MICROBIAL PHYSIOLOGY

New electricigens get wired

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The discovery of electron-conducting cell-surface nanowires in *Geobacter sulfurreducens* was greeted by excitement, in part because of the implications for exploiting nanowires in energy production and bioremediation. Now, according to Gorby *et al.*, it seems that conductive nanowires are not exclusive to *Geobacter* species but are also produced by the dissimilatory metal-reducing bacterium *Shewanella oneidensis* MR-1, the cyanobacterium *Synechocystis* PCC 6803 and the thermophile *Pelotomaculum thermopropionicum*.

Most bacteria use soluble electron acceptors such as oxygen or carbon dioxide to derive energy from organic foodstuffs by respiration, but in some harsh environments the only available electron acceptors are insoluble. Conductive nanowires can bridge the gap to mediate electron transfer between cells and these extracellular molecules.

By limiting the availability of oxygen to *S. oneidensis* MR-1, Gorby *et al.* were able to observe and characterize functional nanowires. Deposited linear arrays of nanocrystalline magnetite were observed along nanowires by transmission electron microscopy after *S. oneidensis* MR-1 was grown anaerobically with a virtually insoluble iron source. The authors argue that this is consistent with electron transfer to extracellular insoluble metals. Analyses of *S. oneidensis* MR-1 mutants lacking two cell-surface cytochromes or a functional type II secretion system confirmed that both contribute to conductance, although just how nanowires conduct electrons remains unresolved.

The authors caution that culturing conditions are of paramount

importance when assessing bacterial nanowire production. They contend that bacteria have a propensity to synthesize artefactual pilus-like appendages in a plethora of growth conditions — and that these pili might not always be conductive, which might explain why initial attempts by others to document nanowires in *S. oneidensis* MR-1 have ended in failure.

Intriguingly the authors detected synthesis of nanowires in non-metal-reducing bacteria. Limiting carbon dioxide facilitated the production of conductive nanowires by *Synechocystis* PCC 6803. Perhaps *Synechocystis* PCC 6803 uses nanowires to discard excess electrons that would otherwise be used for fixing carbon dioxide under non-limiting conditions. The fermentative thermophile *P. thermopropionicum* produced conductive nanowires when limited for fumarate, and

seemed to synthesize nanowires that contacted *Methanothermobacter thermoautotrophicus* when these bacteria were co-cultured with limiting propionate.

Interspecies hydrogen transfer is well documented in microbial communities, and the authors point out that when 'the going gets tough' in terms of electron acceptor availability, electron transfer might be another means of interspecies energy exchange. With the unrelenting progress in the characterization of microbial communities using metagenomics, unravelling complex physiological interactions between community members is crucially important in microbiology today.

Susan Jones

ORIGINAL RESEARCH PAPER Gorby, Y. A. *et al.* Electrically conductive bacterial nanowires produced by *Shewanella oneidensis* strain MR-1 and other microorganisms. *Proc. Natl Acad. Sci. USA* **103**, 11358–11363 (2006)

Electron microscopy image showing the photosynthetic cyanobacterium *Synechocystis* PCC 6803 colonizing the surface of the anode (graphite fibre) of a microbial fuel cell that is making electricity with light (energy source) and water (electron source). The image was prepared by Orianna Bretschger and Bruce Arey, and false-coloured by Eric Hill. Image courtesy of Yuri Gorby, Pacific Northwest National Laboratory, Richland, USA.