2015 WORLD CHANGING IDEAS

INNOVATION

10 big advances that will improve life, transform computing and maybe even save the planet

In 1878 Thomas Edison took to the pages of this magazine to clear up a few misconceptions about a new invention of his: the phonograph. Seventy years later one of our correspondents wrote about a replacement for the vacuum tube, a device that could deliver "tinier hearing aids, really small portable radios [and] more compact electronic devices for aircraft." It was called the transistor. To celebrate our 170th birthday, we have collected dozens of historic entries like these from *Scientific American*'s past: the list starts on page 40. And as we do every December, we have gathered 10 of the year's biggest advances for our annual celebration of "World Changing Ideas." Maybe some of them will make the greatest-hits collection 170 years from now.

—The Editors

Illustrations by Tavis Coburn

Eye-Controlled Machines

Software that translates eye movement into commands to control devices could be a boon for motion-impaired people

Earlier this year when Erik Sorto, a quadriplegic man, used his thoughts to direct a robot arm to bring a beer to his lips, the media went wild. It was an impressive feat. The catch is that the technology behind it—an electrode-laden chip implanted in Sorto's brain—is expensive and invasive and often requires months of training. Worse, few paralyzed people have the psychological and physical profile the technology requires.

There could be a better way. Rather than creating a direct link between the brain's electrical activity and machines, Aldo Faisal, an associate professor of neurotechnology at Imperial College London, wants to use eye movements to control wheelchairs, computers and video games. With off-the-shelf video-game cameras, Faisal and his colleagues built goggles that record the user's eye movements and feed those data to a computer. Software then translates the data into machine commands. Almost anyone can use the technology, including amputees, quadriplegics and those suffering from Parkinson's disease, multiple sclerosis or muscular dystrophy. The system costs less than $50 to build. At a science exhibition, the vast majority of thousands of volunteers grasped the technology well enough after 15 seconds to play the game Pong, no instructions needed.

Scientists have long known that the eyes can reveal people's objectives—where they want to go, what they want to do, who they want to interact with. Drawing on 70 years of research into the neuroscience of eye movements, Faisal and his colleagues wrote algorithms that turn a glance into a command for a wheelchair, a wink into a mouse click or the dart of a pupil into the swing of a game paddle. To predict intention, the algorithms depend on training from real-world data, acquired by recording volunteers' eyes as they drove a wheelchair with a joystick or operated a robotic arm. Gradually the software learned to tell the difference between, for example, the way people look at a cup when they are evaluating its contents and when they want to pick it up and take a drink.

Before Faisal can commercialize any medical devices based on the invention, he must secure funding for clinical trials. In the meantime, a €4-million grant from the European Union will support his group as it develops robotic exoskeletons that paralyzed people could control using the eye-tracking software it developed. "I want to see what I can do to help people move again," Faisal says. "That's my focus." *—Rachel Nuwer*

Microwave Rocketry

Beamed power could create a low-cost paradigm for access to space

Humans have been riding rockets into space for more than 50 years, and for all that time, the cost of reaching orbit has remained astronomical—$5,000 to $50,000 per kilogram, depending on which rocket is used. The problem is that *none* of our rockets is very efficient. About 90 percent of a rocket's weight is fuel and propellant, leaving little room for payload. If it could lose some of that weight, a rocket could lift more cargo, reducing the cost of putting a given kilogram of stuff into orbit.

In 1924 Russian scientist Konstantin Tsiolkovsky proposed a way to make this happen, suggesting that beams of microwaves from ground-based transmitters could power a rocket's ascent. Tsiolkovsky proposed using parabolic mirrors to aim "a parallel beam of electromagnetic rays of short wavelength" at the belly of a rocket, heating propellant to produce thrust without the need for large amounts of onboard fuel. This, he wrote, was the most attractive method available "to acquire cosmic velocity." The idea languished until recently, when technology finally caught up with Tsiolkovsky's vision. Microwave lasers—masers—were invented in the 1950s, but it was not until the advent of better, more affordable generators called gyrotrons that masers could reach the megawatt-scale power levels required for space launches. Recent advances in batteries and other energy-storage systems have also made it possible to power sufficiently large gyrotrons without straining the electrical grid.

Today researchers around the world are investigating the concept, including Kevin Parkin, who led a pioneering study in 2012 while at the California Institute of Technology. Based in part on Parkin's work, one private company, Escape Dynamics, is now conducting tests to develop a microwave-powered, reusable system that could launch satellites—and eventually humans. NASA is taking notice: in July the agency added beamed rocketry to its road map for future technology development. —*Lee Billings*

The problem is that *none* of the rockets we use today is very efficient.

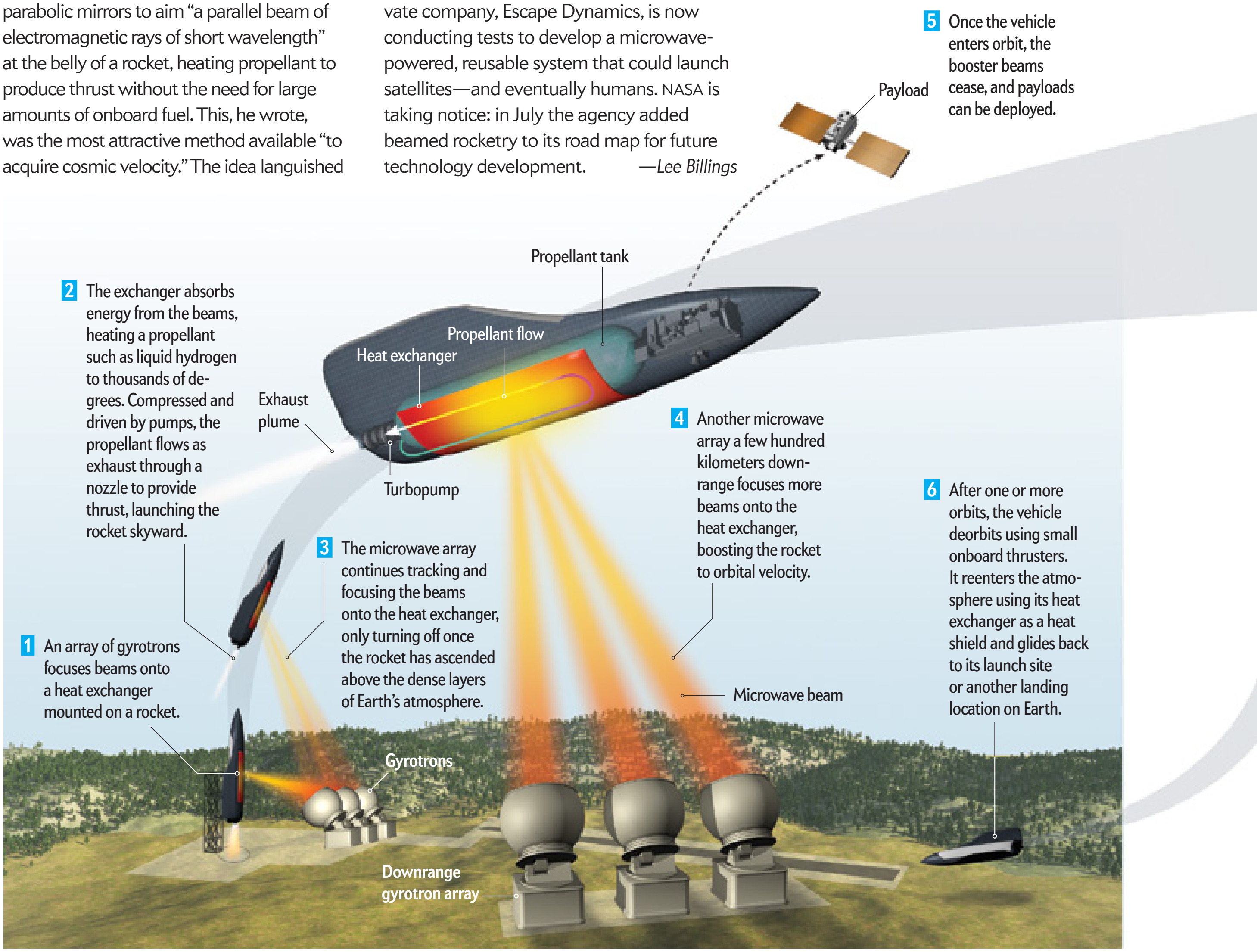


Illustration by Don Foley

Soft, Injectable Electronic Probes for the Brain

Conductive polymer mesh could be a boon to brain research

To solve the mysteries of the brain, scientists need to delicately, precisely monitor neurons in living subjects. Brain probes, however, have generally been brute-force instruments. A team at Harvard University led by chemist Charles Lieber hopes that silky soft polymer mesh implants will change this situation. So far the researchers have tested the mesh, which is embedded with electronic sensors, in living mice. Once it has been proved safe, it could be used in people to study how cognition arises from the action of individual neurons and to treat diseases such as Parkinson's. —*Seth Fletcher*

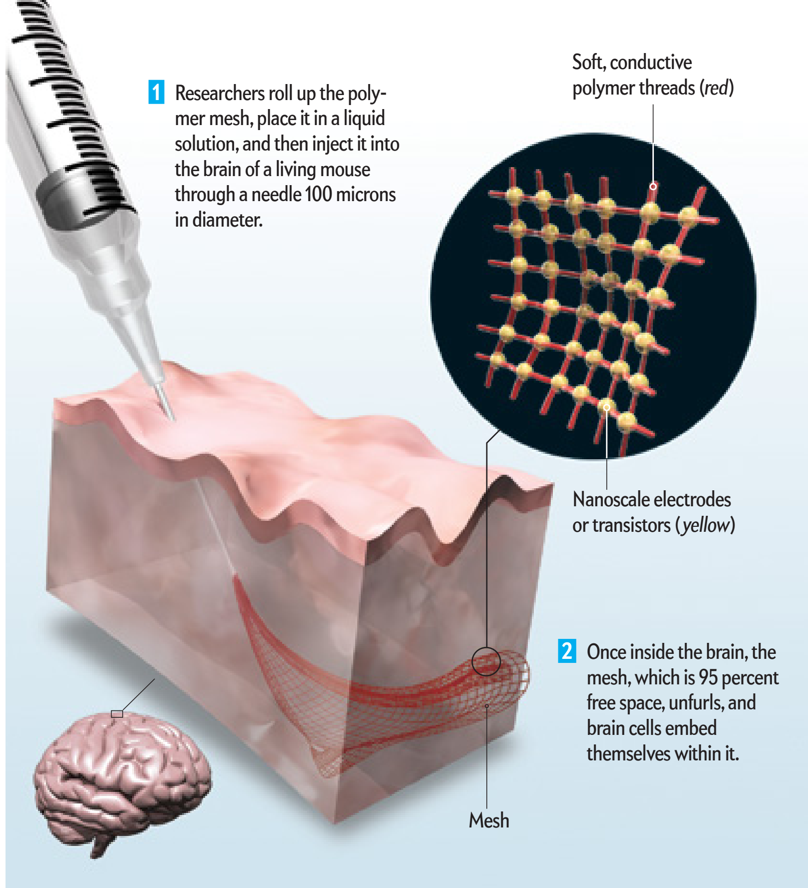
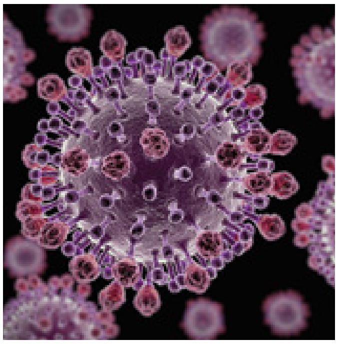


Illustration by Don Foley



H1N1 INFLUENZA is one of many viruses snared by a single new test.

