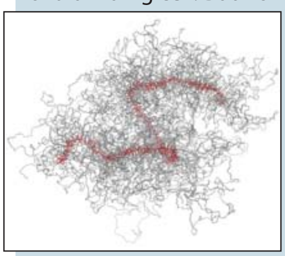
## physics update

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

**Florida's mangroves expand northward.** Just north of St. Augustine, around a latitude of 30° N, lies the stretch of Florida's east coast where the littoral vegetation switches from the mangrove forests of the south to the salt marshes of the north. Stubby, salt-tolerant mangrove trees thrive in warm climates. As Earth's mean temperature rises, Florida's mangroves should expand northward, says Kyle Cavanaugh of the Smithsonian Environmental Research Center in Edgewater, Maryland, and Brown University in Providence, Rhode Island.

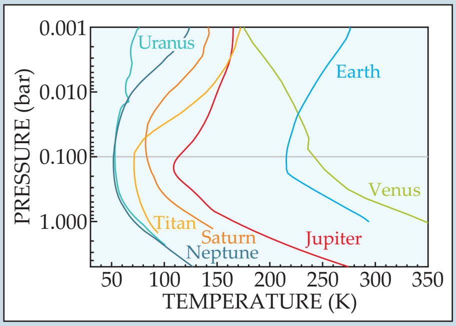
He and and his collaborators analyzed 28 years of *Landsat* images of Florida's east coast and found that mangroves are indeed pushing northward—but in a surprising way. South of 27° N, the area covered by mangroves remained the same during the study's 1984–2011 span. North of that latitude, however, mangrove coverage grew—at a rate that increased with latitude. In the study's northernmost zone, 29°–29.75° N, the coverage doubled. Locally, mean annual and mean winter temperatures have risen throughout Florida since 1984, but neither trend correlated with the expansion's latitude dependence. Of all the environmental factors that Cavanaugh and his colleagues investigated, the only one to yield a strong correlation was a threshold: the annual change in the number of days with minimum temperatures below −4 °C. Such days are becoming rarer throughout Florida, but their frequency is falling fastest in the northern part of the state. Thanks to their deep roots, mangroves protect fragile coasts. Though benign, the dramatic expansion of Florida's mangroves underlines the importance of identifying thresholds in other ecosystems that could trigger a rapid, possibly disastrous, response to climate change, the study's authors say. (K. C. Cavanaugh et al., *Proc. Natl. Acad. Sci. USA*, in press.) —CD

**Picturing the organization of mitotic chromosomes.** Chromosomes, with their tightly coiled but elongated X-shaped profile, are among the most recognizable features of a dividing cell. But how DNA is organized inside the chromosomes is largely unresolved. Although a chromosome may look hopelessly tangled, there exist distinct patterns in how it contorts and arranges itself. Methods known collectively as chromosome conformation capture, first developed by Job Dekker of the University of Massachusetts



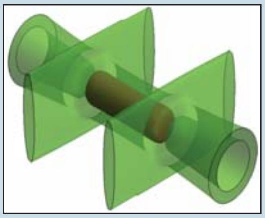
Medical School and colleagues a decade ago, offer a way to examine the folded conformations by chemically linking parts of the chromosome that are spatially close. Sequencing the linked DNA segments allowed the researchers to figure out which parts of the chromosome are likely to have intersected. The result was a map of contact points at which segments of base pairs fold inside a nucleus (see Physics Today, December 2009, page 19). Dekker, Leonid Mirny (MIT), and their colleagues have now combined chromosome conformation capture with polymer simulations of DNA to model how a chromosome disassembles and then reassembles itself during mitosis. They found that as the cell nucleus is dissolved, chromosomes become reorganized in two phases. First, the long chromosome fiber of protein and DNA compacts itself into an array of consecutive loops of some 80 000 to 120 000 base pairs that emanate from and return to a central scaffold—the flexible, dark-colored rod pictured here. That phase is then followed by axial compression of the scaffold to form a short, dense cylinder. (For a movie that illustrates the process, see the online version of this update.) Yet to be understood is what interactions guide the reorganization. (N. Naumova et al., *Science* **342**, 948, 2013.) —RMW

