higher intracellular magnesium concentrations compared with the wild-type strain. As magnesium ions stabilize the structure of the ribosome, the authors suggested that increased expression of magnesium transporters leads to increased intracellular magnesium levels, which decreases hyperpolarization and increases cell growth and survival possibly owing to increased stability of the ribosome complex. In agreement with this hypothesis, the addition of excess magnesium ions to the growth medium reduced hyperpolarization in wild-type cells in the presence of the antibiotic. By contrast, other cations, such as potassium, sodium or calcium, were less effective at reducing hyperpolarization, which is in agreement with the finding that mainly magnesium transporters were upregulated under ribosomal stress conditions. Moreover, increasing the concentration of magnesium in the growth medium reduced hyperpolarization of the L34-deletion strain and rescued the growth defect.

In summary, this study uncovers a functional link between ion flux and ribosome function and indicates an alternative mechanism for bacterial survival under antibiotic stress. The results presented suggest that hyperpolarization induced by ribosome destabilization in the presence of ribosome-targeting antibiotics increases the expression of magnesium transporters and thus magnesium influx. Increased ion flux promotes growth owing to the magnesium-mediated stabilization of the ribosome complex. Further studies are now needed to uncover the mechanisms responsible for the observed cell-to-cell variability of ion flux in bacteria. Finally, the findings might have implications for the development of treatment strategies, as the efficiency of ribosome-targeting antibiotics could be enhanced by targeting magnesium transporters.

Andrea Du Toit

ORIGINAL ARTICLE Lee, D. D. et al. Magnesium flux modulates ribosomes to increase bacterial survival. *Cell* https://doi.org/10.1016/j.cell.2019.01.042 (2019)

the basal disk) but lacked components of the flagellar inner membrane, rod and hook. Furthermore, the authors showed that the retained partial flagellar structures are not flagellar assembly precursors. On the basis of the results, they proposed that those structures are the 'relics' of ejected flagella. Relics were also found in *V. cholerae*, *V. fischeri*, *Shewanella putrefaciens* and *Pseudomonas aeruginosa*, which suggests that ejection of the flagellum is widespread among γ-proteobacteria. Interestingly, the authors noticed an extra density in all the relic structures that 'plugged' the P-ring in a position that was previously occupied by the periplasm-spanning rod. The evidence suggests that this additional structure does not stem from conformational change in a previously assembled flagellar component, but the authors could not identify the protein that plugs the P-ring. However, they speculate that this protein might prevent periplasmic leakage following ejection of the flagellum.

But what triggers flagellar ejection? The authors showed that mechanosensing by the filament under high cell density conditions is not the trigger for ejection. However, cells grown in spent medium from *P. shigelloides* lost their flagellum within one cell cycle, and cells grown in minimal media stopped swimming and subsequently lost their flagella, whereas the ejection of flagella could be rescued by adding yeast extract to the minimal medium. These findings suggest that a lack of nutrients triggers ejection of flagella and entry into a non-motile state. Further studies are now required to elucidate the underlying molecular mechanism of flagellar ejection.

In summary, the study shows that under nutrient depleted conditions, γ-proteobacteria eject their flagellar hook, distal rod and filament and that relics of these ejected flagella are retained at old cell poles. The authors hypothesize that the bacteria eject their flagella and switch from a motile to non-motile state to conserve energy in nutrient-limited environments.

Andrea Du Toit

ORIGINAL ARTICLE Ferreira, J. L. et al. γ-proteobacteria eject their polar flagella under nutrient depletion, retaining flagellar motor relic structures. *PLOS Biol.* https://doi.org/10.1371/journal.pbio.3000165 (2019)

IN BRIEF

HOST RESPONSE

TRIM5α controls HIV-1 infection in humans

Interferon-α (IFNα) induces the expression of interferon-stimulated genes (ISGs) that inhibit HIV-1 replication. Malim and colleagues set out to characterize human ISGs that suppress HIV-1 replication and identified well-established genes, such as those encoding IFN regulatory factor 9 or myxovirus resistance 2, as well as human tripartite-containing motif 5α (TRIM5α), a ubiquitin ligase that was previously thought not to be active against HIV-1. By contrast, non-human TRIM5α proteins have been shown to be HIV-1 restriction factors that target the early post-entry phases of infection. The authors now show that in the presence of IFNα, human TRIM5α suppresses HIV-1 infection. The inhibitory effect is regulated by the IFNα-mediated activation of the immunoproteasome; IFNα promotes the proteolytic turnover of TRIM5α and effective capsid-dependent inhibition of HIV-1 DNA synthesis and infection. Thus, the results suggest that TRIM5α contributes to the control of HIV-1 in infected humans.

ORIGINAL ARTICLE Jimenez-Guardeño, J. M., Apolonia, L., Betancor, G. et al. Immunoproteasome activation enables human TRIM5α restriction of HIV-1. *Nat. Microbiol.* https://doi.org/10.1038/s41564-019-0402-0 (2019)

BACTERIAL PATHOGENESIS

Reducing the second messenger

The second messenger cyclic di-GMP (c-di-GMP) enables bacteria to rapidly respond to changes in their environment. Miller and colleagues used a biosensor to measure the levels of intracellular c-di-GMP of *Salmonella enterica* subsp. *enterica* serovar Typhimurium during infection of macrophages. Following initial phagocytosis, the intracellular c-di-GMP levels are reduced, and the authors identified three redundant sensor phosphodiesterases that were responsible for maintaining low c-di-GMP concentrations. Deletion of all three enzymes decreased survival of a population of slow-replicating bacteria during macrophage infection, and deletion of the cellulose synthase machinery restored virulence in mutant bacteria lacking enzymatic activity, which suggests that low c-di-GMP concentrations prevent the overproduction of cellulose. The authors hypothesized that glucose limitation in the intracellular environment drives the reduction of cellulose production and promotes survival.

ORIGINAL ARTICLE Petersen, E., Mills, E. & Miller, S. I. Cyclic-di-GMP regulation promotes survival of a slow-replicating subpopulation of intracellular *Salmonella* Typhimurium. *Proc. Natl Acad. Sci. USA* https://doi.org/10.1073/pnas.1901051116 (2019)

VIRAL INFECTION

Modulating host metabolism

Viruses hijack host metabolism to complete their life cycle. Here, Wobus and colleagues show that host cell metabolism is also important for modulating replication of murine norovirus (MNV). Using metabolomics profiling they found that infection of mouse macrophages by MNV increases host cell metabolism. To establish the effects of this increase in host metabolic activity they inhibited glycolysis, which attenuated MNV infection. By contrast, although the pentose phosphate pathway and oxidative phosphorylation were also increased during infection, those pathways only have a minor effect on MNV infection. The authors went on to show that glycolysis is important during the early steps in the viral life cycle following viral entry and capsid uncoating. Finally, they report that MNV infection activated the protein kinase Akt, which is a master regulator of cellular metabolism.

ORIGINAL ARTICLE Passalacqua, K. D. et al. Glycolysis is an intrinsic factor for optimal replication of a norovirus. *mBio* https://doi.org/10.1128/mBio.02175-18 (2019)