Trawling for Viruses

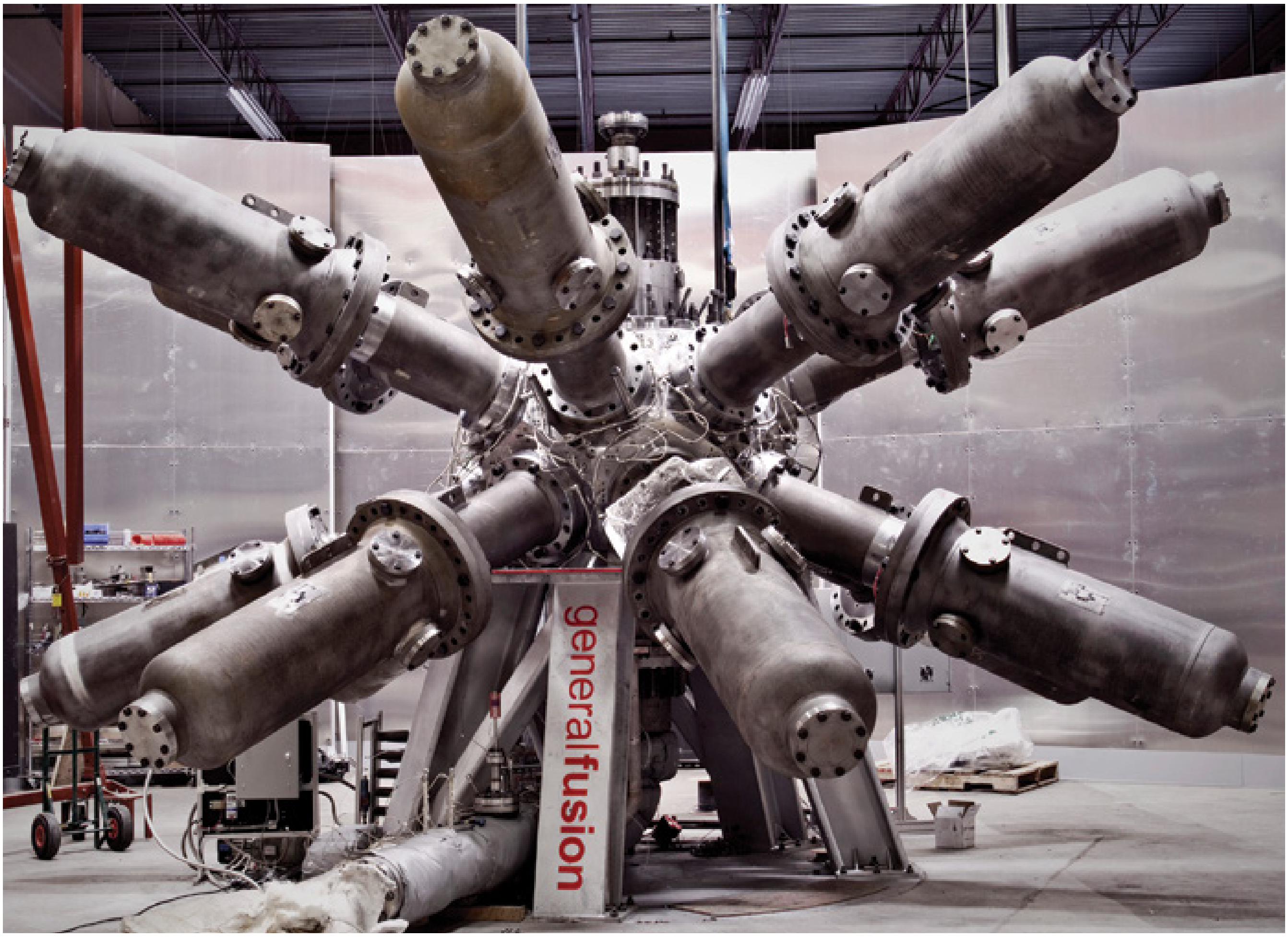
A new method identifies every virus in a given sample with near-perfect accuracy

When doctors want to identify the virus behind an infection, they usually turn to the polymerase chain reaction (PCR), a method for "amplifying" scattered bits of DNA into a sample large enough to study. To use PCR, however, a physician must know what kind of virus to look for, and that involves guesswork.

This past September a team of Columbia University researchers described a new method that could eliminate that guesswork. The technique, which has the unfortunate name of "virome capture sequencing platform for vertebrate viruses," or VirCapSeq-VERT, can find every virus in a given drop of saliva, tissue or spinal fluid with near-perfect accuracy. The method makes it possible to simultaneously analyze 21 samples in less than 48 hours at an estimated cost of just $200 per sample. It can also detect novel or mutated viruses, so long as they are at least 40 percent identical to known ones. "When someone goes into an emergency room and winds up having all kinds of tests run, it costs thousands of dollars," says W. Ian Lipkin, John Snow Professor of Epidemiology at Columbia University's Mailman School of Public Health. "This method is very inexpensive and allows us to personalize medicine by telling you exactly what you have."

To develop the technique, Lipkin and his colleagues first created a database of more than 1,000 vertebrate viruses. Then they synthesized genetic probes to match every strain of every virus—two million of them, each a strand of DNA 25 to 50 nanometers long. When a probe encounters a matching virus, it binds to it. To extract those viruses, laboratory workers add magnetic beads measuring one to three microns in diameter to the mix; a chemical linker binds the beads to the genetic probes and the viruses they have captured. Researchers then insert a tube containing the mixture into a magnet stand, which pulls the probes to the tube's walls. After researchers isolate and wash the probe-bead-virus combos, they genetically sequence the viruses, eliminating the risk of false positives. Lipkin and his colleagues are now looking to team up with a commercial provider that can distribute the technology to hospitals and clinics around the world. They are also planning on adding probes for all known infectious bacteria and fungi. —*R.N.*

SCIENCE SOURCE (*virus*)



PROTOTYPE compression system for General Fusion's reactor is seen here. The full-scale plant will use 200 pistons to compress plasma in a central sphere.

COURTESY OF GENERAL FUSION

Little Fusion

After decades of slow progress and massive investment, some fusion power researchers are changing tactics

You can accuse fusion power advocates of being overly optimistic but never of thinking small. Fusion occurs when two elements combine, or "fuse," together to form a new, third element, converting matter to energy. It is the process that powers the sun, and the fusion world's marquee projects are accordingly grand. Consider the International Thermonuclear Experimental Reactor (ITER), which a consortium of seven nations is building in France. This $21-billion tokomak reactor will use superconducting magnets to create plasma hot and dense enough to achieve fusion. When finished, ITER will weigh 23,000 metric tons, three times the weight of the Eiffel Tower. The National Ignition Facility (NIF), its main competitor, is equally complex: it fires 192 lasers at a fuel pellet until it is subjected to temperatures of 50 million degrees Celsius and pressures of 150 billion atmospheres.

Despite all this, a working fusion power plant based on ITER or NIF remains decades away. A new crop of researchers are pursuing a different strategy: going small. This year the U.S. Advanced Research Projects Agency–Energy invested nearly $30 million in nine smaller projects aimed at affordable fusion through a program called Accelerating Low-Cost Plasma Heating and Assembly (ALPHA). One representative project, run by Tustin, Calif.–based company Magneto-Inertial Fusion Technologies, is designed to "pinch" a plasma with an electric current until it compresses itself enough induce fusion. The approach has pedigree: scientists at Los Alamos National Laboratory used the pinch technique in 1958 to create the first sustained fusion reaction in a laboratory.

Companies unaffiliated with the ALPHA project are also working on alternative fusion schemes. British Columbia–based General Fusion has built a device that uses shock waves propagating through liquid metal to induce fusion. Tri Alpha Energy is building a colliding beam fusion reactor, a device just 23 meters long that fires charged particles at one another. And defense giant Lockheed Martin has claimed to be working on a magnetic fusion reactor the size of a shipping container that will be commercially available within a decade.

Fusion's track record suggests that these projects should be viewed skeptically. Yet if any of these approaches succeeds in delivering clean, abundant power with no radioactive waste, it could solve ills ranging from energy poverty to climate change with a single innovation. —*David Biello*

2015
WORLDCHANGINGIDEAS

Kill Switches for GMOs

A genetic kill switch could prevent industrial espionage and environmental contamination

Untold numbers of genetically modified *Escherichia coli* bacteria live in vats around the world, churning out useful things such as medical insulin, plastic polymers and food additives. When the reprogrammed bugs have served their role, they are packed away as industrial waste or repurposed for fertilizer.

This arrangement currently poses little environmental risk because genetically modified *E. coli* is weak compared with its wild cousins; it would not survive for long outside the lab. But engineered bugs not yet invented might go where they are not wanted and create risks. What if, say, an accident released more resilient engineered bugs that took over a well-balanced ecosystem? Or if tweaked bacteria shared modifications such as antibiotic resistance with their counterparts in nature through horizontal gene transfer? Or if a rival firm stole a patented bacterium for the trade secrets encoded in its DNA? Scientists are developing fail-safes for such contingencies.

