WAT and mediate leptin-stimulated lipolysis is not surprising. However, Zeng and colleagues' study fills a gap in our understanding of precisely how organisms respond to an abundance of leptin. Their work also specifically demonstrates that sympathetic neurons projecting to WAT are a central trigger for leptin-mediated lipolysis.

Of course, questions arise from these findings. Leptin is thought to signal through several brain areas[11], but it remains unclear which neuronal networks sense increased blood leptin concentrations and control sympathetic relay stations to ultimately regulate lipolysis and fat mass. Notably, only half of the nerve fibres found in WAT expressed tyrosine hydroxylase, and the authors did not analyse the other half, nor the characteristics of the fat cells that the neurons innervate. Although their identities remain elusive, these neurons and fat cells hold the potential for further exciting discoveries. Future experiments should define the key brain areas that control sympathetic traffic to WAT and the molecular circuitry that controls lipolysis downstream of these effectors.

Zeng *et al.* estimated that tyrosine-hydroxylase-expressing neurons envelop between 3 and 12% of fat cells, a relatively sparse coverage. Nonetheless, the fact that optogenetic activation markedly increased lipolysis indicates that catecholamine signalling through neuro-adipose junctions has an important role in the control of lipid homeostasis. Given that leptin resistance is a common feature of obesity, it is to be hoped that this study will fuel further dissections of the brain–fat axis. It might also open a door to assessing the therapeutic potential of controlling catecholamine signalling in fat. ■

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MICROBIOLOGY

Electrical signalling goes bacterial

The discovery that potassium ion channels are involved in electrical signalling between bacterial cells may help to unravel the role of ion channels in microbial physiology and communication. SEE ARTICLE P.59

SARAH D. BEAGLE & STEVE W. LOCKLESS

Biological membranes separate cells or cellular compartments from the rest of the world, protecting the internal contents from the sometimes hostile, and always different, external milieu. However, cells are not closed systems and must pass information and matter, including ions, selectively across the membrane barrier. Proteins called ion channels facilitate the movement of ions across the membrane by allowing each ion to flow passively down its electrochemical gradient. Although ion channels mediate rapid, long-range communication in eukaryotes (the group of organisms that includes plants, animals and fungi), a signalling role for bacterial ion channels has remained elusive[1,2]. In this issue, Prindle *et al.*[3] (page 59) report the first example of a bacterial potassium channel that functions in a signalling role, through long-range coordination of metabolic oscillations.

The current study is an extension of the same laboratory's previous discovery[4] that adherent communities of *Bacillus subtilis* bacteria, known as biofilms, grow in periodic cycles once the colony reaches a threshold size (Fig. 1). The authors proposed that these oscillations arise when the cells in the biofilm's interior become deprived of glutamate, owing to high consumption of the amino acid by peripheral cells. Glutamate starvation in the interior cells reduces their production of ammonium ions, which the peripheral cells need, resulting in arrested cell growth in the periphery. Following replenishment of glutamate in the interior cells, ammonium production increases, leading to growth of peripheral cells. The linked metabolic processes of cells within the biofilm community raised the question of how the metabolic state of cells is communicated over long distances.

Maintenance of the proper intracellular concentrations of glutamate and ammonium depends on the electrical potential across the cell membrane[5,6], known as the membrane potential. Therefore, Prindle *et al.* investigated whether electrical signalling is responsible for the long-range coordination of metabolic oscillations across the bacterial population. Using a voltage-sensitive fluorescent dye, the authors detected rhythmic synchronized fluctuations in membrane potential across the biofilm. Eliminating the need for glutamate and ammonium by adding the amino acid glutamine to the cells' growth medium quenched these fluctuations, thereby linking electrical signalling and metabolism.

The observed changes in the membrane potential could result from sodium ions (Na^+) moving into the cell, potassium ions (K^+) moving out, or a combination of both. Using fluorescent dyes that specifically bind to either Na^+ or K^+, the researchers found a direct correlation between the timing of K^+ efflux and changes in membrane potential, suggesting that K^+ efflux might propagate signals across the biofilm.

Because the K^+ channel YugO is involved in *B. subtilis* biofilm formation[7], Prindle *et al.* next asked whether this channel mediates K^+ efflux. As expected, glutamate limitation in wild-type cells led to K^+ efflux, whereas no K^+ efflux was observed in cells lacking the *yugO* gene. Similarly, deletion of the TrkA domain of YugO, which gates K^+ flux, decreased the propagation of electrical oscillations under limited glutamate conditions. These results indicate that YugO is activated by glutamate limitation and is required to propagate the K^+ signal through the biofilm (Fig. 1). The use of extracellular K^+ to propagate a metabolic stress signal through the bacterial community is reminiscent of the increase in extracellular K^+ that drives the dilation of blood vessels in the mammalian brain[8] in response to stress, suggesting that some K^+ channels in bacteria and eukaryotes have evolved to accomplish similar outcomes.

