A 50-foot robot called "Family of Explorers" won the Crown City Innovation Award at the 2005 Rose Parade. A joint entry of the Jet Propulsion Lab and Caltech, the float incorporated floral likenesses of the Cassini probe to Saturn; the Stardust comet sample-return mission; the Jason oceanography satellite; the Genesis solar-wind sample-return mission; the Galaxy Evolution Explorer (GALEX) ultraviolet space telescope; the Spitzer Space Telescope, which sees the cosmos in the infrared; the Gravity Recovery and Climate Experiment (GRACE), whose tandem orbiters map Earth's gravitational field; and the indefatigable Mars Exploration Rovers, Spirit and Opportunity. Can you spot them all?

A JPL/Caltech committee solicited design ideas from the Lab and from campus. The float was built by the Phoenix Decorating Company, and was decorated by hundreds of volunteers from the JPL and Caltech communities and several local high schools. Caltech, which manages JPL for NASA, funded the construction.

Thom Mayne to Design Cahill Center

Internationally recognized architect Thom Mayne and his firm, Morphosis, based in Santa Monica, have been chosen to design the Cahill Center for Astronomy and Astrophysics, which will house the astronomers, astrophysicists, and theorists who now work in several campus buildings. Mayne has received 52 awards from the American Institute of Architects, and his recent works include the Caltrans District 7 headquarters in downtown Los Angeles. Called the next Frank Gehry by some, he is known for visually impressive structures that integrate themselves into their surroundings.

The roughly 100,000-square-foot Cahill Center will join the Keith Spalding building on the south side of California Boulevard, north of the athletic fields. The facility will have five floors, two of them underground, and will contain offices, laboratories, remote observing rooms, conference rooms, a library, an auditorium, and classrooms. The design is expected to be completed this spring and, in the words of Caltech president David Baltimore, "will provide the campus and Pasadena with a highly visible icon." □

Crystal Power

"Californians are notorious for their love of crystals and their infatuation with computers," says Erik Winfree, PhD '98, assistant professor of computer science and computation and neural systems (CNS). "Now we've merged these passions by creating a crystal that computes as it grows." At a molecular level, crystals are simple units in a repeating pattern—like wallpaper, or tiles on a bathroom floor. But Winfree; Paul Rothemund, a senior research fellow in CNS and computer science; and former staff scientist Nick Papadakis have designed DNA "tiles" that assemble themselves into a fractal pattern called a Sierpinski triangle, which never repeats itself and becomes more elaborate as it grows. A Sierpinski triangle can be drawn by repeatedly applying a simple mathematical rule. The researchers encoded this rule in how the tiles interlock—the first time a computation has been embedded in a crystalline form. And the crystal grows spontaneously, which is really convenient when you need to build structures one molecule at a time.

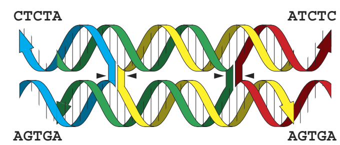
The tiles are roughly 12 by 4 nanometers, or billionths of a meter—tiny knots of DNA so arranged that at each corner of the tile is a free strand, or "sticky end," that can bind to other sticky ends. The key, says Rothemund, is that the tiles "have *programmable* sticky ends. For example, a tile with the sticky end AGGTA would bind to a tile with a sticky end TCCAT, because A binds to T and G binds to C, and not to other tiles."

Because the tiles act as a molecular version of what computer scientists call a universal Turing machine, says Winfree, in principle "this trick allows *any* computer program to be translated into a set of DNA tiles"—an idea he first advanced in his PhD thesis. The tiles, when dissolved and the solutions mixed together, precipitate out in what he calls an "algorithmic crystal." An algorithm, Rothemund explains, is a computer program in the abstract—"it has no preference for Windows over Mac." The program runs as the crystal grows, and each row in the crystal records one time-step in the program's execution. This set of "snapshots" of the computer's processor creates the crystal's pattern, he says. "If, for example, the algorithm multiplies two numbers, all of the intermediate steps with their placeholders and carry digits would be written into the pattern of tiles." Once the algorithm runs its course, the crystal stops growing, and the answer is written in the final row of tiles.

