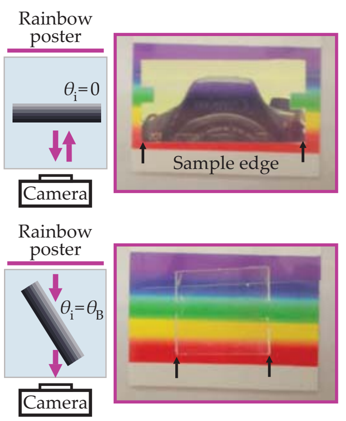
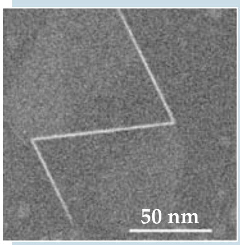
physics update

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

Filtering light by angle. Light comes to us with an infinitude of frequencies and polarizations, and from every direction. Photonic crystals isolate desired frequencies and familiar filters block specific polarizations. Now the first material that selects a specific incidence angle of light for a wide range of optical frequencies has been fabricated by a group of physicists led by MIT's Marin Soljačić. The key element in the new device is a stack of alternating layers of two oxide films with different dielectric constants ε_1 and ε_2. Each of the 14 layers in the stack has the same thickness, and the stack as a whole blocks certain frequencies and incidence angles of light from getting through. But light incident at the Brewster angle, defined by $\tan\theta_B = (\varepsilon_2/\varepsilon_1)^{1/2}$, and polarized in the plane of incidence (a restriction that in principle can be relaxed) passes through the stack, regardless of frequency. In the MIT device, six stacks are deposited on top of each other. Each stack has a different layer thickness—70 nm for the thinnest stack, 150 nm for the thickest. The six-stack gauntlet is no problem for light incident at the Brewster angle, but for incidence angles more than about 4° off from θ_B, one of the stacks reflects the light back. The figure shows the researchers' experimental test. In the top panel, a camera faces the six-stack material, measuring 2 cm × 4 cm, and photographs its own reflection. In the bottom panel, light incident on the stacks at θ_B from the rainbow poster passes through the now-transparent material and is captured by the camera. (Y. Shen et al., *Science* **343**, 1499, 2014.) —SKB



A new angle on electron microscopy. An elusive goal in optics is the perfectly achromatic lens—a lens that focuses every color of light to the same point. When it comes to electron microscopy, however, an imperfect lens isn't necessarily a bad thing. So report Joanne Etheridge (Monash University, Australia) and her colleagues, who have exploited chromatic aberration—the tendency of a lens to bend rays of different wavelengths by different amounts—to devise a chemical-mapping technique for scanning confocal electron microscopes. Standard SCEMs use two lenses: one to focus an electron beam onto a small volume in a target sample and another to focus transmitted electrons onto the detector. The energies of the transmitted electrons carry clues about the chemical identity of the target. Normally, electron spectrometers are used to collect that energy information, but Etheridge and her coworkers adopt a simpler approach: They align their electron beam at an angle through the microscope lenses. Due to chromatic aberration, the lenses spatially separate electrons by energy, much like a prism separates colors of white light. An SCEM image can then be constructed exclusively with electrons of a selected energy. As a proof of principle, the team produced the image here, which shows the distribution of silver atoms in an aluminum–silver alloy. The bright, zigzagged line is a silver-rich region that precipitated out of the surrounding mixture. The million-pixel image took about 25 seconds to capture; with conventional techniques, it would have taken nearly half an hour. (C. Zheng et al., *Phys. Rev. Lett.*, in press.) —AGS

