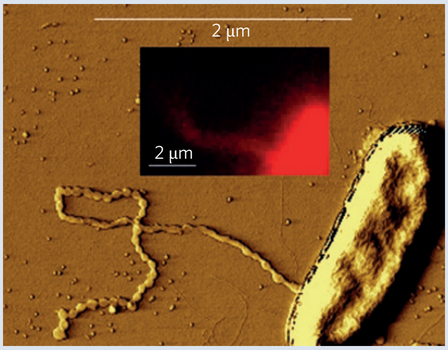
BACTERIAL NANOWIRES

An extended membrane

Transport of electrons from donor to acceptor molecules through reduction–oxidation (redox) reactions generates adenosine triphosphate — life's energy molecules. In bacteria, one way long-distance electron transport occurs is through conductive extracellular filaments, known as bacterial nanowires. These nanowires are thought to be a way by which metal-reducing bacteria link themselves to oxidized metals in the environment that could act as terminal electron acceptors during respiration. However, little is known about the molecular structure and electron transport mechanisms of these nanowires. Now, researchers at the University of Southern California and various other institutes in the USA show that these nanowires are extensions of the outer membrane and periplasm of the bacteria that contain cytochrome proteins, which are responsible for electron transport (*Proc. Natl Acad. Sci. USA* **111,** 12883–12888; 2014).



© NATIONAL ACADEMY OF SCIENCES

Mohamed El-Naggar and co-workers promoted the production of nanowires by growing the bacteria *Shewanella oneidensis* under anaerobic conditions in a laminar-flow-perfusion imaging platform. The nanowires were on average 2.5 µm long, but could reach up to 9 µm. Atomic force microscopy showed that the nanowires can be in the form of a chain of vesicles, a continuous filament or a partially smooth filament containing vesicles, as shown by the atomic force microscope (main) and *in vivo* fluorescence (inset) images. By labelling the bacterial cells with a dye, the authors showed that the production of nanowires correlated with an increase in reductase activity, suggesting increased respiratory activity. Membrane stain experiments and quantitative gene expression analysis demonstrated that the entire length of the nanowire was composed of bacterial membranes and proteins, rather than of the fibrous proteins (called pilin) as suggested previously.

Immunofluorescence experiments showed that cytochrome proteins lined the nanowires. Understanding electron transport in bacterial nanowires and bacterial energy conversion strategies is useful for the development of microbial fuel cells and electrofuels.

AI LIN CHUN

SEMICONDUCTOR LASERS

Taken for a spin

A built-in semiconductor/nanomagnet interface acts as a spin filter in a conventional laser to produce circularly polarized emission without the need for external spin-polarized pumping.

Igor Žutić and Paulo E. Faria Junior

We take lasers for granted, their focused light is used in DVDs, optical communication, medicine, art and by the military. In commercial semiconductor lasers, a sufficiently large number of electrons and holes are generated and the excess charge carriers recombine to emit coherent photons that possess the same wavelength and phase. Although photons, electrons and holes all have spin angular momentum, the working principle of conventional semiconductor lasers is completely unaffected by them, because there is no net imbalance between spins pointing in different directions ('up' and 'down'). However, spin imbalance could be useful in a wide range of applications, from computer hard drives and magnetic random access memories, to innovative technologies, such as spin transistors or even in spin-based quantum computing (spintronics)[1]. Writing in *Nature Nanotechnology*, Yang-Fang Chen and colleagues from the National Taiwan University now report an ingenious method to create spin imbalance in semiconductor lasers[2].

A simple and useful way to explain how lasers work is to use an analogy of water in a bucket[3] (Fig. 1a). Water that is poured into the bucket represents the carriers created in a semiconductor and the water coming out the emitted light. When water from a tap is added slowly to the bucket, it trickles out from holes in the lower part of the bucket. This effect is analogous to emission of ordinary light at low pumping power, such as in light-emitting diodes: photons are not synchronized. However, if water is added at a faster rate, the bucket starts to overfill. In a laser, this regime signals that the lasing threshold has been reached and that coherent photons are emitted. So, how does spin come about? In each step of the lasing process — carrier generation, carrier recombination and light emission — a careful account of angular momentum transfer takes place. In the bucket analogy, a partition is used to separate hot and cold water (that is, spins with up and down[3] orientations). Different taps (hot and cold) are used to add water to each half of the bucket (Fig. 1b). Assuming a perfect partition, filling just half of the bucket is enough to overfill that half (that is, for lasing of circularly polarized light to occur). In practical terms, this means that to reach lasing threshold in spin-