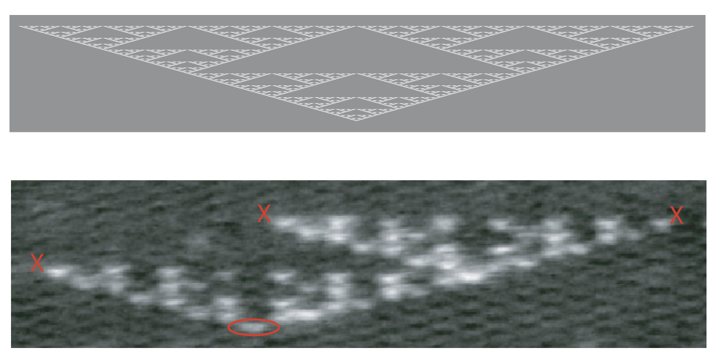
The Sierpinski triangle embodies the addition of the binary numbers 0 and 1. The tiles build the growing crystal in offset rows, like bricks in a wall. The sticky ends are engineered to make 1s find places where a 0 lies next to a 1 in the row below, and 0s bridge pairs of 0s or pairs of 1s. Shake gently, add a pinch of salt, heat to near boiling, cool, and voilà! The 1s are made twice as thick as the 0s, so the resulting pattern can be "read" by an atomic force microscope, "much as a blind person reads the raised dots of braille with a finger," says Winfree. Errors in the self-assembly process usually cause the pattern to go awry after a couple of hundred tiles, but, Rothemund says, the experiment still demonstrates "that one can think of the process of crystal design as an exercise in programming."

Winfree, Rothemund, and grad student Matt Cook have applied for a patent "for algorithmic crystals whose patterns may be used to template nanoscale circuits an order of magnitude smaller than any circuits currently made." But more importantly, Rothemund says, this work shows that algorithms are inherent in the creation of complex ordered systems such as oak trees and insects. "We believe that computation is ubiquitous in the development of biological organisms, and that the story of how algorithms lead to order in the natural world is just beginning to unfold."

Rothemund is the lead author of the paper describing this work, which appears in the December issue of the online journal *Public Library of Science (PLoS) Biology*. □—*DS*



One of the DNA tiles used to create the Sierpinski triangle. Four separate DNA strands (red, yellow, green, and blue) wind around one another; the black arrowheads show where a strand jumps from one double helix to the other. At each corner of the tile is an unpaired bit of DNA whose five-letter sequence acts as a "sticky end" to selectively bind to other tiles. The Sierpinski triangle required four different types of tile, each with a specific array of sticky ends.



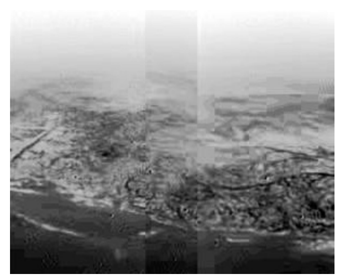
Top: A Sierpinski triangle built from a single white "1" block at the apex. Bottom: A piece of a Sierpinski triangle made from about 300 DNA tiles. The gray blobs are 0s, white blobs are 1s, and the small gaps between tiles are black. The crystal grew as rows of 0s until an error (circled) inserted a 1; three additional errors (red Xs) stopped the pattern's propagation.

Below: *NUMB3RS* may do for academia what the *CSI* franchise has done for forensic science. The new crime drama stars David Krumholtz as Charlie Eppes, a math prodigy on the faculty of CalSci, an L.A.-area university that looks a lot like Caltech. "Everything is numbers," says Charlie, who helps brother Don (Rob Morrow), an FBI agent, solve cases ranging from serial murder to bioterrorism. Series creators and head writers Cheryl Heuton and Nick Falacci are Altadena residents and Feynman fans who had long wanted to showcase the mathematical mind, but needed a tried-and-true format to sell the concept. Good call—*NUMB3RS*'s first appearance in its regular time slot pulled over 15 million viewers and was the 11th most watched show of the week. Heuton and Falacci wanted a Caltech feel, so some scenes are shot here, like this one of Charlie and string-theorist colleague Larry Fleinhardt (Peter MacNicol) walking through the Kerckhoff arcades, and Krumholtz spent several weeks on campus over the summer observing the natives. And the equations Charlie scrawls are real—Professor of Mathematics Gary Lorden (BS '62) provides the formulas and terminology. *NUMB3RS* airs Friday nights at 10:00 p.m. on CBS.