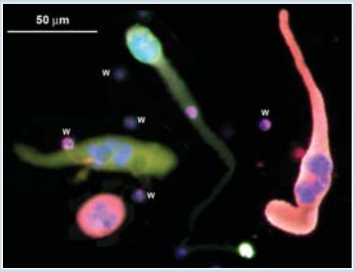


Looking for microscopic black holes. Gravity is by far the weakest of the fundamental forces. In elementary-particle interactions, it's thought to become comparable to the other forces only at collision energies of 10^{16} TeV—the so-called Planck energy. The perplexing disparity between the Planck energy and the TeV energy scale of electroweak unification is called the hierarchy problem. Several appealing attempts to address that problem posit extra spatial dimensions that make gravity only seem to be intrinsically weak (see PHYSICS TODAY, February 2002, page 35); gravity's true energy scale would be in the TeV regime. Such theories predict that the threshold for producing microscopic black holes is somewhere in the TeV collision-energy range of CERN's Large Hadron Collider (LHC, shown in the photo) rather than at the inaccessible Planck energy. Now the collaborations that run the LHC's CMS and ATLAS detectors have both reported the results of their searches for evidence of the production and prompt decay of perhaps a few hundred microscopic black holes in some 10^{15} proton–proton collisions at 8 TeV. Having looked at final states into which black holes with masses just above threshold are expected to decay, neither team finds evidence of black hole production. For a variety of models and final states, the CMS analysis constrained the black hole threshold mass to be above 6.2 TeV. And for one important class of final states not previously examined, the ATLAS analysis sets a lower mass limit of 5.3 TeV. With the LHC scheduled to run next year with a collision energy of 13 TeV, the search will resume. (S. Chatrchyan et al., CMS collaboration, *J. High Energy Phys.* **178**(7), 1, 2013; G. Aad et al., ATLAS collaboration, *Phys. Rev. Lett.* **112**, 091804, 2014.) —BMS


CERN

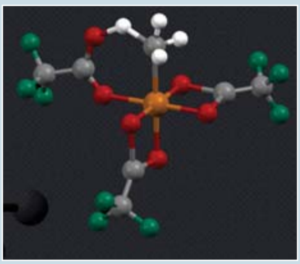
Macrophages in a liquid biopsy. A physician typically turns to an invasive biopsy—the removal of tissue—to determine if a tumor is benign or malignant and, if the latter, to identify the stage of the disease. In many cancer patients, cells leave the tumor, enter the bloodstream, and sometimes engender a new tumor elsewhere. Those circulating tumor cells (CTCs) are showing potential for a so-called liquid biopsy in a routine blood draw, as detailed by Chwee Teck Lim and Dave Hoon in PHYSICS TODAY, February 2014, page 26. Now Daniel Adams of Creatv MicroTech in Rockville, Maryland, and colleagues at several medical centers report using a gentle, low-pressure filtration system that caught not only CTCs but, to their surprise, some previously unknown fellow travelers they dubbed circulating cancer-associated macrophage-like cells (CAMLs). A macrophage is a shape-shifting cell found in the immune system—and in tumors—that can either repair or destroy other cells depending on the biological context.

The gelatinous and fragile CAMLs, like the four shown in the figure, are gargantuan compared with white blood cells



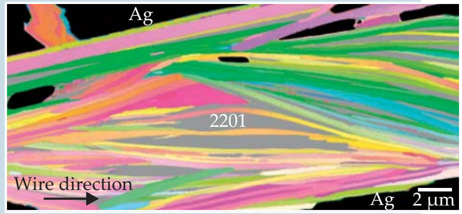
(labeled W). Thus far, the researchers have seen CAMLs in the blood of almost all cancer patients and in none of the healthy individuals they have studied. Further, they find that CAMLs interact with CTCs and respond to chemotherapy. Those findings suggest the possible usefulness of CAMLs for monitoring cancer metastasis and tracking treatment. (D. L. Adams et al., *Proc. Natl. Acad. Sci. USA* **111**, 3514, 2014.) —SGB

Liquid chemicals and fuels from natural gas. Natural gas is mostly methane, but it also contains significant amounts of ethane and propane. Those three hydrocarbons are raw materials for easily transportable liquid commodities such as methanol. A key step in making those compounds is to break a strong carbon–hydrogen bond and attach an oxygen atom to the carbon. Current processes require high temperatures (up to 900 °C) that lead to low reaction efficiencies and high carbon dioxide emissions. For decades now, chemists have worked to enable oxygenation at lower temperatures, mostly using scarce and expensive precious metals such as platinum or palladium. Now scientists from the Scripps Research Institute and Brigham Young University, led by Roy Periana, have discovered that salts of abundant elements like thallium and lead can activate and oxygenate C–H bonds of methane, ethane, and propane. The work could be the first step toward an inexpensive and practical conversion of natural gas into other fuels and chemicals. In experiments run under a variety of conditions but always at temperatures below 200 °C, the Periana group achieved oxygenated product yields



