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Power though goo

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Scientists have boosted the power output of microbial fuel cells more than 10 fold by letting the bacteria congregate in a biofilm.

The research, led by microbiologist Derek Lovley of the University of Massachusetts Amherst, suggests that efficient technologies for generating electricity with microbes are much closer than anticipated. Lovley presented the results yesterday, May 10 in a plenary talk at the meeting of the Electrochemical Society in Denver.

A typical fuel cell converts fuels to electricity without the need for combustion and microbial fuel cells work the same way. They usually comprise two compartments, or cells, which are separated by an electrically insulating membrane. In one compartment, microorganisms pull electrons and protons from some sort of fuel, such as waste organic matter. These protons and electrons are attracted to molecules in the second compartment (usually oxygen) and will move towards those molecules. The protons do this by passing through the membrane. But the electrons can't go through the membrane and so must travel via an alternate route; a wire or electrode that connects the two compartments. It is this flow of electrons through the electrode that supplies power.

Microbial fuels cells harness the electron shuttling that occurs in the energy-making pathway of certain bacteria. In the energy-making pathway of most animals, electrons and protons are also shuttled about, and usually electrons are passed to oxygen brought in through the lungs. Early microbial fuel cells intercepted the bacteria's electron shuttling with compounds called "mediators," which would penetrate the bacteria, snatch electrons and then transfer them to the metal electrode. But the compounds typically used as mediators are often expensive and toxic. A more recent and efficient approach has been to use microbes that can pass electrons directly to a metal electrode.

These "metal-reducing" bacteria are ideal for fuel cells, said Lovley, especially species of Geobacter and Rhodoferax, microbes that evolved means to transfer electrons to metals in the surrounding environment. The microbes use thin wire-like growths, several cell lengths long, that extend from their cell membrane out into the environment. Many bacteria have these extended structures, called pili, and they usually use the hair-like extensions to attach to other cells or surfaces. But Geobacter uses pili to transfer electrons onto iron in the surrounding soil. These so-called "microbial nanowires" also seem to be critical for Geobacter to form a biofilm, said Lovley.

While investigating the microbes' electron transfer mechanism, Lovely's team created a mutant Geobacter that didn't have the gene for making the pili, yet the microbes still produced electricity when placed in a fuel cell. The researchers suspected that a membrane protein that was part of the microbe's energy-making pathway was also able to transfer electrons directly to the metal electrode.

“The microbes were lined up in a single, thin layer along the electrode,” says Lovley. “It seemed that either the nanowires or the membrane protein had to be in direct contact with the electrode for electron transfer to occur,” he said.

But then the researchers adjusted their fuel cell so the second compartment could take as many electrons as the microbes could provide. To the scientists’ surprise, the power output increased dramatically and Geobacter began to grow on the electrode in a thick, sticky mass known as a biofilm. However, the mutant Geobacter that couldn’t make pili couldn’t congregate into a biofilm.

“The mutants produced electricity at a much slower rate” says Lovley. “It seems that Geobacter’s pili are essential for making a biofilm.”

Many bacteria form biofilms; the gluey matrix of sugars serves to anchor free-floating microbes to various surfaces, such as teeth, a refrigerator drawer or rocks in a stream. Biofilms are usually the bane of those who encounter them as they cause tooth decay, ruin the hulls of ships and can cause serious health problems when they glom onto medical implant devices such as catheters. But in this instance, the biofilm is a good thing, said Lovely. It seems to act as one slimy conductive mat, allowing electrons to be transferred by bacteria that aren’t in direct contact with the electrode.

Further experiments by Lovley’s team confirmed that microbes in the centre of the biofilm, too far from the electrode to reach it themselves, were transferring electrons at the same rate as microbes that were closer to the edge. It is a finding Lovley said he never would have predicted.

“It made sense that Geobacter would have to be in direct contact with the electrode to pass electrons,” he said. “But now we have these big slime layers—big red glops of Geobacter growing on the electrode—and they are all passing electrons.”

How the electrons are transferred through the gooey matrix isn’t clear, and Lovley’s team is investigating that question.