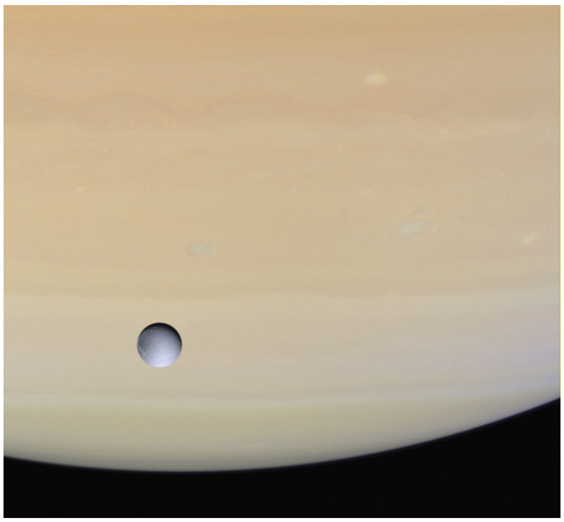
Observing the Roiling Earth

Earthquakes and continental drift are both the result of plate tectonics, but nobody knows what makes the plates move. Now, thanks to a $13 million grant from the Gordon and Betty Moore Foundation, Caltech has established the Tectonic Observatory, under Professor of Geology Jean-Philippe Avouac, to "provide a new view of how and why the earth's crust is deforming over timescales ranging from a few tens of seconds to several tens of million of years." The observatory will focus on major field studies at key plate boundaries in western North America, Sumatra, Central America, and Taiwan. (Caltech faculty have been studying these regions for decades. In fact, Kerry Sieh, the Sharp Professor of Geology, just returned from a post-quake resurvey of Sumatra. His dispatches from the field can be read at http://today.caltech.edu/today/story-display?story%5fid=5903 .)

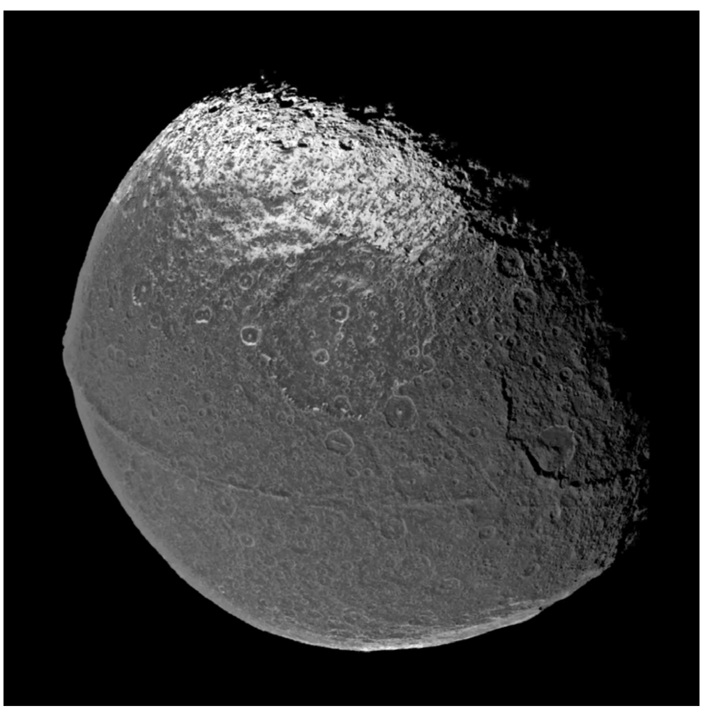
In addition to seismometers, the observatory will use GPS to measure the relative velocity of points on the earth's surface to within a few millimeters per year, satellite images to map broad displacements of the ground over time, geochemical fingerprinting methods to analyze rocks from Earth's deep interior that have been brought to the surface by volcanic eruptions or erosion, and advanced computational techniques "to allow us to develop models at the scale of the global earth," says Avouac. Deployment of a network of 50 seismometers has already begun along a major subduction zone in Mexico. □—*MW*



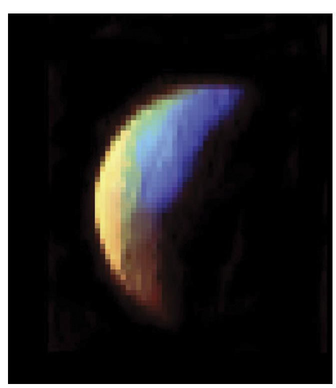
Right: JPL's Cassini gave the European Space Agency's Huygens probe a lift and relayed its signals back to Earth; Huygens landed on Saturn's moon Titan on January 14, returning data all the way down through its thick, hazy atmosphere and for 72 minutes afterward. A composite shot from eight kilometers up (top) shows what could be mistaken for the central California coast, but these hills and channels were carved by methane rain; the dark foreground is believed to be a methane-soaked, ice-crusted mudflat the consistency of crème brûlée. The approximately natural-color image from the surface (bottom) shows pebble-sized chunks of ice.