Prindle and colleagues' study establishes the first example of a signalling function for a bacterial K^+ channel. Although previous studies[9,10] have established a role for various classes of bacterial channel in regulating cellular osmotic pressure, the impressive evolutionary conservation of eukaryotic and bacterial channels at the protein-sequence and structural levels provides additional evidence that some bacterial ion channels probably have signalling roles[11–13]. It is notable that the first demonstration of a signalling role for bacterial ion channels occurs in the context of bacteria acting as multicellular entities, and that this function serves to coordinate the

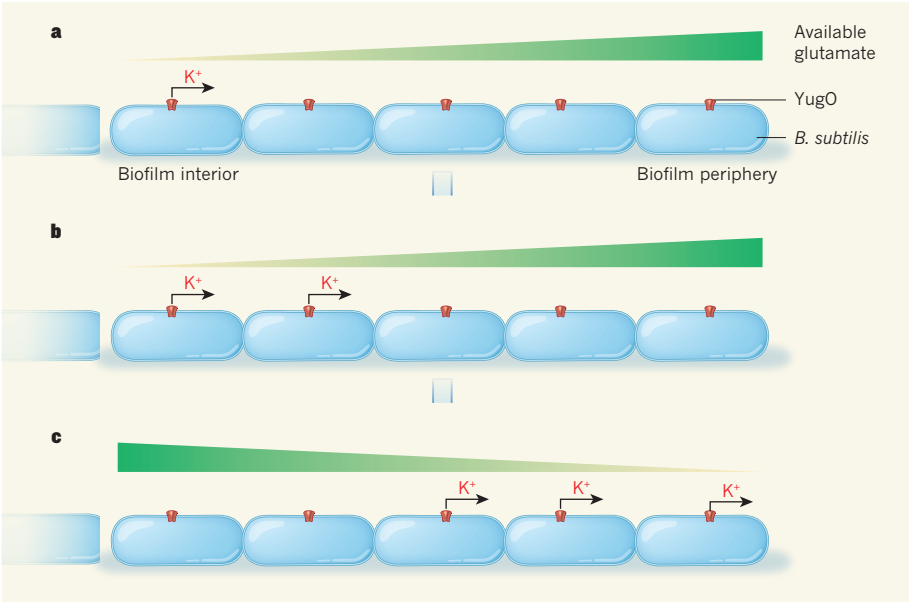

Figure 1 | Shocking communication. *Bacillus subtilis* bacteria can form communities called biofilms, in which cells both in the interior and on the periphery require the amino acid glutamate to survive and grow. **a**, When peripheral cells take up most of the available glutamate, the interior cells become starved. Prindle *et al.*[3] propose that nutrient-stressed interior cells secrete potassium ions (K^+) through the YugO K^+ channel. **b**, The release of K^+ ions then changes the transmembrane voltage of cells and leads to the subsequent release of K^+ ions from neighbouring cells, propagating the starvation signal. **c**, The signal propagation ultimately reduces the uptake of glutamate in peripheral cells. Glutamate becomes available for interior cells to consume and the cycle is reset.

metabolic states of neighbouring cells.

Unlike a eukaryotic action potential (in which electrical signal propagation is fast, owing to the rapid rising and falling of the membrane potential), the signalling that coordinates metabolic oscillations in *B. subtilis* occurs over a longer time period. Using mathematical modelling, the authors provide evidence that K^+ efflux alone can account for the slow signal propagation. This propagation, which is perhaps an evolutionary precursor to the faster action potential, seems to retain overall biofilm stability by synchronizing the growth of peripheral cells and metabolic maintenance of interior cells.

Although the present study highlights similar signalling roles for eukaryotic and bacterial ion channels, many questions remain to be addressed. What are the metabolic intermediates that activate YugO following glutamate starvation in *B. subtilis*? One possibility is that the TrkA regulatory domain senses the energy level of the cell by binding ATP or ADP, two molecules that have been shown[14] to regulate the TrkA protein in other bacteria. What is the magnitude of the changes in membrane potential, and how does this affect other voltage-dependent processes in the membrane? More generally, it will be interesting to determine whether this mechanism is used by other community-forming species as a way to regulate metabolism and growth.

The discovery of this K^+ signalling mechanism highlights the complexities of bacterial social communication. Most bacterial cells are too small to require electrically propagated intracellular signalling; instead, diffusion of signalling molecules in the cytoplasm is sufficiently rapid. It remains to be seen whether other bacterial social behaviours are governed by electrical signalling. Perhaps such signalling plays a part in interspecies communication, for instance between biofilms and epithelial cells in the gut. Like predator–prey interactions in some of the more complex eukaryotic species, it could be that microorganisms compete with each other by secreting toxins that interfere with an adversary's ion-channel activities. Finally, the fact that signalling in the biofilm shares several characteristics with electrical signalling in the nervous system — including the use of the common neurotransmitter molecule glutamate — highlights an exciting functional connection between these evolutionarily distant systems. ■

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QUANTUM PHYSICS

Quantum sound waves stick together

A sensitive cold-ion experiment probes sound at the level of phonons, the fundamental quantum units of vibration. It shows that phonons mix in such a way that they can be classified as 'bosonic' particles, like photons. SEE LETTER P.74

DAVE KIELPINSKI

The phenomenon of wave interference is observed in various settings, including optics, electronics and acoustics. In constructive interference, the crests and troughs of interfering waves reinforce each other, whereas in destructive interference they cancel each other out. Although we think of sound as consisting of macroscopic waves, it has a quantum nature. The energy of a sound wave is an integer multiple of a fundamental quantum of vibrational energy called a phonon. On page 74 of this issue, Toyoda *et al.*[1] report the effect of two-phonon interference, and show that the interfering phonons 'stick together' — they are never observed to go different ways.

The interference of sound waves is not just of academic interest. For instance, it is the operating principle of noise-cancelling