**Many planets, similar tropopauses.** In the troposphere, the lowest layer of Earth's atmosphere (extending to 10–15 km above the surface), temperature decreases with altitude. But in the enveloping layer, the stratosphere, that trend changes direction. At the boundary between the two, called the tropopause, the temperature is at a minimum and, in the global average, atmospheric pressure is about 0.1 bar. (See the articles by Raymond T. Pierrehumbert in Physics Today, January 2011, page 33 and by Bjorn Stevens and Sandrine Bony in Physics Today, June 2013, page 29.)




Curiously, such temperature minima have also been found in the atmospheres of Jupiter, Saturn, Uranus, Neptune, and the Saturnian moon Titan, all at roughly the same pressure despite significant differences in solar irradiation, atmospheric composition, and gravity. Tyler Robinson (now at NASA's Ames Research Center) and David Catling (University of Washington) show how a simple physical model helps explain that commonality. At low altitudes and higher pressures, atmospheres are opaque to long-wavelength thermal IR radiation and are heated from below; the result is convective mixing. At lower pressures, radiative heat transfer at shorter wavelengths dominates. The researchers note that although the various atmospheres differ in their details, they are all generally thick, which leads to a generic pressure-squared dependence for molecular IR absorption. Because of that scaling, stratospheric temperature inversions ascend from a relatively narrow range of parameter space around the observed pressure of 0.1 bar. That general rule, the pair notes, could provide useful insights into exoplanets and exomoons. (T. D. Robinson, D. C. Catling, *Nat. Geosci.* **7**, 12, 2014.) —RJF

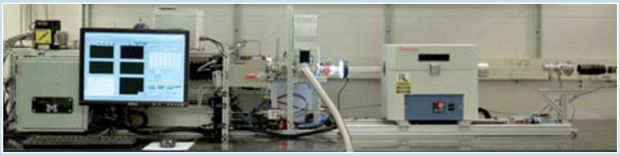
**Noninteracting quantum gas cools when diluted.** Dilute a typical gas by allowing it to expand, and its temperature will change. In classical physics, that so-called Joule–Thomson effect disappears in the ideal-gas limit of vanishing interactions. But as shown theoretically in 1937 by Daulat Kothari and B. N. Srivasava, at very low temperatures, for which the rules of quantum mechanics apply, a Bose gas will cool when diluted, even if the gas molecules don't interact. Now Joule–Thomson cooling of such a gas has finally been observed, by Zoran Hadzibabic and colleagues at the University of Cambridge, thanks to a novel trap. Conventional traps



hold gases in harmonic potentials whose confining forces strongly amplify the effect of any interparticle interactions, thereby obscuring the "ideal" quantum Joule–Thomson effect. The researchers created a nearly uniform confining potential by intersecting a tube-like green laser beam with two sheet-like beams, as shown in the figure. They then filled their trap with a 45-nK Bose gas of very weakly interacting rubidium-87 atoms. The gas became diluted, not because the team expanded it but because atoms were naturally ejected via collisions with the background gas in the trap's vacuum chamber. The rate of exodus is independent of energy, so just as for free expansion, the dilution does not change the energy per particle in the system. In time, 80% of the initial Rb atoms exited, and the temperature dropped to 23 nK, in agreement with theory. (T. F. Schmidutz et al., *Phys. Rev. Lett.*, in press.) —SKB

