Bacteria may be wiring up the soil

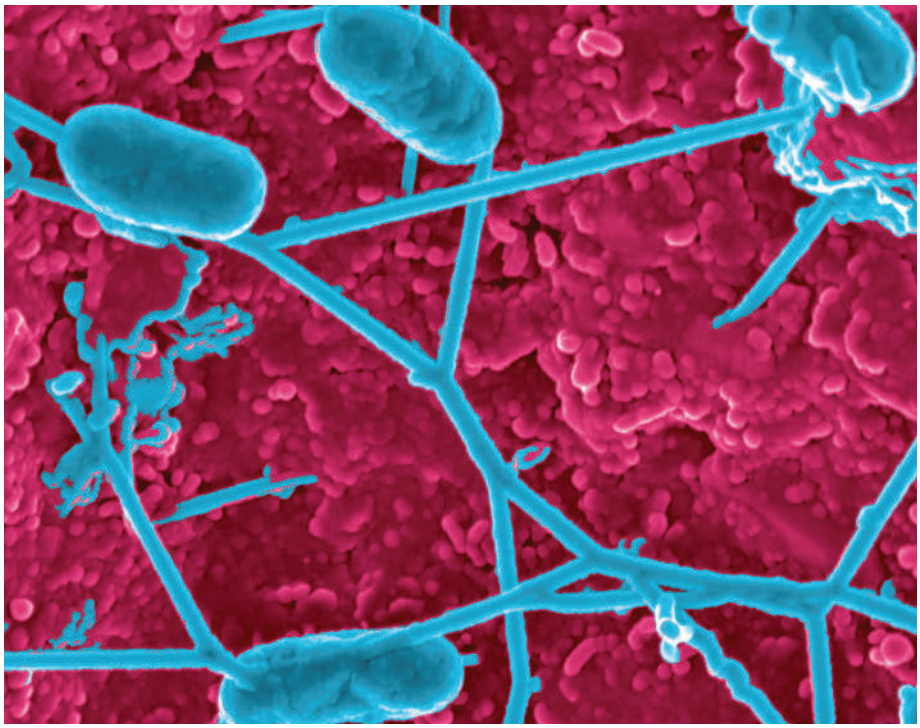
Bacteria can sprout webs of electrical wiring that transform the soil into a geological battery, a team of researchers claims. Some soil bacteria form networks of tiny wires linking individual bacterial cells into a web-like electrical circuit, they report (D. Ntarlagiannis *et al. Geophys. Res. Lett.* **34,** L17305; 2007). The wires allow the bacteria to get rid of electrons generated during metabolism, transporting them to distant 'electron dumps'.

The earth beneath our feet might act as a gigantic circuit built by microbes to power their metabolic systems, suggests Yuri Gorby, a geochemist previously at the Pacific Northwest National Laboratory in Richland, Washington, and now at the J. Craig Venter Institute in La Jolla, California. As the bacteria consume nutrients for energy, they spit out unwanted electrons into the circuit.

Last year, Gorby and his colleagues discovered that *Shewanella oneidensis* bacteria can grow long filaments, just 100 nanometres (a hundred millionths of a millimetre) thick, which conduct electricity (Y. A. Gorby *et al. Proc. Natl Acad. Sci. USA* **103,** 11358–11363; 2006). The researchers presented evidence that the microbes use these 'nanowires' to shunt electrons produced during metabolic reactions onto the surface of mineral grains in the soil, to be taken up by metal ions. Without an electron acceptor, the bacteria cannot function properly and die. The researchers found that several other bacterial species also produce such nanowires.

Oxygen molecules act as convenient electron dumps for bacteria that lie near the soil surface. But little air penetrates to some environments, such as deep lake sediments or waterlogged soils. Now, Gorby and his team think they have found evidence that the bacterial nanowires can link up into a network, conducting electrons to the aerated surface. The researchers filled plastic columns with wet sand infiltrated with a nutrient compound (lactate), and allowed *S. oneidensis* to grow in this 'fake soil'. Only the top of the column was in contact with air.

Electrodes inserted at various heights up the columns revealed that, after about ten days, electrical charge was coursing up the column. Gorby's team examined the sand under a microscope and found that it was threaded by a web of filaments between the bacterial cells. These are wires that provide the pathways for electron transport up to the surface, they suggest.



B. AREY & E. HILL/PACIFIC NORTHWEST NATL LAB.

Connected: false-colour image showing bacterial cells apparently linked by filamentary 'nanowires'.

In contrast, when the team grew a colony of mutant cells that could spawn only very thin, frail and non-conducting filaments, the electrodes in the column remained uncharged.

"This is a new aspect of microbiology," says Gorby. "I think we will find that it's a dominant lifestyle for microbes to live in an electrically connected community." Sediment batteries, which power low-energy devices such as sensors, might unwittingly be exploiting these electric webs, he says. In these devices, electrodes are inserted into underwater sediments to pick up tiny currents generated by microbial activity. "Our work shows how these electrons are being mobilized," Gorby says.

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"If this idea is right, it is really quite remarkable," says Kenneth Nealson, a geobiologist at the University of Southern California in Los Angeles, who collaborated with Gorby on last year's discovery of microbial nanowires.

But not everyone is persuaded by the claim. "I think many of us would like to believe that microbial communities may be hard-wired, because it is just such an attractive and fantastic notion," says Derek Lovley, a microbiologist at the University of Massachusetts at Amherst. "But there is just no evidence for it." He adds that most microbes in anaerobic environments don't need long-distance access to oxygen in order to get rid of the electrons generated when they break down organic matter.

Besides, he says, the experiments don't show conclusively that the filaments are acting as wires, nor that this is what allows electrons to move through the system. He thinks the microbes probably shed electrons by releasing soluble electron shuttle molecules, not by passing them along nanowires.

"It is well documented that *Shewanella* releases soluble molecules that act as electron shuttles," he says. "The difference between the wild-type and the mutant could be attributed to the mutants' inability to react with a soluble electron shuttle. This is a more plausible explanation."

Bruce Logan, a microbiologist at Pennsylvania State University in University Park, who has worked on microbe-driven sediment batteries, shares such reservations. "I believe they see nanowires, but I see no evidence that a long-distance connection is established here," he says. "It may be possible, but these data don't prove it."

"There are clearly way more questions raised than answered at this point," Nealson admits. ■

Philip Ball

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