To deal mathematically with genetic drift in a finite population, they adopted the model developed in the 1930s by R. A. Fisher and Sewall Wright and the mathematical framework developed in the early 1970s by Motoo Kimura and Tomoko Ohta.

The model yielded a quantitative picture of TF evolution. For example, under famine conditions and when the food supply fluctuates much faster than the mutation rate, neither control mode has an evolutionary edge over the other. But as the fluctuations in the scarce food supply lengthen, mutations have more time to accumulate and the wear-and-tear principle increasingly prevails: Evolution selects (+ +) control rather than the (− −) control of use it-or-lose-it.

The effect of finite population size emerged from the model as expected, but with a twist. Small populations are more vulnerable to adverse effects of genetic drift than large populations are. Under famine conditions and when the fluctuations are modest, (− −) control emerges as the winner and use-it-or-lose-it prevails. But at a critical population size, (− −) control loses its advantage over (+ +) control and wear-and-tear prevails.

Gerland and Hwa ran their model for billions of generations and found rare cases where use-it-or-lose-it is literally true: In small populations, genetic drift could destroy TF function within one nutrient fluctuation period. When that happens, TF-mediated gene regulation becomes extinct until random mutations eventually restore it.

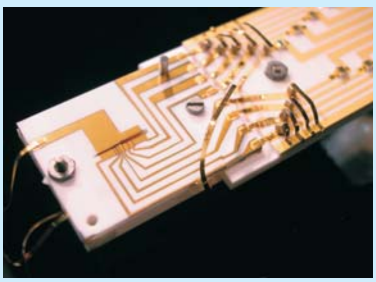
Figure 2 shows the phase diagram Gerland and Hwa derived for the case

physics update

These items, with supplementary material, first appeared at http://www.physicstoday.org.

Entangled mechanical oscillators. Entanglement is one of the hallmarks of quantum mechanics and is a key tool in the burgeoning field of quantum information processing. Generating entangled states has become routine in the quantum realms of photons and of electron and atomic spins. Now John Jost and colleagues at NIST in Boulder, Colorado, the Weizmann Institute of Science, and Lockheed Martin Corp have demonstrated entanglement in separated mechanical oscillators. Each oscillator consists of a pair of ions—one $^{9}Be^{+}$ and one $^{24}Mg^{+}$—that behave like two unequal masses connected by a spring 4 μm long. The pairs are separated by 240 μm, so their individual vibrational motions are decoupled. To entangle those vibrational modes, the researchers cool the four ions in one zone of a multizone ion trap (shown here) while coaxing them with electrode voltages to line up in a specific order: a Be ion at each end. They next entangle the spins of the two Be ions and then separate the pairs into different trap zones. Lasers tuned to the Mg ions recool the separated pairs while maintaining the Be entanglement. The team finally uses laser pulses to coherently transfer the entanglement from the Be spin states onto the pairs' motional states. The end product is the entangled superposition of vibrational oscillations in the pairs' ground and first excited states. Along the way, the team also demonstrated the entanglement between one ion's spin state and the motion of the other ion pair. Mechanical entanglement and the tools developed to achieve it will be important ingredients for scaling up quantum information processing with trapped ions. (J. D. Jost et al., *Nature* **459**, 683, 2009.)

—RJF



Bees trade energy efficiency for stability when flying in turbulent winds. Traveling smoothly through a turbulent medium is no mean feat, as anyone who regularly flies in an airplane can attest. Scientists have investigated how fish navigate through turbulent currents, but until recently they had not addressed the analogous issue of animal flight through turbulent air. Now biologist Stacey Combes has filmed male orchid bees (genus *Euglossa*) flying in turbulent airstreams and, with colleague Robert Dudley, has described the effects of the turbulent air on the bee's flight stability and maximum speed. Combes induced the bees to fly in a turbulent airstream by luring them with an attractive scent. As the airspeed increased, the bees found it increasingly difficult to avoid rolling. When the airspeed was high enough and maintaining stable flight difficult enough, the bees extended their hind legs, as depicted in the photograph. That move increased the moment of inertia about the roll axis by roughly 50% and improved stability, but it also increased body drag and energy expenditure by about 30%. In a second experiment, Combes altered the turbulence of the stream by inserting different geometric grids. Bees flying in the lower-turbulence environment were able to reach higher speeds before instabilities caused them to be ejected from the air stream. (S. A. Combes, R. Dudley, *Proc. Natl. Acad. Sci. USA* **106**, 9105, 2009.)

—SKB

Smog reduced for Beijing Olympics. In an effort to reduce the pervasive smog in Beijing (see photo), Chinese authorities imposed measures to restrict traffic and close factories around the city during the 2008 Olympics. Were those efforts successful in reducing total atmospheric aerosol? Climate scientists Jan Cermak and Reto Knutti at ETH Zürich in Switzerland attempted to find out. They began by comparing absolute values of aerosol

optical thickness—transmittance measurements from the Moderate-Resolution Imaging Spectroradiometer aboard NASA's *Terra* satellite—for the years 2002–08. They found that within a of either a hearty feast or a severe famine (the two cases are mathematically symmetrical in the model). The solid line marks the critical population at which wear-and-tear and use-it-or-lose-it are equally likely to be selected. Above the line, wear-and-tear prevails; below, use-it-or-lose-it. But how strongly a population feels that preference depends on the number of generations that have elapsed: The smaller the number, the farther a population must be from the critical line before one principle wins.