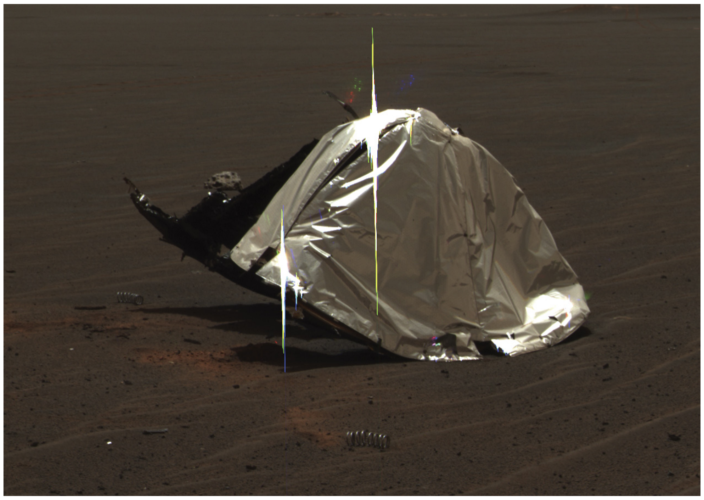
Cassini, meanwhile, continues to tour the Saturnian system, snapping this natural-color shot (left) of Dione against the parental planet en route to a flyby of that moon on December 14. Grayish Dione's most prominent features are bright, wispy streaks (above, right) that were thought to be surface deposits of some sort. But close inspection (above) showed that they're shiny cliffs of ice that have been upthrust along fractures in Dione's crust.

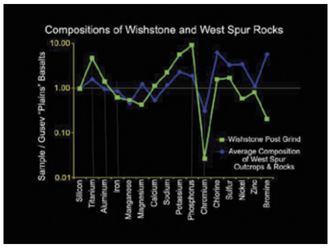


Left: Next up was Iapetus, which Cassini buzzed on New Year's Eve, discovering a feature unlike anything ever before seen in the entire solar system. For at least a quarter of the moon's circumference, a ridge some 20 kilometers wide and, where it can be seen in profile, about 13 kilometers tall runs along the equator like the seam on a cheap metal globe. Future studies may determine if Iapetus actually unscrews.



Left: In this infrared composite view, the blue region, which is bright in visible light, represents water ice. The dark brown area is rich in organics, and the yellow zone is a mixture of the two. The organic stuff coats Iapetus's leading hemisphere, making it look chocolaty to the eye, and may be swept up by the moon's orbit.



