geobacter. The nanowires are incredibly fine, only 3-5 nanometers in width, but quite durable and more than a thousand times long as they are wide.

“Such long, thin conductive structures are unprecedented in biology,” said Lovley. “This completely changes our concept of how microorganisms can handle electrons, and it also seems likely that microbial nanowires could be useful materials for the development of extremely small electronic devices.”

“The microbial world never stops surprising us,” said Dr. Aristides Patrinos of the U.S. Department of Energy, which funds the Geobacter research. “The remarkable and unexpected discovery of microbial structures comprising microbial nanowires that may enable a microbial community in a contaminated waste site to form mini-power grids could provide new approaches to using microbes to assist in the remediation of DOE waste sites; to support the operation of mini-environmental sensors, and to nano-manufacture in novel biological ways. This discovery also illustrates the continuing relevance of the physical sciences to today's biological investigations.”

Eugene Madsen, a Cornell University research microbiologist, noted, “I have watched and judged, in peer review, many of Dr. Lovley's remarkable scientific advancements since the discovery of Geobacter in 1987. The latest advancement, microbial nanowires, is another major milestone because it may usher in a new era of exploration of both microbial respiration and bio-electronics.” The findings, he said, are “promising and exciting,” although he emphasized the information must be independently confirmed and extended by other microbiologists and biophysicists.

Geobacter are the subject of intense investigation because they are useful agents in the bioremediation of groundwater contaminated with pollutants such as toxic and radioactive metals or petroleum. They also have the ability to convert human and animal wastes or renewable biomass into electricity. To carry out these processes, Geobacter must transfer electrons outside the cell onto metals or electrodes. This new research provides an explanation of how this can happen.

Previous studies in Lovley's laboratory demonstrated that Geobacter produces fine, hairlike structures, known as pili, on just one side of the cell. Lovley's team speculated that the pili might be miniature wires extending from the cell that would permit Geobacter to carry out its unique ability to transfer electrons outside the cell onto metals and electrodes. This was confirmed in a study in which microbiologist Gemma Ruegera teamed with physicists Mark T. Tuominen and Kevin D. McCarthy to probe the pili with an atomic force microscope. They found the pili were highly conductive. Furthermore, when Geobacter was genetically modified to prevent it from producing pili, Geobacter could no longer transfer electrons.

“These results help us understand how Geobacter can live in environments that lack oxygen and carry out such unique phenomena as removing organic and metal pollution from groundwater,” Lovley said. Geobacter can live in the absence of oxygen because of its ability to transfer electrons outside the cell onto iron minerals, which are natural constituents of most soils. However, prior to the discovery of its conductive pili it was unknown how this electron transfer might take place.

**The conductive pili that Geobacter produces may have a variety of applications for the electronics industry.** Ultrafine wires, often referred to as nanowires, are required for further miniaturization of electronic devices. Manufacturing nanowires from more traditional materials such as metals, silica, or carbon is difficult and expensive. However, it is easy to grow billions of Geobacter cells in the laboratory and harvest the microbial nanowires that they produce. Furthermore, by altering the DNA sequence of the genes that encode for microbial nanowires, it may be possible to produce nanowires with different properties and functions.

Another interesting implication of this research is that it suggests a mechanism for microbes to share energy in a mini-power grid. The nanowire pili of individual Geobacter often intertwine, suggesting a strategy by which Geobacter might share electricity.

Geobacter was discovered by Lovley in 1987 at the muddy bottom of the Potomac River in Washington D.C., and over the past 18 years his research has earned widespread media attention and major funding from government and private sources. The tiny organisms, widely found in soils and aquatic sediments, have demonstrated promise as cleaners of toxic spills and generators of energy. They are anaerobic bacteria (living without oxygen) that use metals to gain energy the way humans and other organisms use oxygen. They are distributed throughout the world in a wide variety of soils and sediments. Geobacter have been used to help remove contaminants from underground petroleum spills and landfill pollution of groundwater, as well as remove uranium from contaminated groundwater at a number of U.S. Department of Energy sites.

The title of the paper published in Nature is **"Extracellular Electron Transfer Via Microbial Nanowires."** The authors are Derek R. Lovley, Gemma Reguera, Teena Mehta and Julie S. Nicoll of the UMass Amherst Department of Microbiology; and Kevin D. McCarthy and Mark T. Tuominen of the UMass Amherst Department of Physics.

Source: University of Massachusetts at Amherst