In his lab experiments, Savageau saw evidence for use-it-or-lose-it but not wear-and-tear. By applying their quantitative model, Gerland and Hwa could see why that might be the case. *E. coli* lives for a few hours; their mammalian hosts for a few decades. A mammal's gut therefore hosts up to 10^5 generations of *E. coli*. Given a typical colony size is also about 10^5, Savageau's bacteria-infected hosts were squarely in the use-it-or-lose-it region of Gerland and Hwa's phase diagram.

Besides quantifying gene regulation, the model might help pharmacologists understand and combat the resistance of bacteria to antibiotics. One strain of *E. coli*, called mar, is resistant to tetracycline, an otherwise potent antibiotic, thanks to the working of two transcription factors.

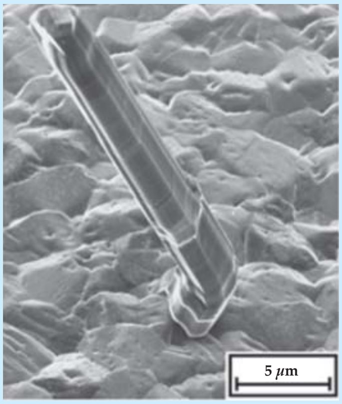
Charles Day

References

1. U. Gerland, T. Hwa, *Proc. Natl. Acad. Sci. USA* **106**, 8841 (2009).
2. M. A. Savageau, *Proc. Natl. Acad. Sci. USA* **71**, 2453 (1974).

150-km radius of Beijing, the average 2008 AOT value was more than 14% lower than the previous years. But what would it have been without the mandated emissions reductions? To answer that question, the researchers used a neural network approach: With data from the preceding six summers, they trained a model to predict AOT as a function of relative humidity, wind velocity, and precipitation. The model then predicted that within a 500-km radius of the city, AOTs in 2008 would have been 10%–14% higher than the actual observed values; the model was less accurate when larger regions were analyzed. Although the magnitude of the reductions was lower than expected, the emissions restrictions did have a statistically significant local impact. (J. Cermak, R. Knutti, *Geophys. Res. Lett.* **36**, L10806, 2009. Photo by Michael Silverman, 6 August 2006.) —JNAM

How tin whiskers grow. Late Stone Age metal smiths added a little tin to copper to usher in the eponymous Bronze Age; over the ensuing five millennia, many new combinations and applications of the two metals have appeared. Today, for example, a thin tin coating on a copper substrate often works like solder to interconnect electronic components of various kinds, such as are found in medical devices and satellite equipment. Unfortunately, micron-sized tin whiskers (see figure) sometimes arise spontaneously and can short out the equipment, with great technological and economic repercussions. After decades of widespread effort, the actual mechanism underlying such whisker growth has only now been elucidated. Led by Eric Mittemeijer, a group from the Max Planck Institute for Metals Research in Stuttgart, Germany, working with the Robert Bosch company and Argonne National Laboratory in Illinois, examined growing whiskers and their crystallographic environment. Using Laue diffraction measurements made at Argonne's Advanced Photon Source, the researchers noted that at the Cu–Sn interface, Cu_6Sn_5 develops along the tin grain boundaries and is most pronounced directly beneath a whisker's root. That observation, coupled with residual strain measurements, led the team to propose that deep penetration of Cu_6Sn_5 into the 3-μm-thick tin layer induces in-plane compressive strains near the Cu–Sn interface and in-plane tensile strains nearer the surface. Out-of-plane and in-plane strain gradients—not the strains themselves—then provide the driving force that leads to whisker growth by transporting Sn atoms to the whisker nucleation site as a strain-relief mechanism. (M. Sobiech et al., *Appl. Phys. Lett.* **94**, 221901, 2009.) —SGB



Cosmic-ray electron spectrum. Last fall, the ATIC balloon collaboration reported a tantalizing peak near 500 GeV in its measured spectrum of high-energy cosmic-ray electrons (PHYSICS TODAY, January 2009, page 16). The peak suggested that 500-GeV dark-matter particles of the kind predicted by extra-dimensional extensions of standard particle theory might be annihilating each other in nearby accumulations of dark matter to produce energetic electron–positron pairs. Now NASA's recently launched *Fermi Gamma-ray Space Telescope* has measured the electron spectrum out to 1 TeV with much higher statistics (see the figure). Designed primarily to record high-energy gammas, *Fermi* can also detect electrons. The data show no narrow spectral feature near 500 GeV, nor anywhere else; but above 100 GeV there is a growing excess over the predictions of a conventional diffusive model of electrons from very distant astrophysical sources. The positron spectrum measured by the orbiting PAMELA magnetic spectrometer showed a similar excess above 10 GeV. (Neither ATIC nor *Fermi* can distinguish electrons from the much rarer positrons.) Taken together, the *Fermi* and PAMELA results suggest that our local galactic neighborhood harbors either an undiscovered astrophysical electron–positron source (most likely a pulsar) or a dense concentration of unidentified, heavy dark-matter particles. Much should be revealed when the *Fermi* collaboration reports electron spectral data beyond 1 TeV and the spectrum of the diffuse gamma-ray background out to 1 TeV. (A. A. Abdo et al., *Fermi* collaboration, *Phys. Rev. Lett.* **102**, 181101, 2009; O. Adriani, PAMELA collaboration, *Nature* **458**, 607, 2009.) —BMS