often exceeding 70%. The figure (courtesy of the Scripps Energy and Materials Center) shows an intermediate state for the reaction of methane with thallium trifluoroacetate [Th(CF_3COO)$_3$]. As the thallium (orange) grabs onto the methane carbon atom above it (gray), an oxygen (red) from an acetate group prepares to pluck off one of the methane's hydrogen atoms (white). An acetate group from the reaction solvent replaces the removed hydrogen; then the newly oxygenated methane disengages from the complex. (B. G. Hashiguchi et al., *Science* **343**, 1232, 2014.) —SKB

Better superconducting wires. Magnets are the biggest market for superconducting wire, and the favored wire for generating high fields is round and contains multiple filaments. The round geometry enables flexible conductor designs that support high magnetic stresses and can be wound in complex patterns to precisely shape the field. Although wires made from $YBa_2Cu_3O_{7-x}$ (YBCO) and other high-temperature cuprate superconductors offer the allure of high current densities, that goal has been realized primarily only in broad, flat, single-filament "tape" geometries that reduce the prevalence of current-limiting misalignments between crystal grains (see the article by Alex Malozemoff, Jochen Mannhart, and Doug Scalapino, PHYSICS TODAY, April 2005, page 41, and also January 2008, page 30). Now David



Larbalestier (National High Magnetic Field Laboratory) and colleagues have found a way to make round, multifilament wire out of the superconductor $Bi_2Sr_2Ca_1Cu_2O_{8-x}$ (Bi-2212). The team's key observation is that the usual wire fabrication process, which involves melting Bi-2212 powder packed inside a long silver tube, introduces bubbles that compromise the superconductor's connectivity, and those voids, not grain boundaries, are what place the dominant constraint on the current density. By applying a pressure of 100 bar during the heat treatment, the researchers could suppress the bubble formation. The resulting wires are denser and better connected, and despite having numerous grain boundaries (colors in this wire image reveal the significant grain misorientation), at liquid-helium temperatures they can carry a higher current density in strong fields than cuprate tapes. The wires open up new opportunities for 20- to 30-tesla magnets for nuclear magnetic resonance spectrometry and other applications, from physics labs to particle accelerators. The incorporation of similar improvements into YBCO wires could yield a transformational technology for helium-free high-field magnets. (D. Larbalestier et al., *Nat. Mater.* **13**, 375, 2014.) —RJF

Fewer large waves for eastern Australia. For about 36 days each year, Australia's east coast is battered by storms whose waves top 4 meters. That average rate, which pertains to 1992–2010, was derived from meteorological data. How the number of such storms could change as Earth's climate warms is the subject of a new computational study led by Andrew Dowdy of Australia's Bureau of Meteorology. Because climate models do not directly predict wave activity, Dowdy first had to identify a proxy. Large waves on the east coast are typically caused by midlatitude cyclones (like the example in the figure) that develop over the Pacific Ocean. Dowdy found that the occurrence of large waves is strongly related to the curvature of the region's atmospheric pressure contours—specifically, of the height above mean sea level at which the pressure is 500 hectopascals (0.49 atm). He and his team ran 18 different models for the years 2006–2100 under two scenarios: By 2100, greenhouse gas concentrations could be about 50% higher than today (the realistic scenario) or risen to about three times the current levels (the pessimistic scenario). All the models predicted a decrease in the annual number of large-wave days. For the realistic scenario, the all-

model average fell to 27 days by the year 2100; for the pessimistic scenario, it fell by 2100 to 22 days. The physical origin of the decrease is uncertain, as is the likely economic impact. On the one hand, large waves exacerbate the damage caused by rising sea levels. On the other, the waves attract money-spending surfers. (A. J. Dowdy et al., *Nat. Clim. Change* **4**, 283, 2014.) —CD ■