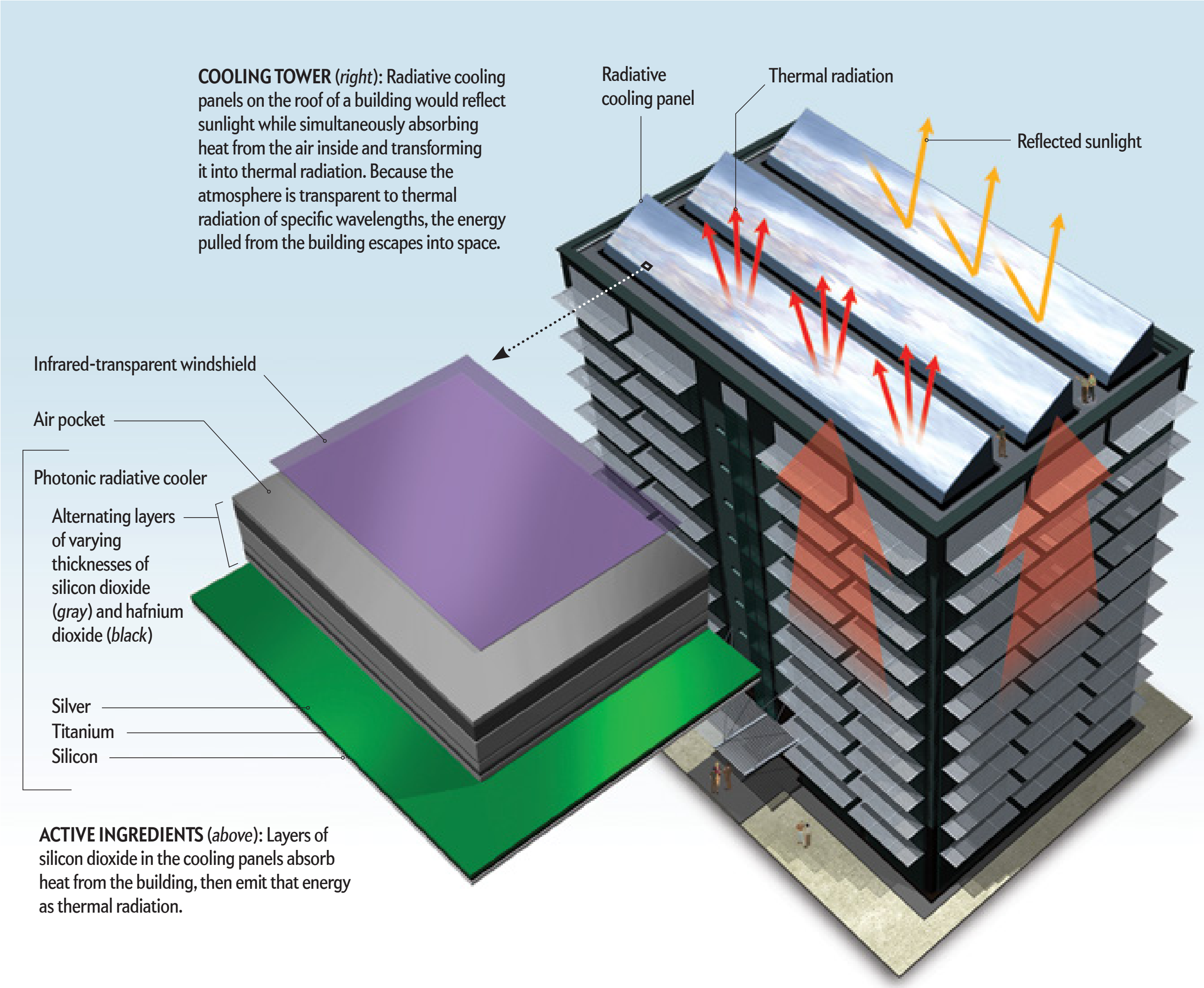
In 2009 Brian Caliando, a bioengineer then at the University of California, San Francisco, began working on a way to ensure that a genetically modified organism's engineered DNA could be destroyed before a bug could escape or be stolen. He had recently read about CRISPR, a newly discovered defense tactic bacteria use to cut up and destroy DNA from invading viruses, and realized that he could use it like a built-in kill switch for genetically modified bacteria.

Caliando, under Christopher Voigt, first at U.C.S.F. and then at the Massachusetts Institute of Technology, developed DNAi, a CRISPR-based system that compels bacteria to chop up their own modified DNA. Using CRISPR, Caliando programmed plasmids—tiny circles of autonomously replicating DNA—to code for the RNA bases and enzymes that form the kill switch. He then inserted those plasmids into genetically modified *E. coli,* where they boot up and infect the bacteria with their deadly program. Adding a sugar called arabinose to the vat throws the kill switch, and the DNAi device begins slicing up the bacteria's genetically modified DNA.

Caliando's work, published in *Nature Communications* this year, is a proof of concept. The same principles could be adapted to fit a variety of organisms and conditions. For example, he says, DNAi could prevent genetically modified organisms from cross-pollinating nearby fields. —*Jennifer Abbasi*

Genetically engineered bugs not yet invented might go where they are not wanted. Scientists are developing fail-safes for such contingencies.

SCIENTIFIC AMERICAN ONLINE For more on this year's "World Changing Ideas," go to ScientificAmerican.com/dec2015/world-changing



The Heat Vacuum

A multipurpose mirror sucks up heat and beams it into outer space

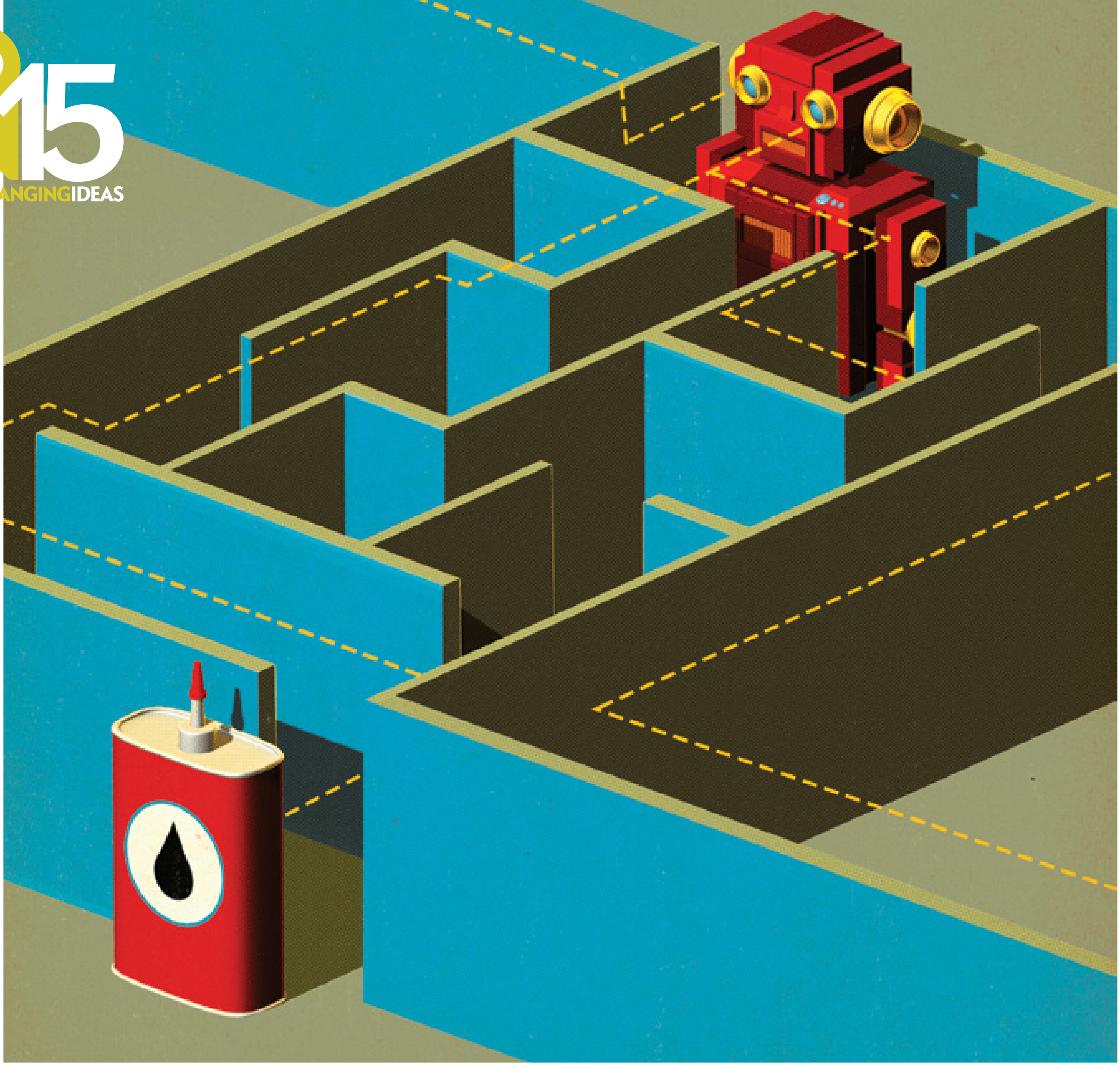
Air-conditioning accounts for nearly 15 percent of building energy use in the U.S. today. The number of days with record heat could soar in the coming decades. These two facts present a difficult problem: In a warming world, how can we cool our homes and workplaces while reducing energy use?

Researchers at Stanford University say part of the solution is a material that sucks heat from sun-drenched buildings and radiates it into outer space. The basic concept, known as radiative cooling, originated in the 1980s, when engineers found that certain types of painted-metal roofing pulled heat from buildings and radiated it in wavelengths that pass through the earth's atmosphere unimpeded. Radiative cooling never worked during the day, however, because no one had made a material that both radiates thermal energy and reflects sunlight. Reflection is critical: if a material absorbs sunlight, heat from the sun negates any cooling that thermal radiation might achieve.

To solve the problem, the Stanford team created what amounts to a very effective mirror. In trials on the roof of its lab, the material, made of layers of hafnium dioxide and silicon dioxide on a base of silver, titanium and silicon, reflected 97 percent of sunlight. The silicon dioxide atoms behave like tiny antennas, absorbing heat from the air on one side of the panel and emitting thermal radiation on the other. The material radiates primarily at wavelengths between eight and 13 nanometers. The earth's atmosphere is transparent to these wavelengths, so rather than warming the air around the building, the heat escapes to space. Even in direct sunlight, the group's 20-centimeter-diameter wafer is about five degrees Celsius cooler than the air.

Shanhui Fan, an electrical engineer at Stanford and senior author of a 2014 *Nature* paper describing the work, imagines panels of the material covering the roofs of buildings. With its roof continually expelling heat, a building's air-conditioning can relax and consume less energy. There could be other applications. Remove the mirror component and pair the material with solar cells, for example, and it could cool the cells while allowing light to reach them, making them more efficient. "It's very interesting to think about how one could tap into this enormous thermodynamic resource that the universe as a heat sink represents," Fan says. "We're really only at the beginning of recognizing this underexplored renewable energy resource." —*R.N.*

Illustration by Don Foley



Machines That Teach Themselves

Deep-learning technology is helping A.I. fulfill its promise

Google, Facebook and other corporate giants are taking major strides in building technology that can learn on its own. Their efforts rely heavily on something known as deep learning.

Rooted in the decades-old idea that computers would be smarter if they operated more like the human brain, deep-learning networks consist of layer on layer of connected computer processing units called artificial neurons, each of which performs a different operation on the input at hand—say, an image to be classified. The difference between conventional neural networks and deep-learning ones is that the latter have many more layers. The deeper the network—the more layers—the higher the level of abstraction at which it can operate.

Deep learning gained momentum in the mid-2000s through the work of three key figures—Geoffrey Hinton of the University of Toronto, Yoshua Bengio of the University of Montreal and Yann LeCun of New York University—but it only recently began making commercial inroads. An example is the Google Photos app, which came out in May. The software can upload all the images from my iPhone, correctly identify my wife, son and grandson, and then dump their photographs in separate digital bins marked by thumbnail images. It can do this because it has learned to recognize faces through exposure to millions of images analyzed by the system. As it runs an image through each successive layer of its network, the software identifies elements within the image at an increasing level of abstraction—until it ultimately can detect the whole face within the picture.

Once it has trained on enough faces, it can spot the noses and mouths of individual people in images it has never seen before.

