requires more energy dissipation per unit of time. To test this energy–speed–accuracy relation, Lan *et al.*[1] considered a microscopic model of the chemotaxis network of the bacterium *Escherichia coli*, finding that as the system is driven further away from equilibrium, the energy-dissipation rate approaches that predicted by the energy–speed–accuracy relationship. Moreover, by comparing the network with a large class of models, they found that the design of the *E. coli* network is close to optimal — for a given energy-dissipation rate and adaptation time, the uncertainty cannot be reduced much by choosing different model parameters.

Last, although the energy–speed–accuracy relation shows that the energy-dissipation rate is proportional to the adaptive speed and accuracy, it does not predict whether energy is traded for accuracy or speed (or a combination of both) under biological conditions. To test this, the authors performed experiments on starving *E. coli* cells, showing that in the stressed system, the adaptive speed becomes progressively slower, whereas the adaptive accuracy remains constant.

Many signalling systems employ futile cycles, in which two pathways run in opposite directions with no apparent function. The results of Lan *et al.*[1] show that these cycles can have a function: they enable accurate adaptation. At the same time, they come at an energetic cost. This trade-off between accuracy and energy is emerging as a general design principle of biological systems. The classical example is kinetic proofreading[2,3], in which energy is consumed to discriminate between two possibilities — the binding of the 'right' molecule instead of the 'wrong' molecule, for example — with higher fidelity than that allowed by equilibrium thermodynamics.

Recently, it was shown that there is a trade-off between the energetic cost of making a regulatory network and the precision of its regulatory function[4,5]. In the coming years, new examples of this interplay between precision and energy will undoubtedly be revealed. Given the tremendous progress that has recently been made in describing systems driven arbitrarily far from equilibrium, such as the Jarzynski relation[6] and new fluctuation theorems[7–9], the study of precision and energy in living systems holds great promise for the future of non-equilibrium physics. ❐

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ANTIMATTER

Anything out there?

The Universe seems to be made of matter rather than antimatter, but our current understanding of cosmology does not exclude the possibility of there being small regions of antimatter out there. However, new observations reported by a Japan–US collaboration using the Balloon-borne Experiment with a Superconducting Spectrometer (BESS) show no sign of antihelium in cosmic rays, setting an even lower limit on the possible abundance of antimatter (K. Abe *et al. Phys. Rev. Lett.* **108,** 131301; 2012).

The asymmetry between matter and antimatter is one of the fundamental puzzles in modern physics. In the Big Bang, equal amounts of matter and antimatter should have been created, and would have annihilated each other except that some kind of symmetry breaking between particles and antiparticles seems to have led to the disappearance of antiparticles at an early stage in the history of the Universe. Pockets of primordial antimatter could still exist, but finding them isn't easy. Matter and antimatter emit photons of the same wavelength, so light from distant galaxies does not provide much of a clue, although annihilation occurring at the boundaries with normal matter regions would show clear gamma-ray signatures — signatures that have not yet been seen.

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Simple antiparticles such as antiprotons can, however, be created in high-energy collisions of normal matter; BESS and other spectrometers have recorded many thousands of them in cosmic rays and large numbers of them can be created for use in accelerators (such as in CERN's Antiproton Decelerator). But more-complex antiparticles such as antinuclei must originate from antimatter regions of space: the discovery then of even a single antinucleus heavier than hydrogen would have significant impact in cosmology. But how do you look for an atom-sized needle in a haystack the size of the Universe?

Since 1993, BESS (pictured) has been hunting for signs of antihelium in cosmic rays, carrying aloft a magnetic spectrometer with time-of-flight and Čerenkov-radiation detectors to identify helium and possible antihelium nuclei through determination of their mass and charge. The BESS Polar I and Polar II missions flew over Antarctica in 2004 and 2007–2008, collecting more than a month's worth of data. Analysing the large data set has, however, revealed no antihelium in the cosmic rays, implying that antihelium is at least ten million times less abundant than its normal matter twin.

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