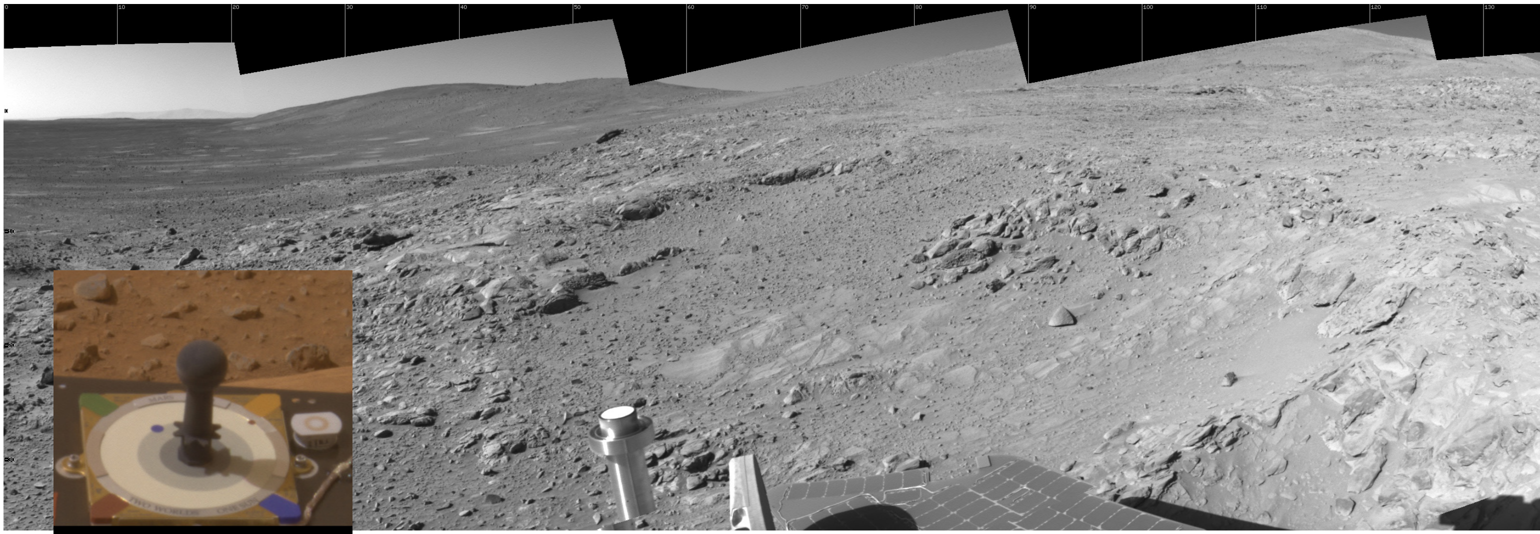


JPL's doughty Mars Exploration Rovers, Spirit and Opportunity, just celebrated their first Earth-year anniversary on the Red Planet. Opportunity is now examining its own heat shield (above), which had landed a kilometer or so away. The engineers were astonished to find the shield had actually turned itself inside out, like an umbrella in a high wind. In the background is a basketball-sized nickel-iron meteorite (left), the first ever found on another planet. If meteorites prove common on Meridiani Planum, it may mean the terrain is eroding away to expose them.

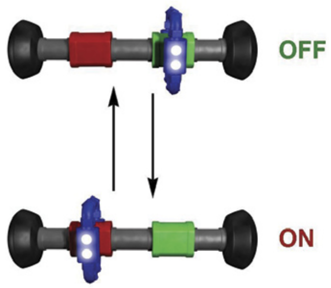
Meanwhile, Spirit continues climbing into the Columbia Hills. This 360° panorama (below) of its perch on the West Spur was shot on sol, or Martian day, 305. The graph (left) shows the ratios of elements in the hillside rocks to those in volcanic basalts from the plains, which are plotted as 1.0. The new rocks, particularly one called Wishstone, are extremely high in phosphorus, which may mean they were altered by water. Both rovers are slowly being covered by a thin layer of Martian dust—Spirit about 70 percent faster than Opportunity—as shown by the two inset photos. While this robs them of some solar power, there's plenty of life in them still.

Getting in on the Ground Floor

"There's plenty of room at the bottom," as Caltech Nobelist Richard Feynman once famously remarked in these very pages. Well, the bottom is beginning to get a little more crowded these days. Over the past decade, nanotechnology has become a hot field, and President Clinton visiting Caltech in January 2000 to announce the launching of a "National Nanotechnology Initiative" didn't hurt any. Nanotechnology, broadly speaking, includes anything from silicon micromachines made from the same stuff that computer chips are, and by the same methods; to proteins and other cellular apparatus modified for new uses; to individual molecules designed to act as electronic components, and, if you're clever, to assemble themselves into



Spirit sol 9 (Jan. 11, 2004)



Left: A rotaxane switch. In the ground, or OFF state, the blue ring sits on the green site. A positive voltage oxidizes the green site, pushing the ring to the red site, flipping the switch; adding electrons to the system restores it to its initial state. The ON state is metastable, meaning that, if left alone, it will eventually "relax" back into the ground state.