Deep learning can do much more than organize pictures. It may, in fact, mark a step toward artificial intelligence that exhibits intelligent behaviors virtually indistinguishable from those of its human masters. In February a team of A.I. experts from the London-based firm DeepMind (which Google bought in 2014 for $617 million) reported that it had used deep learning to build a computer that could teach itself to play dozens of Atari video games. After a lot of practice, the software beat expert human players at half of those games. A small step, but the machine age has to start somewhere. *—Gary Stix*

Slow-Motion Cameras for Chemical Reactions

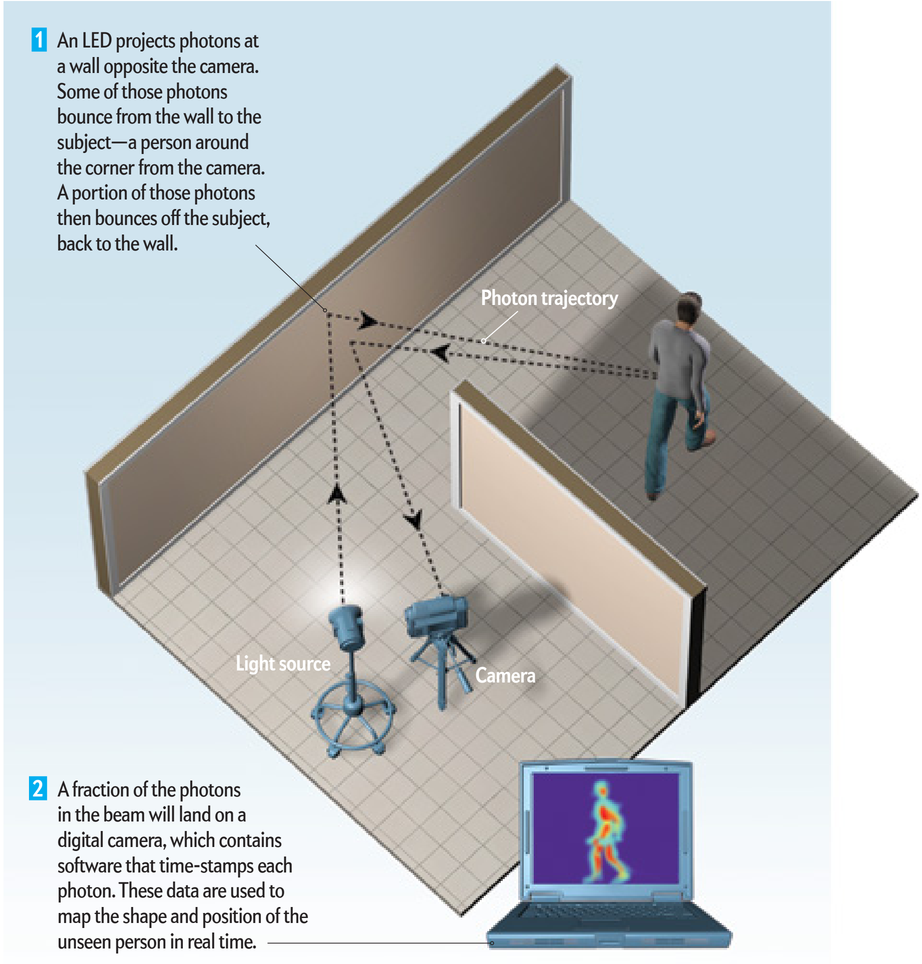
Infrared spectroscopy and computer simulations reveal the hidden world of solvent-solute interactions

The hydrogen bonds that hold together the molecular base pairs of our DNA form in intracellular fluid. Much of our planet's environmental chemistry occurs in oceans and other bodies of water. Most drugs are synthesized in solvents. Yet chemists generally study the bond-by-bond mechanics of chemical reactions only in the gas phase, where molecules are relatively sparse and easy to track. In a liquid there are more molecules and more collisions among them, so reactions are fast, messy and complicated. The process you want to observe will look like an undifferentiated blur—unless, that is, you can take snapshots of the reaction in a few trillionths of a second.

Andrew Orr-Ewing, a chemist at the University of Bristol in England, uses lasers to study chemical reactions. He knew that reactions in liquid catalyzed by heat create vibrations that can be observed in the infrared spectrum. In experiments conducted between 2012 and 2014, Orr-Ewing and then Bristol doctoral student Greg Dunning shot an ultrafast ultraviolet pulse at xenon difluoride molecules in a solvent called acetonitrile. The laser pulse acted like a scalpel, carving off highly reactive fluorine atoms, which in turn stole deuterium atoms from the solvent molecules, forming deuterium fluoride. The speed with which the telltale infrared vibrations appeared and then vanished after the first laser pulse—observed using a standard technique called infrared spectroscopy—revealed how quickly bonds formed between atoms and how quickly the reaction reached equilibrium.

The experiments were a proof of concept for observing the split-picosecond details of reactions in liquids. Most chemists, however, use computer simulations to observe and refine chemical reactions instead of expensive lasers and detectors. For them, Orr-Ewing's Bristol colleagues David Glowacki and Jeremy Harvey wrote simulation software that predicted the results of Orr-Ewing's spectroscopy experiments with an extraordinary level of accuracy. "We can use these simulations to peer more deeply into what's going on," Orr-Ewing says, "because they tell us more precise information than we can get from the experiments."

Together the experiments and simulations provide the best insights so far into how a chemical reaction actually happens in a liquid. Developers are already starting to incorporate the team's methods into computer simulations for academic and industrial use, which could benefit scientists doing disease research, drug development and ecological studies. *—J.A.*

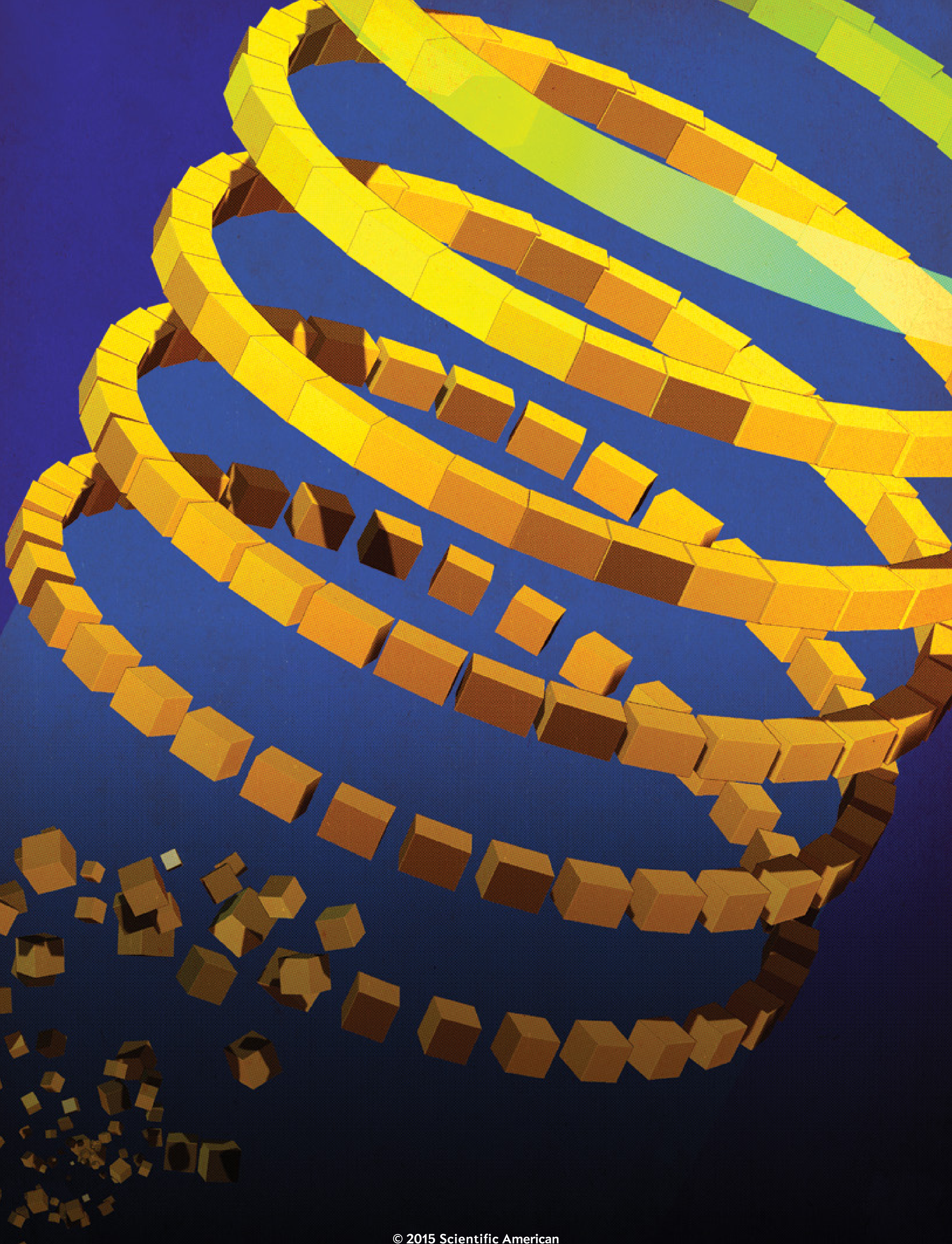


Seeing around Corners

Bouncing photons let cameras see beyond the line of sight

If cameras could see around corners, they could warn drivers of danger waiting around the bend, help firefighters search burning buildings and enable surgeons to see hard-to-reach areas inside the body. A few years ago researchers at the Massachusetts Institute of Technology's Media Lab figured out how to build such a camera, but it was an expensive early prototype. The device used a laser pulse to bounce light from a wall or door onto a stationary object in the next room. A $500,000 camera then recorded the light that bounced back, and software recorded the arrival time of individual photons, calculated distances and reconstructed the unseen object. Since then, the M.I.T. team has improved the technology significantly. Now it can record moving objects beyond the line of sight, and instead of a laser and a $500,000 camera, an LED and a $100 Microsoft Kinect sensor will do. *—Larry Greenemeier*

Illustration by Don Foley



INVENTING THE WORLD

1845

INNOVATION

Scientific American came out 170 years ago celebrating the individual tinkerer and wound up bearing witness to major technological upheaveals in the nation and the world

By Daniel J. Kevles

Rufus Porter lived through a remarkable technological transformation. When he was born, in 1792, Americans traveled overland by foot and horse, communicated by hand-carried letters and resorted to being bled when ill. Fifteen years later Robert Fulton's paddle-wheel steamboat began transporting people up the Hudson from New York City to Albany. By the time Porter published the first issue of *Scientific American* magazine on Thursday, August 28, 1845, steam engines were driving the nation's burgeoning factories, mines and mills, and steam-powered railroads were transporting goods and people across

Illustration by Tavis Coburn

land at breathtaking speeds. “Superbly splendid long cars,” Porter wrote, could carry from 60 to 80 passengers in safety, comfort and convenience “while flying at the rate of 30 or 40 miles per hour.”

Porter, the son of a well-to-do New England family, had galloped through careers as a landscape artist and inventor; he edited *Scientific American* for only two years. That was enough, however, to fashion it into an organ of technical prophecy. For 170 years *Scientific American* has chronicled the astonishing advances in science and technology and frequently offered commentary on how these advances might transform the ways Americans live and work.