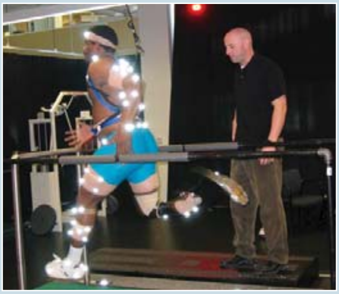
**A phase-change alloy that crystallizes without shrinking.** In the race to become the next technology for computer memory, phase-change memory (PCM) is among the leading contenders. The basis of PCM is a reversible, temperature-induced change between a shiny, low-resistance crystalline phase and a dull, high-resistance amorphous phase. In prototype devices, either the change in reflectivity or the change in resistance is exploited to write and store data. Unfortunately, in most PCM materials, the phase change is accompanied by a change in density that's large enough to create performance-sapping voids beneath electrodes. And the materials that exhibit the biggest change in reflectivity or resistance also exhibit the biggest change in density. Magali Putero of Aix-Marseille University in France and her colleagues from CNRS and IBM have been systematically investigating the phase-change behavior of a wide range of PCM materials. Most of them shrink when they crystallize, but others swell. Using a beamline at the European Synchrotron Radiation Facility, Putero and her colleagues found that 50-nm-thick films of one PCM material, a gallium–antimony alloy, can do both, depending on the composition ratio. Films of the lowest Sb composition that they studied, 55%, expanded in thickness by 3%, and films of the highest Sb composition, 95%, shrank by 4%. At 70% Sb, the thickness remained the same. That desirable property came with another: The change in resistance at that composition was large enough to qualify the alloy as a good PCM material. The researchers are now looking for other PCM materials that behave in the same way. (M. Putero et al., *APL Mat.* **1**, 062101, 2013.) —CD

**High-speed nanomaterial synthesis and discovery.** Researchers working to develop nanomaterials with novel properties often rely on educated guesses and one-off experiments to gradually improve, but not always optimize, the fabrication process. Consider thin films made with chemical vapor deposition (CVD): A sample substrate is placed in a tube in which the pressure is adjusted and suitable gases are introduced; the tube is inserted into a furnace for heating and cooling, then the sample is removed and analyzed, and the next experiment is set up. In a typical workday, 2–4 experiments can be done. John Hart of MIT and his group have created Robofurnace, shown here, which can execute up to 16 CVD experiments in 24 hours. Built mostly using off-the-shelf components, the robotic system incorporates a magazine that can hold up to 10 sample substrates, a transfer arm that loads each sample into the furnace tube, several different gas lines, pressure- and humidity-control systems, and a furnace (the box on the right) that slides along the tube. Each sample can be processed using a different "recipe." Rapid heating to a given temperature of up to 1100 °C, and subsequent rapid cooling, can be accomplished by precisely posi-



tioning the furnace around the sample, then sliding the furnace away. In an early demonstration of Robofurnace's capabilities, the researchers used a sequence of experiments to find a new recipe to grow carbon-nanotube forests—films of vertically aligned CNTs used in myriad commercial applications—that are an order of magnitude more dense than they had grown in a static tube furnace. (C. R. Oliver et al., *Rev. Sci. Instrum.* **84**, 115105, 2013.) —SGB

**Capturing the chaos of running.** None of us are perfect—and neither are our gaits. In any given stride, we might extend a knee a bit further, swing a leg a bit wider, or raise a foot a bit higher than in the stride before. In nonlinear dynamics, such deviations from perfect periodicity are often characterized by the Lyapunov exponent, a measure of the rate at which small perturbations grow into big ones. A large Lyapunov exponent indicates an unstable, chaotic system prone to large fluctuations; a small exponent indicates a stable system that's nearly periodic. (See the article by Adilson Motter and David Campbell, PHYSICS TODAY, May 2013, page 27.) Now Nicole Look, her advisers Elizabeth Bradley and Rodger Kram, and their colleagues at the University of Colorado Boulder have used motion-capture technology to determine Lyapunov exponents associated with human running. The researchers tracked the movements of 17 subjects—six of



whom had below-knee amputations and were fitted with prostheses—as they ran at paces varying from a trot to a sprint. (One test subject is pictured here.) As expected, the amputees' knee and hip motions were less stable than those of nonamputees. But surprisingly, amputees had, on average, a slightly more stable center of mass. Moreover, the center-of-mass dynamics of all subjects tended to grow more stable with increased running speed, even as knee and hip movements grew more chaotic. One proposed explanation: Runners may instinctively compensate for diminished lower-body control by exerting more control over their core. (N. Look et al., *Chaos* **23**, 043131, 2013.) —AGS ■