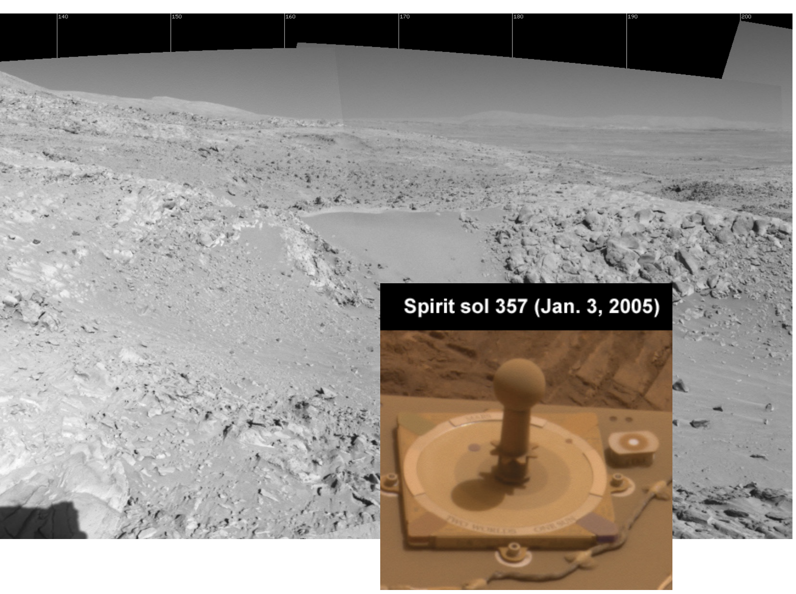
Speaking of Feynman, here he is on a postage stamp to be issued on April 5. Other prominent American scientists will be similarly honored in May—Dr. Bunsen Honeydew and Beaker appear in the series commemorating Jim Henson and the Muppets.

working circuits.

In the latter category are molecular switches developed by researchers in the labs of UCLA's Fraser Stoddart and James Heath, the Gilloon Professor and Professor of Chemistry at Caltech. The switches are based on structures called rotaxanes, invented in Stoddard's lab, in which a ring-shaped molecule slides back and forth on a molecular shaft like a washer on a bolt; in lieu of a nut, the shaft's ends bulge. A pulse of positive voltage sends the washer to one end of the shaft, turning the switch ON; a negative pulse turns it OFF by returning the washer to its original position.

Heath's lab has built a 64-bit random access memory circuit out of rotaxanes, and is working on a 16-kilobit one. These molecules work in solution, which makes chemists happy, and in the solid state, which makes engineers happy. The switches can be flipped at will even when they're deep in a layer of rubber-like material. But the speed at which they flip depends on what they're in, Stoddart says—what happens instantaneously in solution can take 10 minutes in the solid state, allowing the switches to be used as memory elements.

Some two dozen Caltech faculty are carving out niches at the bottom, and last November the Gordon and Betty Moore Foundation provided $25.4 million to establish a campuswide Nanoscale Systems Initiative, augmenting the $7.5 million grant last March from Fred Kavli and the Kavli Foundation to establish the Kavli Nanoscience Institute. Michael Roukes, professor of physics, applied physics, and bioengineering at Caltech and founding director of the initiative, says Caltech will exploit its strengths in nanophotonics and nanobiotechnology.



Nanophotonics uses the quantum interactions of light and atoms to make microlasers, optically active waveguides that can "steer" light around corners or act as switches, and other gadgets to harness photons for telecommunications and even, perhaps someday, quantum computers.

Nanobiotechnology merges inanimate objects with the molecular and cellular machinery of living systems. One of its first uses will be in the emerging field of "systems biology," which views biological systems in terms of their underlying "circuit diagrams"—mapping how signals are sent within a cell by a series of Rube Goldberg–like interactions between individual molecules, for example, or how the interplay of genes turning one another on and off causes an innocuous mole to turn cancerous. Much of this work is based on testing lots and lots of infinitesimal samples in parallel for some kind of biological activity, and with nanobiotechnology, analyses of individual cells or molecules could become routine and automatic.

And while supporting individual scientists who will continue to work the frontiers of fundamental nanoscience, the initiative will also provide centralized nanofabrication facilities that will let engineers exploit economies of scale and develop real-world nanotechnology. Says Roukes, "If we can reproducibly create new nanoscale tools, even in modest production, we'll be far ahead of the curve." Any real-world nanomajig will require the harmonious integration of many kinds of parts—sensors, electronics, readouts, control units, and mechanical pieces—and learning how to assemble all this stuff will be not unlike building a Model T from scratch. But as we get better at it, nanodevices will become as common in the lab as pH meters. And then who knows what will happen. . . . □—*DS*