Porter was farsighted in founding a magazine that celebrated science and technology. In the 1870s the nation began running out of new arable land for settlement beyond its western fronti er. Science and technology offered new frontiers to conquer. At the time, game-changing technologies came mainly from individual inventors such as Fulton or Samuel F. B. Morse, the progenitor of the telegraph. Yet the process of invention was itself going through an important transformation. During the half a century that began in the late 1870s, industrial research facilities such as the Bell Telephone Laboratories rose in prominence, exploiting the rich potential of physics and chemistry and overshadowing the industrial development by even the era’s founding inventors, such as Henry Ford. They increasingly provided the big breakthroughs that were changing American life—principally in electrical, chemical and automotive technologies.

The Second World War ushered in a new transformation. Beginning in the 1940s, the federal government began to fuel much of the nation’s scientific and technological development through grants and contracts in support of research and training, vastly enlarging opportunities for technical careers and accelerating the pace of innovation. Public and private investment together produced antibiotics and vaccines, transistorized electronics, as well as digital computers, and promised cheap nuclear power.

The rise of the personal-computer and biotechnology industries in the 1970s expressed a reinvigoration of private small-scale innovation. Entrepreneurs were encouraged by the promotion of free-market capitalism, governmental policies that fostered economic deregulation, tax write-offs for research, the patenting of living organisms and vital software, and the transfer from universities to small business of useful knowledge gained with federal research support. Innovators spawned high-tech start-ups in Silicon Valley and elsewhere, which played an outsized role in reshaping the technology landscape. They brought new technologies, such as the now ubiquitous microprocessor, to the marketplace with startling speed. Handsomely funded federal agencies, such as the National Institutes of Health, pushed advances in molecular biology and genomics, stimulating dramatic changes in the diagnosis and treatment of disease.

To appreciate the sweep and magnitude of the changes, I have imagined what each period would seem like through the eyes of a few curious observers. We start with Aurora, a teenager in the 1870s and a grandmother in the 1930s, reflecting on the vast changes in American life with her young grandson Michael. We will also follow Michael, from his boyhood during World War II to his grandfatherly years in 1970s, and his grandson Joel, our contemporary.

Daniel J. Kevles writes about science and technology in American society, past and present. His books include *The Physicists* (1978), *In the Name of Eugenics* (1985) and, as a co-author, *Inventing America: A History of the United States* (2006).

IN BRIEF

When the first issue of *Scientific American* magazine was published in 1845, steam engines were driving the nation’s burgeoning factories, mines and mills, and steam-powered locomotives were transporting goods and people overland on railroads at astonishing speeds.

Industrial research laboratories rose to exploit possibilities in physics and chemistry in the late 1800s and government facilities after World War II. In the 1970s entrepreneurs got into the action with microprocessors.

Although technology has had its critics, Americans for the most part have not dissented from the advances that have transformed society many times over.

170 YEARS OF SCIENTIFIC AMERICAN

Since 1845, *Scientific American* has chronicled ideas and inventions that have changed the world. On the following pages, we present highlights from our archives on evolution, the cosmos, the brain and other topics, including a few written for us by our 155 Nobel Prize–winning authors.

N Indicates a Nobel award winner who wrote for *Scientific American*

EARTH & ENVIRONMENT

Scientists blow the whistle on human activities that threaten our food supply, our atmosphere and our future—and offer solutions

1968 PANGAEA

Citing convincing data from the young field of plate tectonics, Patrick Hurley maintains that the present continents were indeed once assembled into two great landmasses, called Gondwanaland in the south and Laurasia in the north.

2001 KATRINA FORESHADOW

Editor Mark Fischetti presents climate models and maps that show that a large hurricane crossing the Gulf of Mexico would drown New Orleans under many feet of water. Four years later, unfortunately, Hurricane Katrina does just that.

1946 DDT

Sixteen years before Rachel Carson's famous book, *Silent Spring,* prompts investigations that lead to a ban on the pesticide DDT, D. H. Killiffer writes an article entitled "Is DDT Poisonous?"

1953 Earthquakes

The Amateur Scientist column, which ran from 1952 to 2001, told readers each month how to investigate scientific phenomena on their own while using the latest technology or methods. The June 1953 edition shows how to run an electronic seismometer.

1990 Worldview

Al Gore, a senator from Tennessee, proposes that the U.S. launch a Strategic Environmental Initiative to protect the world's forests, close the ozone hole, prevent mass extinctions and keep huge quantities of carbon dioxide out of the atmosphere.

Planetary Boundaries

2010 To protect the earth from ruin, the world must stay within nine environmental limits, each given a specific measure. They include levels of ocean acidification (2.75 omega units), ozone depletion (276 Dobson units), freshwater use (4,000 cubic kilometers a year), and so on, according to Jonathan Foley and an international team.

1959 Carbon Dioxide

Long before scientists begin to publicly raise concern about global warming, Gilbert Plass writes "Carbon Dioxide and Climate," which considers the question: "How do man's activities influence the climate of the future?"

2009 SUSTAINABLE ENERGY

Mark Jacobson and Mark Delucchi calculate that wind, water and solar technologies can provide 100 percent of the world's energy by 2030. Needed are 3.8 million wind turbines, 1.7 billion rooftop solar modules, 900 hydroelectric plants, a better power distribution system, and more.

1984 NUCLEAR WINTER

Richard Turco and his co-authors, including Carl Sagan, make a case that immense clouds of smoke and dust raised by a medium-scale nuclear war could shroud the earth in a long period of darkness and cold, killing crops worldwide.

2006 Warming Wedges

Robert Socolow and Stephen Pacala draw a pie chart with seven wedges—steps that each reduce global carbon emissions by 25 billion tons. Overall, 15 technologies can be used to achieve the goals.

170 YEARS OF SCIENTIFIC AMERICAN

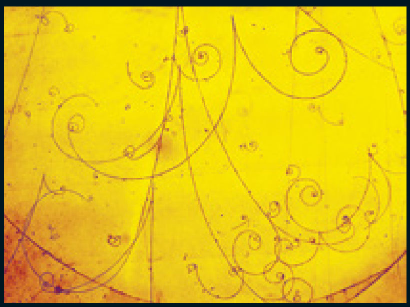
THE COSMOS

Slowly, we discover how the universe formed, how it works and how we came to be here

1956 RADIO GALAXIES
N Martin Ryle explains that radio telescopes are discovering galaxies far beyond those seen by optical telescopes and that many are colliding violently.

1925 Corona
Scientific American publishes its first color photographic cover in April 1925—an image of the sun's corona.

1956 Humans as Stardust
N In "The Origin of the Elements," William Fowler tackles a new theory that the heavier atoms on Earth were built up from hydrogen in stars.



1920
CALLING MARS
H. W. Nieman and C. Wells Nieman propose a vocabulary of dots, dashes and pictures to communicate between beings living on different planets of the solar system.

1970 FASTER THAN LIGHT
Gerald Feinberg explains why proposed particles called tachyons would comply with the theory of relativity even though they would move faster than the speed of light.

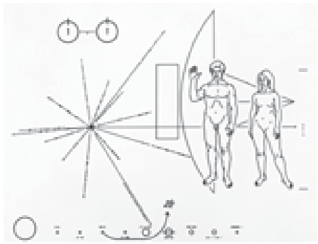
1984 Inflation
A new theory puts cosmologists on their heels: the universe is embedded in a much larger region of space that is eternally inflating.

N
2004 Dark Energy
Adam Riess co-authors an article suggesting that pinpointing when the expanding universe switched from slowdown to speedup could reveal the nature of dark energy and the ultimate fate of the universe.

1950 Einstein Unsuited
N Having transformed physics and philosophy, the most famous scientist of all time still struggled to expand his general theory of relativity. When submitting his 1950 article about that to *Scientific American,* he writes, "The article is somewhat long and not quite easy to grasp. I should, therefore, not be astonished if you find it unsuited for publication."

2003 The Multiverse
Max Tegmark says observations of space prove that we live among an infinite number of parallel universes.

1975 E.T.
Carl Sagan and Frank Drake explain in "The Search for Extraterrestrial Intelligence" how messages could be sent and received. They have little doubt that civilizations more advanced than Earth's exist elsewhere in the universe.



1976
Black Holes
Physicist Stephen Hawking has defied the odds by living and working for many years while paralyzed by ALS. In "The Quantum Mechanics of Black Holes," he also defies the accepted wisdom about black holes, observing that particles of matter could actually escape them by "tunneling" out.

LIGHT, SOUND AND MOBILITY

When Aurora visited the nation's Centennial Exhibition in Philadelphia in 1876, she took a horse-drawn coach from the train station to the exhibition. Horsepower was how people traveled locally and wherever else the railroads and steamboats did not go. Aurora raised her skirts and held her nose whenever she walked the manure-speckled streets. Her mother did the cleaning and washing by hand and kept the family food fresh in boxes cooled by ice. When her brother broke his leg, the doctor could only guess at the location of the fracture. She and her friends kept in touch mainly by postal mail, although some acquaintances sent missives via their servants. Aurora found pleasure, if she had the time, mainly in live entertainments—lectures, concerts, theater, vaudeville—and her brother especially liked the increasingly popular sport of baseball.

But Aurora knew, in part because she read *Scientific American,* that enormous changes were germinating. The year of the centennial, Alexander Graham Bell demonstrated the ability of his new telephone to convey conversations over wires. Some experts derided the invention as a toy, but the magazine's editors noted just a few years later: "Who … can have the courage … to forecast the social and commercial changes which the annihilation of time and trouble, and the doing away of forgetful or erring servants, will bring in their train? Soon it will be the rule and not the exception for business houses, indeed for the dwellings of all well-to-do people as well, to be interlocked by means of the telephone exchange."

Chemistry and electricity transformed the horseless carriage into the ubiquitous "automobile," a name that signified autonomy of movement.

One day the next year Thomas Edison walked into the magazine's offices on Park Row in New York City, set down a small contraption on a table, and, saying little, turned the crank. To the editors' astonishment, the machine said, "How do you do? How do you like the phonograph?" Edison predicted, correctly, that the phonograph would record and play the spoken texts of entire novels such as *Nicholas Nickelby* and the voices of prima donnas, prime ministers and presidents.

At the time, Edison was devoting his energies to the development of the incandescent electric light, which he first demonstrated to 3,000 people on New Year's Eve in 1879 at his pioneering industrial research lab in Menlo Park, N.J. The demonstration included a crucial element—a practical means of generating and distributing electric power. "After the electric light goes into general use, none but the extravagant will burn tallow candles," Edison was widely reported to have said. Electric lighting soon began replacing gas in streets, offices and homes. *Scientific American* detailed the advantages: it was brighter, didn't flicker, and didn't take the oxygen out of the air or load it with soot.

Through the succeeding decades the magazine's editors prognosticated on the dividends to come from the discovery of x-rays for their potential uses in medicine and the detection of contraband; the advent of the horseless carriage, which would rid cities of "the dust and mud" (the editors were too decorous to mention manure) "and noise" of horses clattering on cobblestone pavements; and the prospects of heavier-than-air flight. They failed, however, to appreciate the invention of the three-element vacuum tube in 1907, which, by generating and amplifying variable signals such as those characteristic of voice and music, would in little more than a decade turn out to be crucial in the development of electronics, including wireless communications.

By the 1930s Aurora could recognize how much electricity and chemistry had changed everyday life. Her son worked in an office lit by electricity, came home to an electrically lit house and went out to dinner in a downtown of bright lights. She and her daughter stored food in an electric refrigerator and vacuumed the floors. She dialed family and friends, who lived on the other coast, directly on the telephone, without having to go through an operator. She and her husband listened to political conventions, concerts and prizefights on the radio and watched movies in air-conditioned theaters.

Chemistry and electricity had transformed the horseless carriage into the ubiquitous "automobile," a name that signified autonomy of movement. The open touring car that sold for $1,500 in 1915 had turned into the sleek family sedan, with a $680 sticker price that included safety glass, durable paints, cushioning rubber tires and electric lights. With electric starters, Aurora no longer had to turn the crank to start the engine. Gasoline was cheap, not least because between 1910 and 1930 oil company chemists had figured out how to quadruple the volume of gasoline they could extract from a barrel of crude.

The new technologies brought out a corps of critics. The metropolis of automobiles, streetcars, loud radios and foul smells had created a cesspool of pollutions, hazardous to life, limb and sanity. With the onset of the Great Depression, some attributed the collapse to technological unemployment. During the 1930s the auto industry was engulfed in bitter, sometimes deadly labor strife that was largely of its own making.

But the industrial bet on the new frontier had paid off, generating new industries, new jobs, and a cornucopia of consumer conveniences in transportation, communications and daily life. The leaders of the auto industry could rightly say that, counting ancillary businesses such as repair shops, gas stations, and steel, paint, glass, rubber and fabric producers, their overall operations accounted for one in five or six of the country's jobs. Even in the depths of the Depression, Americans remained optimistic that science and technology would forge a better future.

Aurora herself might have enjoyed the report in *Scientific*

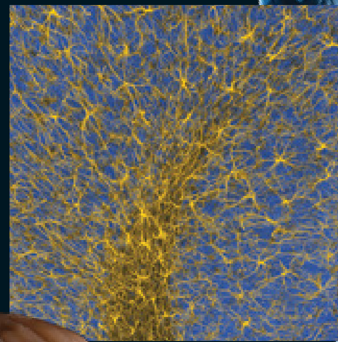
PAGES 42 AND 43:: COURTESY OF NASA/NOAA/GSFC/SUOMI NPP/VIIRS/NORMAN KURING (*Earth*); CORBIS (*DDT*); *SCIENTIFIC AMERICAN*, APRIL 1990 (*cover*); ROGER VIOLLET *Getty Images* (*nuclear blast*);
OPPOSITE PAGE: GORONWY TUDOR JONES, UNIVERSITY OF BIRMINGHAM *Science Source* (*particle tracks*); NASA AND JPL-CALTECH (*Mars and black hole*); NASA *Science Source* (*Pioneer 10 and 11 plaque*); *SCIENTIFIC AMERICAN*, APRIL 1925 (*cover*)

170 YEARS OF SCIENTIFIC AMERICAN

MIND & BRAIN

Increasingly powerful tools have revealed how thinking, memory, emotions and behavior arise, defining who we are

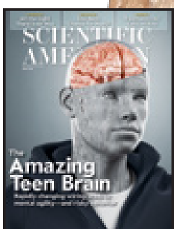
2004 GLIA
In “The Other Half of the Brain,” R. Douglas Fields claims that long-overlooked glial cells may be nearly as critical to thinking as neurons are—a view now widely accepted.



1898 EARLY YEARS

The nascent science of psychology receives this review: “The history of psychology here prior to 1880 could be set forth as briefly as the alleged chapter on snakes in a natural history of Iceland—‘There are no snakes in Iceland.’”

2015 TEEN BRAIN
Jay Giedd makes a case that the teen brain is not an old child brain or a half-baked adult brain but its own unique entity, prone to risky behavior but also capable of leaps of cognition.



1967 SPLIT BRAINS

Michael Gazzaniga reveals that the human brain’s two hemispheres can think independently and have their own consciousness.

1993 AUTISM
Uta Frith describes her pioneering work on autism in an article for *Scientific American* that is still frequently cited as a clear explanation for this enigmatic disorder.

1992 LEARNING

N Eric Kandel co-authors an article on discoveries that show that learning occurs by strengthening connections among neurons.

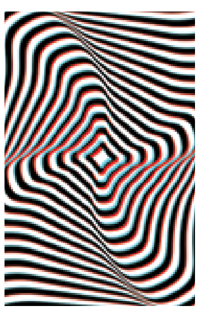
2012 FREE WILL
In a *Scientific American Mind* story, Christof Koch questions whether humans actually have free will.

2004
SA MIND
As the science of mind and brain matures, the premier issue of *Scientific American Mind* explores altruism, memory and antidepressant drugs.

1964 Hallucinogens

In the psychedelic era of Timothy Leary, *Scientific American* publishes a hard-hitting debate on whether the dangers of psychoactive drugs such as mescaline and LSD outweigh possible benefits in treating mental illness.

2010 Two psychiatrists explore whether drugs such as LSD and mescaline “can in fact help people overcome their addictions.”

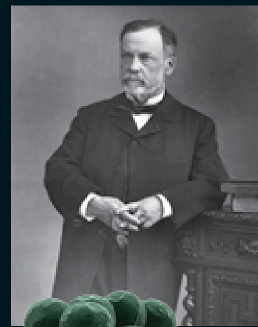


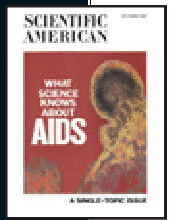
1956 FEAR AND SEX

James Olds makes a case that the brain has local seats of emotions such as fear and has centers of pleasure that can be stimulated by eating or by sex.

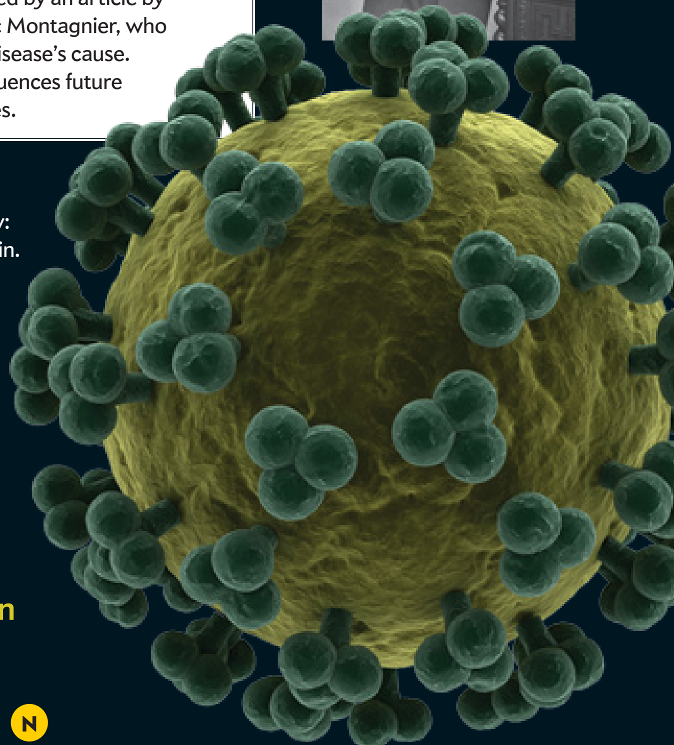
1980 CLONING
In “Monoclonal Antibodies,” Cesar Milstein explains how cloning could allow cells to live forever.

1881 VACCINATION
The magazine publishes a lecture by Louis Pasteur, “Vaccination of Animals,” which explains how immunizing animals could protect humans from contagious diseases.





1988 AIDS
Scientific American devotes an entire issue to the AIDS epidemic, led by an article by Robert Gallo and Luc Montagnier, who isolated HIV as the disease’s cause. The issue greatly influences future research into vaccines.



1961 PROTEIN FOLDING
John Kendrew reports on a major discovery: how amino acid chains fold to form a protein.

HEALTH, MEDICINE & BIOLOGY

By drilling down into the tiny building blocks of human and animal biology, science has prompted sweeping changes in how we fight illness and disease

1962 SMOKING AND CANCER
An 1848 article indicates that smoking tobacco causes “emaciation.” In 1923 the magazine says that although smoke contains poisons, it is not injurious to the mouth or throat. But in 1962 E. Cuyler Hammond writes “there is no longer any doubt” that smoking tobacco is linked to lung cancer.

1984 PRIONS
In his first of three articles for *Scientific American*, Stanley Prusiner notes that “proteinaceous infectious particles” can spread maladies such as mad cow disease without DNA or RNA. He also notes this infection pathway was “once dismissed as an impossibility.”

1976 Cancer Growth
Judah Folkman shows how tumors recruit blood vessels that help them grow. Two decades later he authors another article on how cancer can be treated by attacking its blood supply.

1955 POLIO
While waiting for field-test results of his polio vaccine, Jonas Salk argues that a killed-virus vaccine could be as effective as a live-virus vaccine—and safer.

1990 GENE THERAPY
Kary Mullis writes that he conceived the polymerase chain reaction—the process for making unlimited copies of segments of DNA—while driving along a moonlit mountain road in California, with his female chemist friend asleep in the car.

1954 DNA
Francis Crick diagrams the double-helix, base-pair structure of DNA only a few months after he, James Watson and Rosalind Franklin discover it.

2004 OUR GENETIC CODE
John Mattick makes the case that the genetic effects of RNA, more than DNA, are responsible for human evolution.

American in early 1940 that the DuPont Corporation had developed a cluster of synthetic superpolymers that it dubbed "nylon" and that could be made into woven dresses, bathing suits, underwear and stockings—all advertised as feeling smooth as silk. When Michael accompanied his grandmother to the 1939 World's Fair in New York City, he was more excited about the new high-technology miracles such as television that the exhibits promised were just around the consumer corner.

MEDICINE AND ELECTRONICS

YOUNG MICHAEL, growing up in the late 1930s, took for granted that families listened to radios and phonographs. Both appliances were big, and not always reliable, because they depended on multiple vacuum tubes, which were prone to failure. His parents knew all too well that their doctor's bag included few medicines for the treatment of infectious diseases and nothing to combat dreaded polio. They had worried during the Depression about unintentionally incurring the expense of raising another child because the birth control they used—condoms or a diaphragm—was not altogether reliable. The principal treatment for cancer was surgery; the radiation from such sources as radium or x-ray machines posed their own risks of injury. Michael's older sister worked in an office as a "computer"—processing numerical data using hand-operated adding machines. Most computers were women.

Not everyone was happy with the high-tech changes. Rachel Carson's searching and eloquent *Silent Spring* helped to stimulate a new environmental movement.

During the decade following victory in World War II in 1945, Michael learned from *Scientific American* that the wartime mobilization of science and engineering had yielded major innovations applicable to civilian life. Among the most significant was microwave radar, a system that emitted and detected echoes of ultrahigh-frequency radio pulses, tracking aircraft in the sky and revealing targets on the ground. In peacetime, the magazine rightly predicted, microwave networks could simultaneously carry "hundreds of thousands" of private phone calls and deliver "high-definition and color television" programs all over the country.

Wartime research on chemical weapons had serendipitously led to chemotherapy for certain cancers; it had a significant impact on survival rates of childhood leukemia and lymphomas. But the dramatic medical dividend of the war was penicillin, the by-product of mold. This first of many antibiotics offered an effective treatment for syphilis and other infectious diseases. By 1952 the development of other antibiotics such as streptomycin and tetracycline constituted, the magazine rightly said, a "revolution in medicine."

Research on polio had long been hindered by the inability of scientists to grow this virus except in the spinal tissue of monkeys, a scarce commodity. Yet in 1952 the magazine wrote glowingly about the achievement of scientists at Harvard University who had found a way to multiply the virus in ordinary tissue culture, a breakthrough that gave "a tremendous impetus to the study of the disease" and the development of a vaccine against it. In 1955 bells rang out across the country on the announcement that Jonas Salk's polio vaccine had been successfully tested in a nationwide trial.

The war had also given birth to the electronic digital computer. The first models contained thousands of vacuum tubes, occupied entire rooms and consumed enormous amounts of power. Reliance on these tubes was a major obstacle to increasing the complexity of what the machines could accomplish. In 1948, however, as Michael read in *Scientific American,* engineers invented a device, called a transistor, that performed the same work as tubes but was smaller and less power hungry.

By the 1970s Michael was flying around the world in jets, another spinoff of defense research, confident that radar would track his plane through its entire journey and that electronic instruments would guide it to a safe landing in bad weather.

Michael and his wife could purchase inexpensive goods for his home, including microwave ovens, plastic furniture, and clothing made of polyester that was easy to clean and resistant to shrinkage and wrinkling, not to mention moths. He did not have to worry that his grandson, Joel, might contract polio because vaccinations were widespread in the U.S. Cancer was still a dread but could often be staved off by an expanding menu of chemotherapies. His wife thought it wonderful that their daughters, one married, the other not, could use birth-control pills to divorce sexual pleasure from the risk of pregnancy.

Grandfather Michael liked to point out to Joel and his friends how much autonomy they enjoyed in listening to whatever they wanted on their transistorized portable radios and compact stereophonic record and tape players. Michael himself wore a transistorized hearing aid, unobtrusively miniature in size and powered by a long-lasting battery. He took great pleasure in joining Joel to watch live distant news and sporting events such as Wimbledon because, as *Scientific American* had predicted in 1961, communication satellites operating thousands of miles above the earth now relayed "not only telegraph and telephone messages but also television pictures ... to the farthest corner of the globe."

Yet not everyone was happy with the high-tech changes. In the 1960s Rachel Carson's searching and eloquent *Silent Spring* helped to stimulate a new environmental movement whose targets were DDT and toxics. Critics attacked computers for relegating human beings to mere entries of code to be managed by academic and industrial bureaucracies. Anger about the Vietnam War, with its use of herbicides as weapons and mass bombings from altitudes of 30,000 feet, was often directed against the scientific and technological enterprise that had produced such armaments.

PAGES 46 AND 47: ADAM VOORHES *Gallery Stock* (*brain*); THOMAS DEERINCK, NCMIR *Getty Images* (*glia*); © ISTOCK.COM (*abstract pattern*); *SCIENTIFIC AMERICAN*, JUNE 2015 (*cover*); *SCIENTIFIC AMERICAN MIND*, DECEMBER 2004 (*cover*); GETTY IMAGES (*DNA strand* and *Salk*); *SCIENTIFIC AMERICAN*, OCTOBER 1988 (*cover*); SCIENCE SOURCE (*Pasteur* and *HIV*); OPPOSITE PAGE: RYOICHI UTSUMI *Getty Images* (*phonograph*); GETTY IMAGES (*laptop*); *SCIENTIFIC AMERICAN*, SEPTEMBER 1977 (*cover*)

170 YEARS OF SCIENTIFIC AMERICAN

COMMUNICATIONS & COMPUTING

Pioneers from Bell to Berners-Lee completely change how people communicate and calculate

1845 Morse Code

On August 28 the premier issue of *Scientific American* reports that Samuel Morse's telegraph, "this wonder of the age," has successfully linked Washington and Baltimore with nearly instantaneous electrical communication.

1878 The Phonograph

Thomas Edison had walked in to the *Scientific American* offices in 1877 and for the first time in public demonstrated his phonograph, to the editors' astonishment. In his 1878 article, he clears up the misconceptions "disseminated by the press" about the technology because "the public is liable to become confused."

1985 Nuclear War

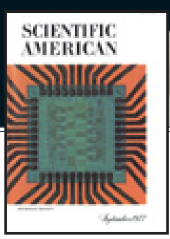
Ashton Carter, a physicist and today the U.S. secretary of defense, explains why "command and control" systems facilitated by satellites and computers may be just as important as policy in deterring nuclear weapons attacks.

1981 Supercomputers

Ronald Levine shows how radical new "supercomputers," such as the Cray-1, can solve complex scientific problems like fluid dynamics.

1977 PRESCIENCE ABOUT PORTABLES

Alan Kay, working at the famous Xerox PARC computer research center, predicts that in a decade or so, many people will possess a notebook-size computer that has the capacity of a large computer of 1977. Kay went on to key jobs at Atari, Apple, Disney and HP.



1977 Who's Who

In September 1977 *Scientific American* publishes an issue on the exploding impact of microelectronics. Articles are written by many Silicon Valley pioneers, including David Hodges (Bell Labs, U.C. Berkeley), James Meindl (Stanford), Ivan Sutherland (Caltech, Sun Microsystems) and Carver Mead (Caltech), who coined the term "Moore's law."

1887 Bell's Telephone

After describing how the ear and brain process speech, Alexander Graham Bell then explains how a selenium rheostat mimics these processes in his telephone.

2010 The Web at 20

Twenty years after inventing the World Wide Web, Tim Berners-Lee sets an agenda for protecting its fundamental principles, under attack from corporations and governments. They must prevail, he says, to make sure that anyone can access the Web and create applications for it and to protect an individual's privacy while using it.

1949 AUTOMATIC BRAINS

In a sweeping account of emerging mathematical machines—today's computers—Harry Davis notes, "Already the building and operating of automatic brains is becoming a big business. The electronic brains cost from $50,000 to $1,000,000 each, and there are eager waiting lists of customers."

2000 Computer-Generated Actors

Alvy Ray Smith, co-founder of Pixar Animation, assesses whether animators can digitally create realistic humans to star in computer-generated films.

170 YEARS OF SCIENTIFIC AMERICAN

PHYSICS & MATH

Accurately describing how the world works reveals magnificent and dangerous ways to exploit it

1985
Fractals
A. K. Dewdney delights in the brilliant geometric images called fractals, developed by IBM researcher Benoit Mandelbrot.

1910
RADIATION
N Marie Curie explains the nature of radiation in "Radioactivity" before winning the Nobel Prize in Chemistry in 1911.

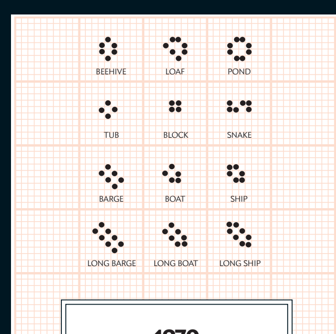
1963 INFERIOR EXPERIMENTS
N Nobel Prize winner P.A.M. Dirac explains that physics theories, seemingly stalled, must evolve; otherwise, scientists will have to rely on experiments, an inferior option.

N

1950
The Bomb
After leaving the Los Alamos defense laboratory, physicist Hans Bethe writes "The Hydrogen Bomb II," which is quickly censored by the U.S. government; the Atomic Energy Commission destroys 3,000 copies of the magazine.

2003 Neutrinos and Nobels
N In 2015 two *Scientific American* authors, Takaaki Kajita and Arthur McDonald, win the Nobel Prize in Physics for pinning down traits of the elusive neutrino particle. Related articles, written by them and co-authors, are "Detecting Massive Neutrinos" (Kajita, 1999) and "Solving the Solar Neutrino Problem" (McDonald, 2003).

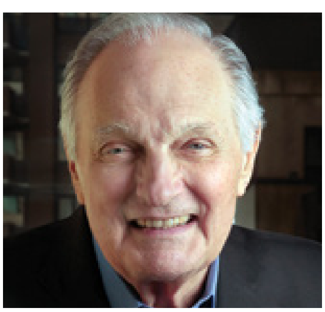
1975 No Backward for Time
In "The Arrow of Time," David Layzer asks why time never goes backward and explains why the answer lies in the conditions that prevailed during the early universe.



1970
Fun with Math
Martin Gardner's popular Mathematical Games column ran for 29 years; a game in October 1970 simulates the rise and fall of living organisms.

1979 Quantum Existence
According to Bernard d'Espagnat, quantum mechanics indicates that objects cannot exist unless they can be grasped by human consciousness.

1999
Actor Explains Cats
Alan Alda, star of television hit show *M.A.S.H.*, grapples with the physics paradox known as Schrödinger's cat. He is one of many science-interested celebrities who have appeared in our pages, including filmmaker and explorer James Cameron.

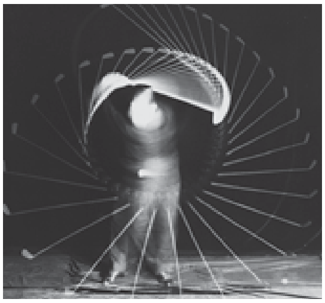


1910
Quantum Theory
N Max Planck writes that the long-prevailing "mechanical theory" of nature cannot adequately explain light and other phenomena, leading him to create quantum theory, which revolutionized physics and our understanding of matter.

Illustrations by Don Foley

1939 Strobe Photography

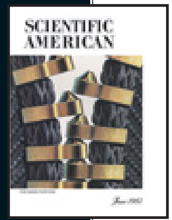
Scientific American introduces a young engineering professor from M.I.T. who creates "stop-action" photography using a strobe light. Harold "Doc" Edgerton would become famous as the man who stopped time in his photographs of bullets, milk drops and golfers.



1996

NANO CONTROVERSY

In "Waiting for Breakthroughs," editor Gary Stix takes a skeptical look at the promise of molecular machines that will "produce anything from a rocket ship to minute disease-fighting submarines that roam the bloodstream," setting off a backlash from the nanotechnology community.



1983 THE ZIPPER

Occasionally *Scientific American* publishes a complete surprise, such as "The Slide Fastener," with 10 large, beautiful illustrations showing in incredible detail the many different designs for … the zipper.

1904

INCANDESCENT LAMP

Thomas Edison writes "a brief personal narrative" of how he created the incandescent lamp, which was republished from *Electrical World and Engineer.*

1989 COMPETITIVENESS

Political economist Robert Reich, before becoming the U.S. secretary of labor under President Bill Clinton, writes that instead of relying on enormous, centralized projects to spur competitiveness, the federal government should link its research and development programs to those in corporations.

1936 ATLANTIC FLYOVER

"New York to London in 36 hours, with passengers, mail, and express!" So exclaims the first line of the article, "And Now, the Atlantic," about the debut of commercial air service across the pond.

1948 TRANSISTOR RADIO

Frank Rockett introduces the "transistor," made from solid materials, which he notes could make the vacuum tube used in most electronic equipment obsolete. The device promises "tinier hearing aids, really small portable radios, more compact electrical devices for aircraft," and more.

2007

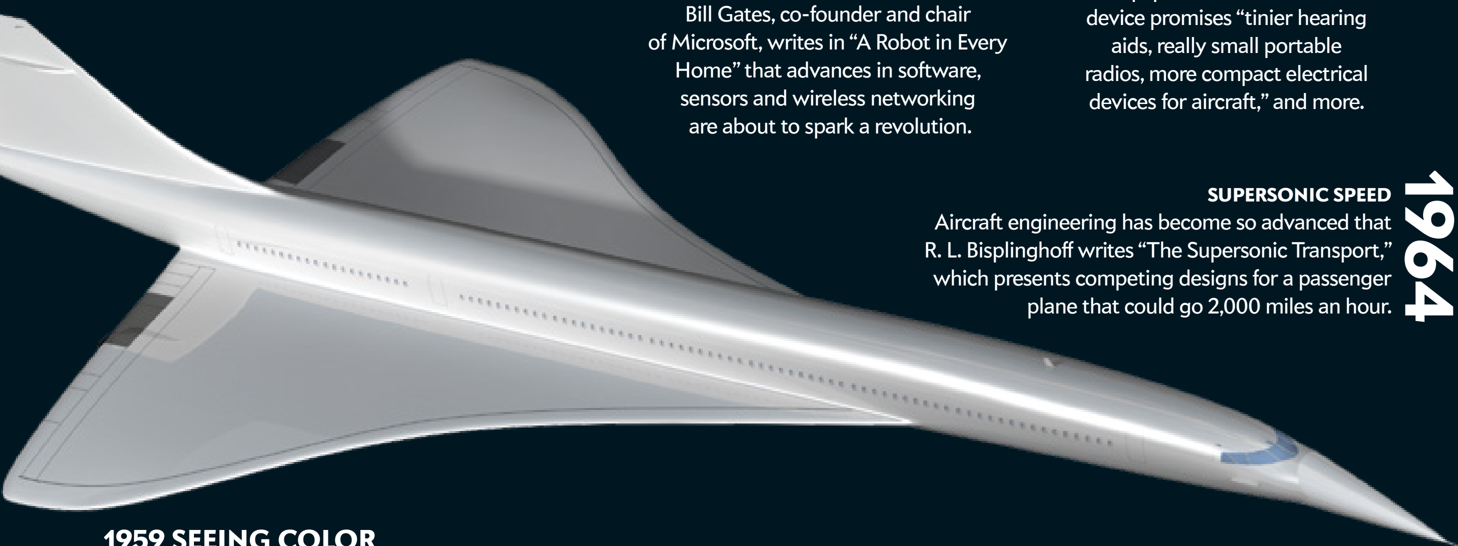
ROBOT REVOLUTION

Bill Gates, co-founder and chair of Microsoft, writes in "A Robot in Every Home" that advances in software, sensors and wireless networking are about to spark a revolution.

1964

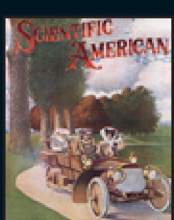
SUPERSONIC SPEED

Aircraft engineering has become so advanced that R. L. Bisplinghoff writes "The Supersonic Transport," which presents competing designs for a passenger plane that could go 2,000 miles an hour.



1959 SEEING COLOR

Edwin Land invented the instant camera, marketed from 1947 on by Polaroid (which he co-founded). But Land was also a scientist. In a 1959 article he proposes new insights into how the human eye perceives color, and 18 years later he completes the explanation in an article entitled "The Retinex Theory of Color Vision."



1906 HORSELESS CARRIAGES

Munn & Co. is now publishing an annual "Automobile Number" of *Scientific American,* filled with details and practical advice about the increasingly popular motor car.

TECHNOLOGY & INDUSTRY

Science and innovation relentlessly alter daily life, allowing people to see at night, travel across oceans and (maybe) rely on robots big and small

170 YEARS OF SCIENTIFIC AMERICAN EVOLUTION

The theory of evolution, along with spectacular fossil and archaeological finds, fuels heated debate about the origins of humans and other organisms

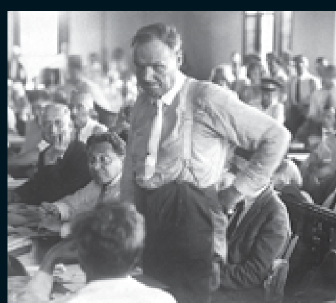
2000
HUMANS APLENTY
Ian Tattersall contradicts conventional wisdom with robust evidence that for at least four million years many humanlike species shared the planet.

2002
Creationist Nonsense
Editor in chief John Rennie debunks the arguments against evolution in "15 Answers to Creationist Nonsense."

1950 Nature and Nurture
Very early in the new science of genetics, Theodosius Dobzhansky writes "The Genetic Basis of Evolution," which says that the variety of plants and animals results from a subtle interplay between genes and the environment.

1982 Leakey Dynasty
Anthropologist Mary Leakey shares her interpretation of a bonanza of animal tracks—including those from human predecessors—that she found in 3.5-million-year-old volcanic ash in Tanzania. Her famous anthropologist husband, Louis, had written for *Scientific American* in 1954, and her son Richard and daughter-in-law Meave, rising stars in the field, write or co-author four articles over the years.

1958 Behavior
N Konrad Lorenz maintains that behavioral traits—from how dogs scratch to how birds defend their nest—are as much an evolutionary characteristic as body structure and appearance.

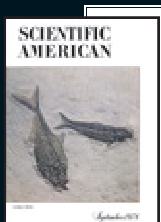


1959 Scopes Monkey Trial Redux
In the infamous 1925 trial of substitute science teacher John Thomas Scopes, the State of Tennessee found him guilty of teaching evolution in a public school, against state law. In his 1959 article, Fay-Cooper Cole, an expert witness at the trial, looks back and concludes that the spectacle actually improved public acceptance of the theory.

1877 Infant Development
Charles Darwin explains his observations of infants. He shows that they develop mental faculties at different rates and notes that it is "difficult to decide at how early an age" they feel anger, in an essay *Scientific American* republishes from the journal *Mind.*

2005
Hobbits
Editor Kate Wong chronicles a spectacular find in Indonesia of a mini human species that lived as recently as 13,000 years ago and the rising argument over its authenticity.

1994 Punctuated Equilibrium
Heralded biologist Stephen Jay Gould makes a case that evolution is not a steady process but jumps ahead in fits and starts, in a progression he labels "punctuated equilibrium."



1978 Group Selection
An entire special issue on evolution presents several radical theories, including that *Homo sapiens* arose only 100,000 years ago, that natural selection may favor group survival rather than individual survival, and that the genetic variation within species is much greater than previously thought.

2005
Pretty Penguins
In his long-running humor column, Anti Gravity, Steve Mirsky explains why penguins are a poor example of "intelligent design," despite their natty appearance.

All the same, Americans as a whole did not dissent. People who marched against environmental pollution still relished jet travel, transistorized stereos, color TVs and birth-control pills. Once the war ended, much of the anger subsided. Pollution remained a threat, although reformers found the means to mitigate it using cleanup technologies and science-based regulation.

A BIOMEDICAL AND SILICON SOCIETY

IN THE 1970S Joel had a teenager's impatience with life's inconveniences. Using a computer meant slogging to his school's computer center, submitting a program and picking up the printed output the next day. He had to call a travel agent to book a trip. His television watching was limited to three national networks and a few local stations. To withdraw money from the bank, he had to cash a check, and to make a call outside his home he had to find a payphone. When his mother was diagnosed with an abdominal cancer, she had to undergo exploratory surgery to determine the location and extent of the malignancy. He was pleased to learn in *Scientific American* that new technologies promised to dissolve the reasons for his impatience. The microchip would make it possible to downsize computers. "Desk-sized computers will become nearly as common as typewriters," one of the magazine's contributors predicted. So would access to the World Wide Web, the magazine said in 1991 in an issue devoted entirely to the Internet and its potential uses.

> **Recombinant DNA enabled the manipulation of life at its genetic essence. Scientists could cut out a gene from one organism and insert it into another.**

Scientific American, along with other media, also reported on the advent of recombinant DNA, the molecular biological method that enabled the manipulation of life at its genetic essence. Using the technique, scientists could cut out a gene from one organism and insert it into another. Recombinant DNA could in principle be exploited for many purposes: the diagnosis of hereditary diseases and the application of gene therapies to cure them; the genetic engineering of farm crops such as corn to make them resistant to specific maladies; and the modification of microorganisms to produce advantageous proteins for pharmaceutical purposes.

Recombinant DNA aroused fears that the ability to manipulate life at its genetic essence would lead to a new eugenics, that genetically modified organisms jeopardized environmental balances or that genetic engineering for any purpose constituted an act of human hubris, an invasion of prerogatives reserved only for God. By the end of the 1970s the controversies, though not all the objections, had largely abated, quelled in part by federal regulation of recombinant initiatives in both lab and field, and by the benefits of these new genetic powers, such as the production of human insulin for the treatment of diabetes—the first of an extensive line of pharmaceutical products developed over the decades.

In recent years Joel found the conditions of life not only more satisfying but also more conducive to maintaining the health of himself and his family. In the 1970s *Scientific American* had showcased ultrasound, a technology of medical imaging that, unlike invasive procedures or x-rays, revealed features of the body's interior, including a fetus, "painlessly and with a minimum of risk and expense." It soon reported as well on a cluster of additional game-changing imaging technologies—CT, MRI and PET scans. If Joel or a member of his family fell victim to a chronic disease, physicians could obtain images of his bodily processes such as blood flow and brain activity or of tumors and painful displacements such as in the spine.

Joel lives, as we all do, in a world of microprocessors. They enable his cell phone, tablet and computer; they regulate his car, oven, refrigerator, house alarm, digital camera and the ATM that gives him cash 24/7. He owes a debt of thanks to microprocessors whenever he uses the Internet, which he often does, to find directions on a map or check his Facebook account.

As in the past, new technologies have stimulated new apprehensions, notably about personal and medical privacy in the information age, the vulnerability of a computerized society to attack at its cybernetic core, the impact of technologies and genetically engineered drugs on the costs of medical services, and the human price of learning that you may be fated to contract a genetic disease for which there is no known therapy or cure. Still, Americans relish the Internet's at-will access to commerce and information and the prospect that genetics, imaging and computing will lead to a more individualized, tailored medicine. They also hope that the world's societies can at once feed their voracious demand for energy and retard the pace of global warming through the cheaper technologies of wind and solar power.

If history is a reliable guide, Americans will welcome whatever science and technology may bring, much as they have since Rufus Porter extolled the railroad in the first pages of *Scientific American*. The record of the past 170 years offers ample reasons to believe that, despite any downsides, science and technology will continue to transform American life in preponderantly beneficial ways, many of them as yet unimagined. SA

MORE TO EXPLORE

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